DEPARTMENT OF CIVIL ENGINEERING

GEETHANJALI COLLEGE OF ENGINEERING & TECHNOLOGY

CHEERYAL (V), KEESARA (M), R.R. DIST. - 501 301

(Affiliated to JNTUH, Approved by AICTE, NEW DELHI**,** ACCREDITED BY NBA**)**

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HYDRAULICS AND HYDRAULIC MACHINERY COURSE FILE

(Subject Code: A40111)

II Year B.TECH. (CIVIL ENGINEERING) II Semester

Prepared by **MOHD. ABDUL KHADEER, K.RAVINDER** Asst.**Professor**

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(Name of the Subject /Lab Course): HYDRAULICS AND HYDRAULIC MACHINERY

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4) Date :	4) Date :

Approved by: (HOD)

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1. Introduction to the subject

This course is intended to introduce basic principles of fluid mechanics. It is further extended to cover the application of fluid mechanics by the inclusion of fluid machinery especially water turbine and water pumps. Now days the principles of fluid mechanics find wide applications in many situations directly or indirectly. The use of fluid machinery, turbines pumps in general and in power stations in getting as accelerated fill up. Thus there is a great relevance for this course for mechanical technicians. The Mechanical technicians have to deal with large variety of fluids like water, air, steam, ammonia and even plastics. The major emphasis is given for the study of water. However the principle dealt with in this course will be applicable to all incompressible fluids.

Pre-requisites

1. Statics and dynamics

2. Mathematics of the motion of particles and rigid bodies and the relation of force and motion of particles

3. Fundamental concepts and laws of mechanics including equilibrium and Newton's laws of motion

4. Differential calculus

5. Basic system of units

2. Syllabus

Sl.No	Unit No	Topic
1	1	**Introduction of open channel flow:** type of channels, velocity distribution, Energy momentum correction factors-chezy's, manning's and bazin formulae for uniform flow- most economical sections.
		Critical flow, specific energy, critical depth, computation of critical depth, critical, sub-critical and super critical flows.
		Non uniform flow- Dynamic equation for G.V.F, mild, critical, steep, horizontal and adverse slopes.
		Surface profiles, direct step method, Rapidly varied flow, hydraulic jump, Energy dissipation.
2	2	**Dimensional analysis and similitude:** Dimensional analysis- Rayleigh's method and Buckingham's pi theorem, study of hydraulic models.
		Geometric, kinematic and dynamic similarities, dimensionless numbers- model and prototype relations.

3	3	**Hydrodynamic forces on jets:** hydrodynamic force of jets on stationary and moving flat , inclined and curved vanes, jet striking centrally and at tip, velocity triangles at inlet and outlet.
		Expression for work done and efficiency, angular momentum principle, applications to radial floe turbines.
		Layout of a typical hydropower installation, heads and efficiencies.
4	4	**Hydraulic turbines:** classification of turbines, Pelton wheel, Francis turbine, Kaplan turbine working, working proportions.
		Velocity diagram, work done and efficiency, hydraulic design, draft tube- theory and function efficiency.
		Governing of turbines, surge tank, unit and specific turbines, unit speed, unit quantity, unit power.
		Specific speed performance characteristics, geometric similarity, cavitation.
5	5	**Centrifugal pumps:** pump installation details, classifications, work done, manometric head, minimum starting speed, losses and efficiencies.
		Specific speed, multistage pumps, pumps in parallel, performance of pumps, characteristics curves, NPSH- cavitation.
		Classification of hydropower plants, definition of terms, load factor, utilization factor, capacity factor, estimation of hydropower potential.

Text books:

1. Fluid Mechanics, Hydraulic and hydraulic machines by **Modi** and **Seth**, Standard book house.

2. Open channel flow by **K.Subramanya** , Tata Mc.Grawhill publishers.

3. Fluid mechanics & fluid machines by Narayana pillai, universities press.

Reference Text Books:-

1. Fluid Mechanics & fluid machines by Rajput , S.Chand &co.

2. Fluid Mechanics and Machinery, CSP Ojha, Oxford Higher Education

3. Fluid Mechanics by Frank.M. White (Tata Mc.Grawhill Pvt. Ltd.)

4. Fluid Mechanics by A.K. Mohanty, Prentice Hall of India Pvt. Ltd., New Delhi

5. A text of Fluid mechanics and hydraulic machines by Dr. R.K. Bansal - Laxmi Pub.(P) ltd., New Delhi.

6. Fluid Mechanics and Machinery by D. Ramdurgaia New Age Publications.

Websites:-

1. http://jntuhupdates.net/jntuh-b-tech-2-2-semester-r13-syllabus-book/
2. NPTEL Resources
3. www.**ieee**fmhm.org/

Journals:-

1. International Journal of fluid mechanics

2. International Journal of numerical methods in fluids.

3. Vision of the Department:

To develop a world class program with excellence in teaching, learning and research that would lead to growth, innovation and recognition

4. Mission of the Department:

The mission of the Civil Engineering Program is to benefit the society at large by providing technical education to interested and capable students. These technocrats should be able to apply basic and contemporary science, engineering and research skills to identify problems in the industry and academia and be able to develop practical solutions to them

5. Program Educational Objectives-PEOs:

The Civil Engineering Department is dedicated to graduating Civil engineers who:

A. Practice Civil engineering in the general stems of fluid systems, civil systems and design, and materials and manufacturing in industry and government settings.

B. Apply their engineering knowledge, critical thinking and problem solving skills in professional engineering practice or in non-engineering fields, such as law, medicine or business.

C. Continue their intellectual development, through, for example, graduate education or professional development courses.

D. Pursue advanced education, research and development, and other creative efforts in science and technology.

E. Conduct them in a responsible, professional and ethical manner.

F. Participate as leaders in activities that support service to and economic development of the region, state and nation.

6. Program Outcomes (PO)

Graduates of the Civil Engineering Programme will be able to:

1. Apply the knowledge of mathematics, science, engineering fundamentals, and Civil Engineering principles to the solution of complex problems in Civil Engineering.
2. Identify, formulate, research literature, and analyse complex Civil Engineering problems reaching substantiated conclusions using first principles of mathematics and engineering sciences.
3. Design solutions for complex Civil Engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions related to Civil Engineering problems.
5. Create, select, and apply appropriate techniques, resources, and modern engineering tools such as CAD, FEM and GIS including prediction and modelling to complex Civil Engineering activities with an understanding of the limitations.
6. Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional Civil Engineering practice.
7. Understand the impact of the professional Civil Engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. Apply ethical principles and commit to professional ethics and responsibilities and norms of the Civil Engineering practice.
9. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. Communicate effectively on complex Civil Engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage Civil Engineering projects and in multidisciplinary environments.
12. Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

7. Course objectives

Students who successfully complete this course will have demonstrated ability to:

1. Define the nature of a fluid.
2. Show where fluid mechanics concepts are common with those of solid mechanics and indicate some fundamental areas of difference.
3. Introduce viscosity and show what are Newtonian and non-Newtonian fluids
4. Define the appropriate physical properties and show how these allow differentiation between solids and fluids as well as between liquids and gases
5. The purpose of this course is to learn the Fluid properties and fundamentals of Fluid statics and fluid flow
6. To introduce the concepts of flow measurements and flow through pipes
7. To introduce the concepts of momentum principles
8. To impart the knowledge on pumps and turbines
9. To impart the knowledge of impact of jets.

10. To introduce the flow measuring devices and velocity measuring devices.

8. Course Outcomes

1. Knowledge of basic principles of fluid mechanics
2. Know the definitions of fundamental concepts of fluid mechanics including: continuum, velocity field; viscosity, surface tension and pressure (absolute and gage); flow visualization using timelines, pathlines, streaklines, and streamlines; flow regimes: laminar, turbulent and transitional flows; compressibility and incompressibility; viscous and inviscid.
3. Apply the basic equation of fluid statics to determine forces on planar and curved surfaces that are submerged in a static fluid; to manometers; to the determination of buoyancy and stability; and to fluids in rigid-body motion.
4. Ability to analyze fluid flow problems with the application of the momentum and energy equations
5. Use of conservation laws in differential forms and apply them to determine velocities, pressures and acceleration in a moving fluid. Understand the kinematics of fluid particles.
6. Use Euler's and Bernoulli's equations and the conservation of mass to determine velocities, pressures, and accelerations for incompressible and inviscid fluids.
7. Understand the concepts of rotational vs. irrotational flows; stream functions, velocity potentials.
8. Understand the physical processes which govern the behavior of fluids at rest and in motion
9. Confidently pose and solve problems in engineering fluid mechanics

9. Instructional learning

A mixture of lectures, tutorial exercises, and case studies are used to deliver the various topics. Some of these topics are covered in a problem-based format to enhance learning objectives. Others will be covered through directed study in order to enhance the students' ability of "learning to learn." Some case studies are used to integrate these topics and thereby demonstrate to students how the various techniques are inter-related and how they can be applied to real problems in an industry.

10. Course mapping with PEO's and PO's

PEO/PO	**Program Outcomes**													
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
Program Educational Objectives (PEO)	**A**	**X**	**X**	**X**	**X**	**X**	**X**	**X**					**X**	
	B		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
	C			**X**	**X**	**X**	**X**				**X**	**X**	**X**	
	D	**X**	**X**	**X**	**X**	**X**				**X**	**X**			
	E			**X**	**X**	**X**	**X**		**X**				**X**	

	F										**X**	**X**		

11. Class Timetable

DEPARTMENT OF CIVIL ENGINEERING

Ref: TLE/2014-2015/23.12.2014/SADM /CT -1004

PROGRAMME: B.TECH. (CIVIL ENGINEERING)

SEMESTER: II Year II- SEMESTER

NOTE: "*" Represents Tutorial Classes**.**

Time Table Coordinator **HOD** **PRINCIPAL**

Time	9.30-10.20	10.20-11.10	11.10-12.00	12.00-12.50	12.50-1.30	1.30-2.20	2.20-3.10	3.10-4.00
Period	**1**	**2**	**3**	**4**	**LUNCH**	**5**	**6**	**7**
Monday	**SOM**	**HHM**		**BMC**		**P&S**	**S.A**	
Tuesday	**EVS**	**SOM**		**S.A**		**BMC**	**P&S**	**HHM**
Wednesday	**P&S**	**BMC**	**SA**	**HHM**		**SOM**		**LIBRARY**
Thursday	**EVS**	**SA**	**HHM**	**P&S**		**BMC**		**EVS**
Friday	**LAB**			**P&S**		**CRT**		**EVS**
Saturday	**EVS**	**LAB**				**MENTOR**	**SEMINAR**	

12. Individual Time Table

Name of the faculty: Load = 10 Rev: w.e.f.:

Section- II A and II B

Name of the faculty: MOHD. ABDUL KHADEER Load = 16 ; **w.e.f.**: 29/06/15

Time	9.30-10.20	10.20-11.10	11.10-12.00	12.00-12.50	12.50-1.30	1.30-2.20	2.20-3.10	3.10-4.00
Period	**1**	**2**	**3**	**4**	**LUNCH**	**5**	**6**	**7**
Monday		**HHM**						
Tuesday								**HHM**
Wednesday				**HHM**				
Thursday			**HHM**					
Friday								
Saturday								

13. Unit wise Summary

Unit No	Total Periods	Topic	Reg/Additional	LCD/OHP/BB	Remark
1	**9**	**Introduction of open channel flow:** Type of channels, velocity distribution, Energy momentum correction factors-chezy's, manning's and bazin formulae for uniform flow-most economical sections.	Regular	BB	
		Critical flow, specific energy, critical depth, computation of critical depth, critical, sub-critical and super critical flows.	Regular	BB	
	6	Non uniform flow- Dynamic equation for G.V.F, mild, critical, steep, horizontal and adverse slopes.	Regular	BB	
		Surface profiles, direct step method, Rapidly varied flow, hydraulic jump, Energy dissipation.	Regular	BB	
				54	
2	**6**	**Dimensional analysis and similitude:** Dimensional analysis- Rayleigh's method and Buckingham's pi theorem,	Regular	BB	
		study of hydraulic models	Regular	BB	
	7	Geometric, kinematic and dynamic similarities, dimensionless numbers	Regular	BB	
		Model and prototype relations.	Regular	BB	
3	**6**	**Hydrodynamic forces on jets:** hydrodynamic force of jets on stationary and moving flat , inclined and curved vanes	Regular	BB	
		Jet striking centrally and at tip, velocity triangles at inlet and outlet.	Regular	BB	
		Expression for work done and efficiency, angular momentum principle	Regular	BB	

	6	Applications to radial floe turbines.	Regular	BB	
		Layout of a typical hydropower installation,	Regular	BB	
		Heads and efficiencies.	Regular	BB	
4	**5**	**Hydraulic turbines:** classification of turbines, Pelton wheel, Francis turbine, Kaplan turbine working, working proportions.	Regular	BB	
		Velocity diagram, work done and efficiency, hydraulic design, draft tube-theory and function efficiency.	Regular	BB	
	7	Governing of turbines, surge tank, unit and specific turbines, unit speed, unit quantity, unit power.	Regular	BB	
		Specific speed performance characteristics, geometric similarity, cavitation.	Regular	BB/OHP	
5	**4**	**Centrifugal pumps:** pump installation details, classifications, work done, manometric head, minimum starting speed, losses and efficiencies.	Regular	BB/OHP	
		Specific speed, multistage pumps, pumps in parallel, performance of pumps,	Regular	BB	
	5	characteristics curves, NPSH- cavitation.	Regular	BB	
		Classification of hydropower plants	Regular	BB	
	3	Definition of terms, load factor, utilization factor, capacity factor, estimation of hydropower potential.	Regular	BB	

13. Micro Plan with dates and closure report

Sl. No	Unit No.	Date (No. of Periods)	Topic to be covered in One Lecture	Reg/ Additional	Teaching aids used LCD/OHP /BB	Remarks
1	**I**	-12-2015 01	Introduction of open channel flow**:** Type of channels	Regular	OHP,BB	
2		-12-2015 01	velocity distribution, Energy	Regular	OHP,BB	

			momentum correction			
3		-12-2015 01	factors-chezy's, manning's and bazin formulae for uniform flow	Regular	OHP,BB	
4		-12-2015 -12-2015 02	most economical sections.	Regular	OHP,BB	
5		-12-2015 01	Critical flow, specific energy, critical depth, computation of critical depth	Regular	BB	
6		-12-2015 01	critical, sub-critical and super critical flows.	Regular	BB	
7		01	Non uniform flow- Dynamic equation for G.V.F	Regular	OHP,BB	
8		01	mild, critical, steep, horizontal and adverse slopes.	Regular	BB	
9		01	Surface profiles, direct step method	Regular	BB	
10		01	Rapidly varied flow, and related problems	Regular	BB	
11		02	hydraulic jump, Energy dissipation	Regular	BB	
12		01	Test	Regular	BB	
13	**II**	01	Introduction of Dimensional analysis	Regular	OHP,BB	
14		01	Rayleigh's method	Regular	BB	
15		01	Buckingham's pi theorem	Regular	BB	
16		01	study of hydraulic models	Regular	OHP,BB	
17		02	Geometric similarities	Regular	BB	
18		02	Kinematic similarities	Regular	BB	
19		01	dynamic similarities,	Regular	BB	
20		02	dimensionless numbers	Regular	OHP,BB	
21		01	Model and prototype relations.	Regular	OHP,BB	

22		01	Test	Regular	BB	
23	**III**	01	Introduction of hydrodynamic force of jets	Regular	BB	
24		02	Jets on stationary and moving flat , inclined and curved vanes	Regular	OHP,BB	
25		01	Jet striking centrally and at tip,	Regular	OHP,BB	
26		01	Velocity triangles at inlet and outlet.	Regular	OHP,BB	
27		01	Expression for work done and efficiency,	Regular	BB	
28		02	angular momentum principle	Regular	LCD,OHP,BB	
29		01	Applications to radial floe turbines.	Regular	BB	
30		01	Layout of a typical hydropower installation,	Regular	OHP,BB	
31		01	Heads and efficiencies.	Regular	BB	
32		01	Test	Regular	BB	
	IV	01	**C**lassification of turbines, Pelton wheel,	Regular	OHP,BB	
33		01	Francis turbine and working proportions.	Regular	OHP,BB	
34		02	Kaplan turbine working, working proportions	Regular	BB	
35		01	Velocity diagram, work done and efficiency, hydraulic design,	Regular	OHP,BB	
36		01	Draft tube-theory and function efficiency.	Regular	OHP,BB	
37		02	Governing of turbines, surge tank, unit and specific turbines,	Regular	BB	
38		01	Specific speed of turbines	Regular	OHP,BB	
39		01	Specific speed performance characteristics,	Regular	BB	

40		01	Geometric similarity, cavitation.	Regular	BB	
41		01	Test	Regular	OHP,BB	
	V	01	Introduction of Centrifugal pumps, pump installation details, and classifications,	Regular	OHP,BB	
42		01	Work done, Manometric head,	Regular	OHP,BB	
43		01	Minimum starting speed, losses and efficiencies.	Regular	BB	
44		01	Specific speed, multistage pumps,	Regular	OHP,BB	
45		01	pumps in parallel, performance of pumps,	Regular	OHP,BB	
46		01	Characteristics curves.	Regular	OHP,BB	
47		02	NPSH- cavitation.	Regular	OHP,BB	
48		01	Classification of hydropower plants.	Regular	OHP,BB	
49		01	Definition of terms, load factor, utilization factor, capacity factor,	Regular	OHP,BB	
50		01	Estimation of hydropower potential.	Regular	OHP,BB	
51		01	Discussion of previous question papers	Regular	BB	

GUIDELINES:

Distribution of periods:

No. of classes required to cover JNTUH syllabus : 64

No. of classes required to cover Additional topics : Nil

No. of classes required to cover Assignment tests (for every 2 units 1 test) : 4

No. of classes required to cover tutorials : 2

No. of classes required to cover Mid tests : 2

No of classes required to solve University Question papers : 2

Total periods 64

14. Detailed Notes

Fluid Mechanics

Units and dimensions:

Angular Velocity…………………….rad/g

Angular Acceleration……………….rad/g^2

Discharge ……………………………m^3/g

Sp.mass(mass density)…………….kg/m^3

Stress , elastic modulus……………N/m^2

Sp.weight(weight density)………….N.S/m^2

Dynamic viscosity

Kinematic viscosity ………………….m^2/g

Work, Energy, Torque………………..J(N-m)

Power …………………………………watt(J/g)

Surface Tension……………………..N/m

Momentum, moment of momentum……kg.m/g

Entropy ……………………………..J/kg.k

Sp.heat, gas constant

Thermal conductivity………………..W/m.k

Dynamic viscosity…………poise(p)=1/10=N.S/m^2

Kinematic viscosity –stoke(s)= 10^{-4} m^2/s

Pressure of fluid………………………..10^5 pa

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cos θ, tan θ	cos θ, tan θ
sin θ, cos θ, tan θ	sin θ, cos θ, tan θ

3π/2 ... 0 ... 2π

→ $\sin^2\theta + \cos^2\theta = 1$

→ $1 + \cot^2\theta = \csc^2\theta$

→ $\tan(A+B) = \dfrac{\tan A + \tan B}{1 - \tan A \tan B}$

→ $\sin C + \sin D = 2\sin\dfrac{C+D}{2} \cdot \cos\left(\dfrac{C-D}{2}\right)$

→ $\sin C - \sin D = 2\cos\left(\dfrac{C+D}{2}\right) \cdot \sin\left(\dfrac{C-D}{2}\right)$

→ $\cos C + \cos D = 2\cos\left(\dfrac{C+D}{2}\right) \cdot \cos\left(\dfrac{C-D}{2}\right)$

→ $\cos C - \cos D = 2\sin\left(\dfrac{C+D}{2}\right) \sin\left(\dfrac{D-C}{2}\right)$

$2\sin A \sin B = \cos(A-B) - \cos(A+B)$

$2\cos A \cos B = \cos(A+B) + \cos(A-B)$

$2\sin A \cos B = \sin(A+B) + \sin(A-B)$

$2\cos A \sin B = \sin(A+B) - \sin(A-B)$

$\sin 2A = 2\sin A \cos A$

$\cos 2A = \cos^2 A - \sin^2 A$

$= 2\cos^2 A - 1$

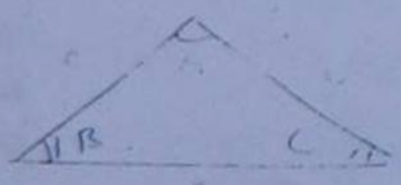
$= 1 - 2\sin^2 A$

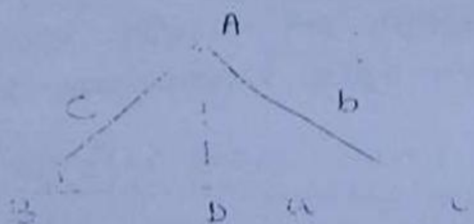
$\tan 2A = \dfrac{2\tan A}{1 - \tan^2 A}$

$\sin 3A = 3\sin A - 4\sin^3 A$

$\cos 3A = 4\cos^3 A - 3\cos A$

$\tan 3A = \dfrac{3\tan A - \tan^3 A}{1 - 3\tan^2 A}$





$\dfrac{\sin A}{a} = \dfrac{\sin B}{b} = \dfrac{\sin C}{c}$

$c^2 = a^2 + b^2 - 2ab\cos C$

similarly —

$\dfrac{a^2 + b^2 - c^2}{\ldots}$

The combination of these two laws is given by

$$L_r^{3/2} = \nu_r$$

OR

$$L_r^{3/2} = \mu_r/\rho_r$$

Above law satisfies both laws of Reynolds & Frouds (viscosity)

2) In case of the rivers normally scale adopted for depth is different from scale for width & length therefore slope of bed is exagrated and according to Manning's law

$$V_r = \frac{R_r^{2/3}\, S_r^{1/2}}{n_r}$$

where $S_r = \frac{D_r}{L_r}$ → Depth Ratio or Height Ratio; L_r → Length Ratio/ width Ratio

For wide rivers $A_r = L_r \times D_r$

(Perimeter) $P_r = L_r$

$$\therefore R_r = (A_r/P_r) = D_r$$

$$\therefore V_r = \frac{D_r^{2/3}}{n_r}\left(\frac{D_r^{1/2}}{L_r^{1/2}}\right)$$

$$\therefore \boxed{V_r = \frac{D_r^{7/6}}{n_r L_r^{1/2}}} \longrightarrow 1)$$

→ In case of the rivers in open channel, Froud Model law is applicable.

$$V_r = D_r^{1/2} \cdot g_r^{1/2} \quad \longrightarrow 2)$$

By eqn (1) & (2),

[put $g_r = 1$]

$$\boxed{n_r = D_r^{4/6} L_r^{-1/2}}$$

$$\boxed{n_r = D_r^{2/3} L_r^{-1/2}} \longrightarrow \text{For distorted model.}$$

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2) Euler Number:

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When the pressure force is very important apart from inertia force as compared to other forces than Euler No. is defined as

$$E_u = \sqrt{F_i / F_p}$$

$$= \sqrt{\frac{\rho L^2 V^2}{p \times L^2}} = \frac{V}{\sqrt{p/\rho}}$$

⇒ $1/E_u$ is called Newton Number.

⇒ Newton Number square is called pressure coefficient.

$$1/E_u^2 = \text{Newton Number} = \frac{F_p}{F_i} = \frac{p}{\rho V^2},$$

Euler Model Law:

ex:

a) Flow through pipes under pressure
b) Flow over submerged bodies when pressure is important
c) Pressure rise due to sudden closure of valve.
d) Discharge through weir & Mouthpieces, under Large head

According to this Law

$$(E_u)_m = (E_u)_p$$

NOTE

1) In some of the cases where viscosity force & gravity force both are important than Reynolds Law & Froud Law both should be applicable.

For Ex:

a) Resistance to ship is generally caused by viscosity & eddies formed by wave here both law should be satisfied

Mach Law: — Mainly in compressible fluid flowing ... high speed, which ... compared with sound.

ex: 1) flow of gases having high speed.
2) water hammer problem
3) ~~Aero~~ dynamic testing
4) Testing of torpido's
5) Motion of airplane with high speed
6) Launching & Projectile of Missiles.

(345)

According to this Law

$$\boxed{(M_a)_M = (M_a)_P}$$

$$\boxed{V_r / C_r = 1}$$

4) Weber Model:

When surface tension force apart from inertia force is important but other forces are less significant than Weber No. is defined as

$$\boxed{W_e = \sqrt{F_i / F_s}}$$

$$\therefore W_e = \sqrt{\frac{\rho L^2 V^2}{\sigma L}}$$

$$\boxed{W_e = \frac{V}{\sqrt{\sigma / \rho L}}}$$

Weber Model Law:

Application
a) capillary movement of water in soil
b) Flow of bloods in veins & ~~arteries~~ arteries
c) Thin sheet flow
d) Liquid atomization
e) capillary tube flow.

According to this Law

$$\boxed{(W_e)_P = (W_e)_M}$$

$$V_r : \sqrt{\sigma_r / L_r \cdot \rho_r} = 1$$

$= \rho_r L_r^{3} g_r \times L_r^{1/2} g_r^{1/2}$

$= \rho_r L_r^{7/2} g_r^{3/2}$

3) Mach number (344): When compressibility force is significant apart from inertia force than Mach number is important and it is defined as

$$\boxed{M_a = \sqrt{F_i / F_c}}$$

$$\therefore M_a = \sqrt{\frac{\rho L^2 v^2}{K \times L^2}} = \frac{v}{\sqrt{K/\rho}}$$

$$\boxed{M_a = v/c}$$

[$\sqrt{K/\rho} \rightarrow$ velocity of sound (C)]

Mach number is significant when velocity is comparable with sound velocity

If :- (i) $M_a > 1 \rightarrow$ Flow is supersonic

(ii) $M_a = 1 \rightarrow$ " " sonic

(iii) $M_a >> 1 \rightarrow$ Flow is hypersonic

(iv) $M_a < 1 \rightarrow$ Flow is sub sonic / ultras...

(v) $M_a < 0.3 \Rightarrow$ Effect of compressibility is neglected.
$\boxed{M_a < 0.4}$

NOTE: Square of Mach Number is called cauchy's

$M_a^2 =$ Cauchy's No.

$\frac{V_a^2}{c^2} =$ "

$= \frac{F_i}{F_c}$.

Imp 2) Flow over spillway of a dam

3) Flow of Liquid Jet of orifice

4) Flow over weir & Notches.

5) Motion of ship in Rough and turbulent

According to this Law (343)

$$\boxed{(F_r)_P = (F_r)_m}$$

$$\therefore \left(\frac{V}{\sqrt{gL}}\right)_P = \left(\frac{V}{\sqrt{gL}}\right)_m$$

$$\Rightarrow \boxed{\frac{V_r}{g_r^{1/2} \cdot L_r^{1/2}} = 1}$$

However $g_r = 1$

a) Time Ratio $T_r = ?$

$$L_r / T_r = V_r = g_r^{1/2} \cdot L_r^{1/2}$$

$$T_r = \frac{L_r^{1/2}}{g_r^{1/2}}$$

$$\therefore \boxed{T_r = L_r^{1/2} \, g_r^{-1/2}}$$

$$\boxed{T_r = L_r^{1/2}} \text{ if } g_r = 1$$

b) Accln Ratio:

$$a_r = g_r = 1$$

c) Force Ratio:

$$F_r = \rho_r L_r^3 \times g_r$$

$$= \rho_r L_r^3$$

Imp d) Discharge Ratio:

$$Q_r = \frac{L_r^3}{T_r} = \frac{L_r^3}{L_r^{1/2} \, g_r^{-1/2}}$$

$$\therefore \boxed{Q_r = L_r^{5/2} \, g_r^{1/2}}$$

> Discharge Ratio [illegible] $= \frac{[illegible]}{L_r^2 * \rho_r} = \frac{[illegible]}{\rho_r}$

> Force Ratio:

$$F_r = M_r \cdot a_r$$

$$= \rho_r \times L_r^3 \times \frac{\mu_r^2}{\rho_r^2 \times L_r^3}$$

$$\therefore \boxed{F_r = \frac{\mu_r^2}{\rho_r}}$$

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5> Power Ratio:

$$P_r = F_r \times V_r$$

$$\therefore P_r = \frac{\mu_r^2}{\rho_r} * \frac{\mu_r}{L_r \cdot \rho_r}$$

$$\therefore \boxed{P_r = \frac{\mu_r^3}{L_r \, \rho_r^2}}$$

> Fraud Number: When gravity force is important apart from Apertia force but other forces are Less significant than Fraud Nuimber is defined as

$$F_r = \sqrt{F_i / F_g} = \sqrt{\frac{\rho L_a^2 v^2}{\rho L^3 \cdot g}}$$

$$\boxed{F_r = \frac{V}{\sqrt{Lg}}}$$

L: Length Parameter

: A/D [For open channel

Fraud Model Law:-]

When gravity force is very important than this Law is applicable.

Ex: > Flow through open channel (waves & Jumps)

Reynolds Model Law :-

(341)

In the flow conditions where viscosity forces are very predominant than other forces than this Law is applied.

example

a) Flow in pipes under Laminar conditions
b) Flow of submarine & air plane but submarine fully emerged.
c) Flow around submerged structure.
d) Flow through Low speed turbo Machines.

→ For such conditions Re for Model be equal to Re for prototype.

$$\left(\frac{\rho V L}{\mu}\right)_m = \left(\frac{\rho V L}{\mu}\right)_p$$

$$\Rightarrow \boxed{\frac{\rho_r V_r L_r}{\mu_r} = 1} \rightarrow \text{Reynolds Law}$$

$\mu/\rho = \nu$, $\boxed{\frac{V_r L_r}{\nu_r} = 1}$

Ex: 1) $T_r = ?$

$$\rho_r \frac{L_r}{T_r} \times \frac{L_r}{\mu_r} = 1$$

$$\Rightarrow \boxed{T_r = L_r^2 \frac{\rho_r}{\mu_r}}$$

2) Acc^n Ratio $a_r = \frac{V_r}{T_r} = L_r / T_r^2$

$$\therefore a_r = \frac{L_r \, \mu_r^2}{L_r^4 \, \rho_r^2}$$

$$\therefore \boxed{a_r = \frac{\mu_r^2}{L_r^3 \, \rho_r^2}}$$

a) Gravity Force = F_g = m · g

$$= \rho L^3 \cdot (L/T^2 \rightarrow \text{same for Model \& prototype})$$

$$= \rho L^3 \cdot g$$

b) Inertial Force ↳ Effect of Mass and it always acts.

$$F_i = M \times a.$$

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$$= \rho L^3 \times L/T^2$$

$$= \rho L^2 (L^2/T^2) = \rho L^2 V^2$$

c) Viscosity Force:

$$F_v = \tau \times A$$

$$= \mu (V/L) \times L^2 = \mu V L$$

d) Pressure Force:

$$= p \times A$$

$$= p \times L^2$$

e) Surface Tension Force:

$$F_s = \sigma \cdot L$$

f) Compressibility Force:

→ Bulk Modulus

$$F_c = K \times A = K \times L^2$$

Reynolds Number: ↓

For situation, viscosity forces are very predominant with inertia forces but other forces are less significant than Reynolds Number is defined as:

$$Re = \frac{F_i}{F_v}$$

$$= \frac{\rho L^2 V^2}{\mu V L}$$

Eff.

L → Length parameter

ρ → Mass density

$Re = \frac{\rho V L}{...}$

$$V_1 + c = \sqrt{\frac{g y_2}{2 y_1}(y_1 + y_2)}$$

$$3 + \frac{2}{y_2 - 2} = \sqrt{\frac{9.81 y_2}{2 \times 2}(2 + y_2)}$$

$\Rightarrow y_2 = ?!$

→ clearity: – The velocity of the surge relative to the initial flow velocity in a canal is called clearity.

$C_f = V_W - V_1$ — D/S

$C_f = V_W + V_1$ — U/S

$$C_f = \sqrt{\frac{g}{2} \frac{y_2}{y_1}[y_1 + y_2]}$$

MODELS

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Similirates: ↓

1> Geometric similarities: – It includes physical para... such as Length, width, b... volume, area. etc.

eg

$$\text{Area ratio } (A_r) = \frac{\text{Area of prototype}}{\text{Area of Model}}$$

$$A_r = L_r^2 = (L_P / L_M)^2 = \left(\frac{\text{Length of prototype}}{\text{Length of Model}}\right)^2$$

$$V_r = L_r^3$$

[L_r = 100:1 or 1:100

2> Kinematic similarity: Those parameters which inv... effect of time such as ve... acc^n, discharge e...

a> $V_r = V_P / V_m = L_r / T_r$

b> Acc^n ratio $= a_r = \frac{V_r}{T_r} = L_r / T_r^2$

c> discharge ratio $= Q_r = L_r^3 / T_r$

3> Dynamic similarity. – It exists if the ratio of the forces at homologus ... Model & prototype are similar.

surge is created and if this surge has zero celerity then $V_1 = \sqrt{gy} \Rightarrow V/\sqrt{gy} = F_r = 1$. Similarly if celerity is +ve means it causes upwards flow than $\boxed{V_1 < \sqrt{gy}}$. Therefore $\boxed{F_r < 1}$ Hence Flow is subcritical..

Similarly at celerity -ve wave wo travels d/s.

Ex:1 A trapezoidal channel with base width of 6m & side slo with 2H:1V conveys water at the rate of 17 m³/sec u a depth of flow of 1.5m. If this flow situation is subcritical or supercritical.

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$$F_r = \frac{V}{\sqrt{gD}}, \quad D = A/T = \frac{(b+ny)y}{b+2ny} \qquad [n = 2$$

Ex:2 A rectangular horizontal channel of 3m width and 2m depth conveys water at 18 m³/sec. If the flow rat is suddenly reduced to 2/3 of its original value. Compute the magnitude of celerity and speed of u/s surge wr Assume that there is no friction in the channel.

$$V_1 = Q/A_1 = 18/b \cdot y_1 = \frac{18}{3 \times 2} = 3 \text{ m/sec}$$

$$V_2 = Q_2/A_2 = \frac{2/3 \times 18}{3 \times y_2} = 4/y_2$$

At stable condition

$$b y_1 (V_1 + C) = b y_2 (V_2 + C) \quad \text{—— (1)}$$

$$P_1 - P_2 = \rho Q [V_2 - V_1] \quad \text{—— (2)}$$

$$\boxed{C = \frac{V_1 y_1 - V_2 y_2}{y_2 - y_1}} \text{ Imp.}$$

$$= \frac{3 \times 2 - 4/y_2 \times y_2}{y_2 - 2}$$

$$\boxed{C = \frac{2}{y_2 - 2}}$$

For prismatic Rectangular channel:

$Q = by_1(V_1+c) = by_2(V_2+c) \Rightarrow y_1(V_1+c) = y_2(V_2+c)$

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$$\therefore \boxed{c = \frac{V_1y_1 - V_2y_2}{y_2 - y_1}} \quad \text{---(1)}$$

If there is no resistance force b/w (1) & (2) then Total Force = 0.

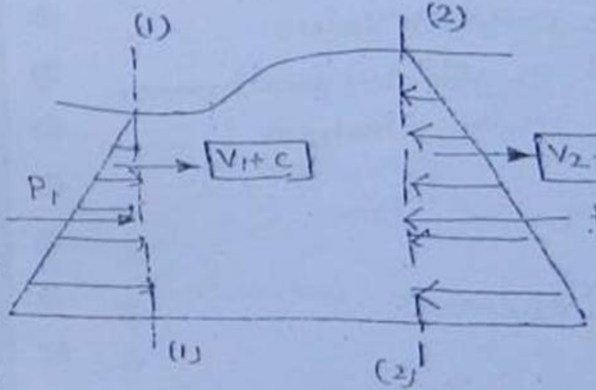
= static force + dynamic force

$= (P_1 - P_2) + \rho Q\{[V_1+c] - [V_2+c]\} = 0$

$\Rightarrow P_1 - P_2 = \rho Q[V_2 - V_1]$

$\therefore \omega b \cdot y_1 * y_1/2 - \omega b\, y_2 * y_2/2 = \rho Q[V_2 - V_1]$

$$\therefore \frac{\rho g b}{2}[y_1^2 - y_2^2] = \rho Q[V_2 - V_1] \quad \text{---(2)}$$



From eqn (1) & (2)

$$\boxed{V_1 + c = \sqrt{\frac{gy_2}{2y_1}(y_1+y_2)}}$$

$[V_1+c] \rightarrow$ vel. of surge relative to wa...

{+ve surge}

For -ve surge: $\boxed{c > V_1}$

$\therefore$ Rel. vel. $= c - V_1 = \sqrt{\frac{gy_2}{2y_1}(y_1+ ...)}$

Special case:

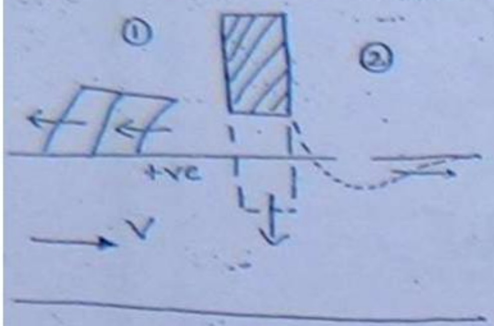
If surge is very small and depth of fl... Large than $y_1 \simeq y_2 \simeq y$ then

$$\boxed{V_1 + c = \sqrt{gy}}$$

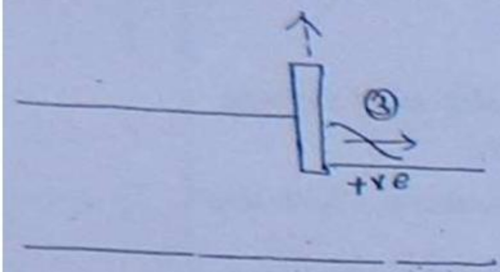
For Rectangular channel:

$$\frac{V_1}{\sqrt{gy}} = F_r$$

For critical Flow $V_1 = \sqrt{gy}$
For Subcritical Flow $V_1 < \sqrt{gy}$
For Supercritical Flow $V_1 > \sqrt{gy}$



→ If the flow in a channel is increased suddenly by means of opening gate a wave is formed which travels D/S.

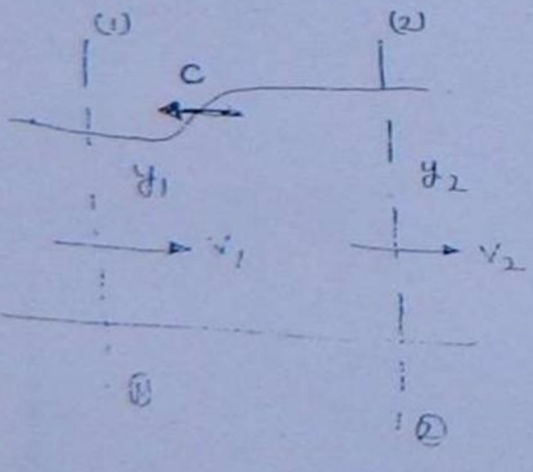


→ Similarily if a gate is suddenly closed and a flo[w] is partially reduced, a wave formed travels suc[h] wave is called surge wa[ve].

-ve surge wave:- Also known as 'elevation surge wa[ve]'
→ If depth of water increases in th[e] direction of motion of wave is call[ed] surge wave.

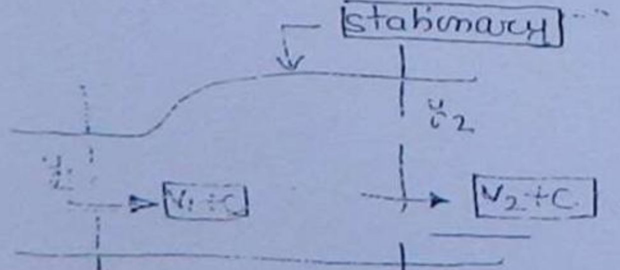
(1) & (3) are +ve surge wave & (2) is -ve surge wave

Analysis:↓



Let vel. of wave is C.
{celerity of wave}

For Analysis:↓



(i) Mild slope:- $y_0 > y_c$ → subcritical flow at Normal depth
(ii) Steep slope:- $y_0 < y_c$ → supercritical flow at
(iii) critical slope:- $y_0 = y_c$ → critical flow at normal depth.
(iv) Horizontal slope:- $S_0 = 0$ → cannot sustain uniform flow
(v) Adverse slope:- $S_0 < 0$ → " "

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$\frac{dy}{dx} > 0$ if (a) $y > y_0$ and $y > y_c$ or
(b) $y < y_0$ and $y < y_c$

$\frac{dy}{dx} < 0$ if (i) $y_c > y > y_0$ or
(ii) $y_0 > y > y_c$

(1) As $y \to y_0 \Rightarrow \frac{dy}{dx} \to 0$ i.e. The water surface approaches the Normal depth line Asymptotically.

(2) As, $y \to y_c \Rightarrow \frac{dy}{dx} \to \infty$ i.e. water surface meets the critical depth vertically.

(3) As, $y \to \infty$, $\frac{dy}{dx} \to S_0$ i.e. water surface meets a very Large depth as a horizontal Asymptote.

At critical depth the curves are indicated by dashed line to remind that the GVF Eqn is strictly not applicable in that neighbourhood.

→ A control section is defined as a section in which a fixed Relation exists b/w the discharge and depth of flow.

- critical depth is also a critical control point.
- Subcritical Flows have controls at the D/S end while supercritical Flows have controls on the U/S end.

$$F_r = (P_2 - P_3) + \rho Q [V_2 - V_3]$$

$$= \rho g [A_2 \bar{x}_2 - A_3 \bar{x}_3] + \rho Q [V_2 - V_3]$$

$$= 1000 \times 9.81 \left[(1 \times 6) \times \frac{1}{2} - (3 \times 6) \times \frac{1.5}{2} \right] +$$

$$1000 \times 65.77 [10.95 - 3.65]$$

$$\therefore \boxed{F_r = 243.83 \text{ KN}}$$

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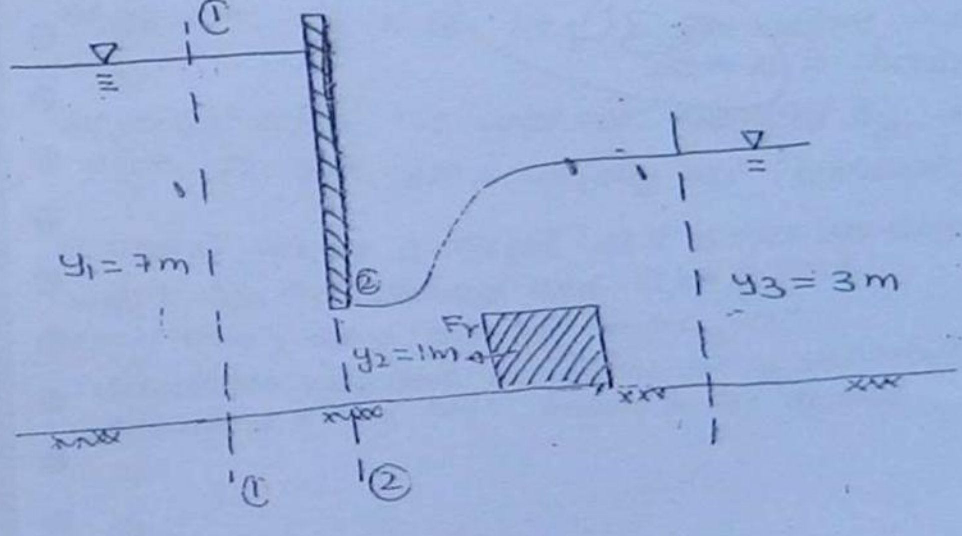
$\therefore$ Loss of energy $= E_1 - E_2$

$$\Delta E = \left(y_1 + \frac{V_1^2}{2g}\right) - \left(y_2 + \frac{V_2^2}{2g}\right)$$

prob2
ES/1992

A sluice across a channel is 6m wide, disch... a stream 1m deep. What is the flow rate when u/s depth of sluice is 7m. On the d/s side a concrete block have been placed, to creat... the condition of hydraulic jump. Determin... the force on the block of d/s. depth is 3...



$$q = (y_1 \times 6) V_1 = (y_2 \times 6) V_2$$
$$= (y_3 \times 6) V_3$$

$$\Rightarrow 7V_1 = V_2 = 3V_3 \quad \text{—— (1)}$$

There is No Loss of Energy b/w (1)-(1) & (2)-(2)

so $\boxed{E_1 = E_2}$

$$\Rightarrow y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g} \quad \text{—— (2)}$$

By eqn (1) & (2)

$= \omega Q(\Delta E)$

\# Height of Jump $= y_2 - y_1$ (33)

\# Length of Jump $=$ 5 to 7 times $(y_2 - y_1)$

Fr_1	Type of Jump
i) 1 - 1.7	Undular Jump
ii) 1.7 to 2.5	weak Jump
c) 2.5 to 4.5	oscilating Jump
d) 4.5 to 9.0	steady Jump
e) > 9.0	strong Jump

Prob 1. A Trapezoidal section having bottom width of 8 m & side slope is 1:1, carries a discharge of 30 m3/sec. Find the depth of conjugate to initial depth of 0.75 m before the Jump. Also determine the Loss of energy in the Jump.

Sp Force

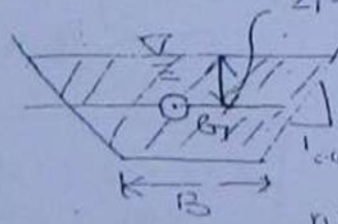
$F_1 = F_2$

$$\frac{Q^2}{A_1 g} + A_1 \bar{Z}_1 = \frac{Q^2}{A_2 g} + A_2 \bar{Z}_2 \quad \text{--- (1)}$$

$\rightarrow B + 2ny = 9.5\,m$

$\bar{Z}_1 = \frac{9.5 + 2\times 8}{9.5 + 8} \times \frac{0.75}{3}$

$= 0.36$



$nH : 1V$

$\Rightarrow n = 1$

$A_1 = (B + n y_1) y_1$

$= (8 + 0.75) 0.75$

$= 6.56\,m$

$A_2 = (B + y_2) y_2$

$$\bar{Z}_2 = \frac{(8 + 2y_2) + 2\times 8}{8 + 2y_2 + 8} \times \frac{y_2}{3}$$

Solving for y_2 from Eqn (1)

$y_2 = 4.167\,m$

Using eqn (iii) we can find y_1 & y_2

Let's Find y_2

$$\therefore y_2^2 \cdot y_1 + y_1^2 \cdot y_2 - \frac{2q^2}{g} = 0$$

$$\Rightarrow x^2 a + b \cdot x + c = 0$$

$$\Rightarrow y_2 = \frac{-y_1^2 \pm \sqrt{y_1^4 + 4y_2(2q^2/g)}}{2 \times y_1}$$

$$y_2 = y_1/2 \left[-1 \pm \sqrt{1 + \frac{8q^2}{g y_1^3}} \right]$$

$$\therefore \frac{y_2}{y_1} = 1/2 \left[-1 \pm \sqrt{1 + \frac{8 V_1^2}{g Y_1}} \right]$$

$$\therefore ^{***} \boxed{y_2/y_1 = 1/2 \left[-1 + \sqrt{1 + 8 F_{r_1}^2} \right]} \text{ imp}$$

OR $[F_{r_1} > 1]$ > only For Rect. Section

$$\boxed{y_1/y_2 = 1/2 \left[-1 + \sqrt{1 + 8 F_{r_2}^2} \right]}$$

Loss of Energy in Jump: J,

$$\Delta E = E_1 - E_2$$

$$= \left(y_1 + \frac{V_1^2}{2g}\right) - \left(y_2 + \frac{V_2^2}{2g}\right)$$

$$\boxed{\Delta E = \frac{[y_2 - y_1]^3}{4 y_1 y_2}} \text{ imp}$$

OR

$$\boxed{\Delta E = \frac{[V_1 - V_2]^3}{2g(V_1 + V_2)}}$$

At minimum Sp. force there is only one critical depth

For other values of F there are two depth of flow y_1 & y_2, called conjugate depth.

$$\boxed{y_1 < y_c < y_2} \text{ imp}$$

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For critical Flow, sp. force is Minimum

for Rect. channel

$$\boxed{F = \frac{q^2 B}{g} \times \frac{1}{y} + \frac{B y^2}{2}}$$

For F(min), $\frac{dF}{dy} = 0$

$$\Rightarrow \frac{q^2 B}{g}\left(-\frac{1}{y^2}\right) + \frac{2By}{2} = 0$$

$$\Rightarrow \boxed{y_c = \left(\frac{q^2}{g}\right)^{1/3}} \quad \text{--- (I)}$$

NOTE: For Non-Rectangular channel

$$\left[\frac{Q^2}{g} = \frac{A^3}{T}\right] \quad \text{---- (II)} \quad \text{at critical Flow.}$$

$$F_1 = F_2$$

$$\Rightarrow \frac{Q^2}{A_1 g} + A_1 \bar{z}_1 = \frac{Q^2}{A_2 g} + A_2 \bar{z}_2$$

[$Q = q \cdot B$ For Rect. channel

$$\therefore \frac{q^2 B^2}{B y_1 g} + B y_1 \left(\frac{y_1}{2}\right) = \frac{q^2 B^2}{y_2 B g} + B y_2 \left(\frac{y_2}{2}\right)$$

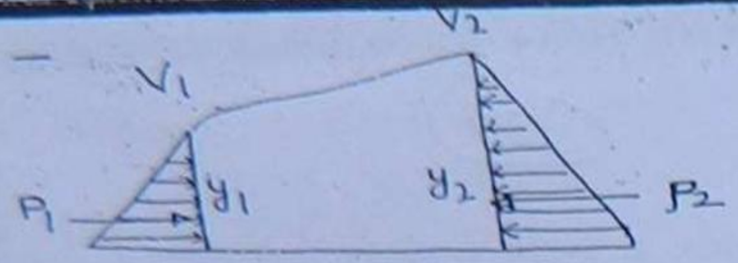
⇓ on solving

$$2 q^2/g = y_1 y_2 (y_1 + y_2) \quad \text{--- (III)}$$

$$\Rightarrow \boxed{y_c^3 = \frac{y_1 y_2 (y_1 + y_2)}{2}} \quad \text{imp --- (IV)}$$

***

For Alternate depth → $E_1 = E_2$ → $\boxed{y_c^3 = \frac{2 y_1^2 y_2^2}{(y_1 + y_2)}}$ ✓



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If Resultant Force is in Equilibrium than $\Sigma F = 0$

$$\Rightarrow \underbrace{(P_1 - P_2)}_{\text{Static Force}} + \underbrace{\rho Q [V_1 - V_2]}_{\text{Dynamic Force}} = 0$$

$\boxed{P_1 = \omega A_1 \bar{x}_1}$ [$\bar{x}_1$ = Position of C.G. From Top surface

$\boxed{P_2 = \omega A_2 \bar{x}_2}$

$$\therefore \omega [A_1 \bar{x}_1 - A_2 \bar{x}_2] + \rho Q [V_1 - V_2] = 0 \quad \text{imp}$$

$$\Rightarrow \omega [A_1 \bar{x}_1 - A_2 \bar{x}_2] = \rho Q \left[\frac{Q}{A_2} - \frac{Q}{A_1} \right]$$

$$\Rightarrow \rho g [A_1 \bar{x}_1 - A_2 \bar{x}_2] = \rho Q \left[\frac{Q}{A_2} - \frac{Q}{A_1} \right]$$

$$\Rightarrow g [A_1 \bar{x}_1 - A_2 \bar{x}_2] = \frac{Q^2}{A_2} - \frac{Q^2}{A_1}$$

$$\Rightarrow A_1 \bar{x}_1 + \frac{Q^2}{A_1 g} = A_2 \bar{x}_2 + \frac{Q^2}{A_2 g}$$

$$\Rightarrow \text{imp} \quad \boxed{A\bar{x} + \frac{Q^2}{Ag} = \text{constant}} \rightarrow \text{specific Force } F = \text{const.}$$

Generally For Rect. channel $\boxed{\bar{x} = \bar{z} = y/2}$ [Either from top or bo

Rapid Varied Flow (RVF) :-

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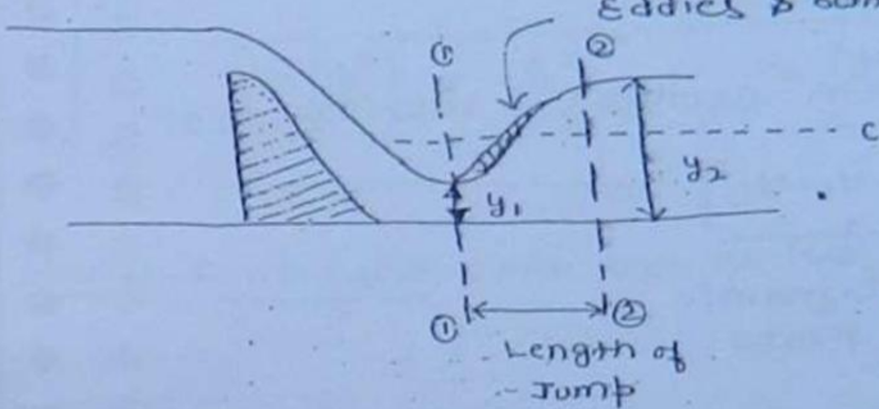


$E_1 \neq E_2$

$E_1 > E_2$

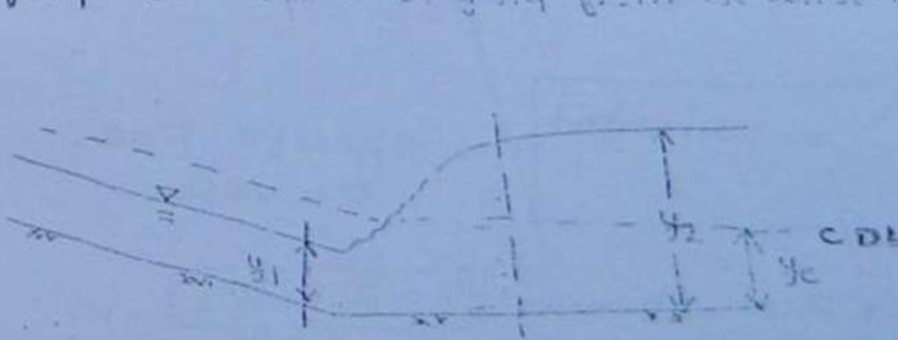
$E_1 - E_2 = \Delta E$ (Loss of Energy)

An essential & necessary condition for hydraulic jump to occur Flow must change supercritical to subcritical & this change is over a small Length hence if flowing fluid having Froud no. greater than 1, jump May be created

Hydraulic jump is defined as sudden & turbulent Passes of water supercritical to subcritical it is also called shooting, rapid, Tranquill, unstable type

→ There is considerable dissipation of energy during the formation of Jmp

Sp. Force concept is always applied with hydraulic jump i.e. Flow changing from supercritical to subcritical



$y_1 < y_c < y_2$

y_1 & y_2 are subsequent depth or Conjugate depth

$E_1 \neq E_2$

- But $F_1 = F_2$ (sp. force)

[illegible] $\left(\frac{q^2}{g}\right)^{1/3}$ [illegible] $\left(\frac{[illegible]}{9.81}\right)^{1/3}$ [illegible]

$\therefore \Delta Z_{Max} = E_1 - \frac{3}{2} \times 1.81$

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$E_1 = y_1 + \frac{V_1^2}{2g}$

$= 2.0 + \frac{3.82^2}{2 \times 9.81}$

$= 2.74 \text{ m}$

$\therefore \Delta Z_{max} = 2.74 - 1.5 \times 1.81$

$= 0.026 \text{ m}.$

b) If Now $y_1' = 2.4 \text{ m}$ (V1 would change)

Discharge would remain same, y_1 would change

$\therefore y_1' + \frac{V_1'^2}{2g} = \Delta Z' + E_{min}$ $[\Delta Z' > \Delta Z_{max}$

$2.4 + \frac{V_1'^2}{2g} = \Delta Z' + \frac{3}{2} \times 1.812$

$\Rightarrow 2.4 + \frac{(3.18)^2}{2 \times 9.81} = \Delta Z' + 1.812 \times 1.5$ $\left[V_1' = \frac{Q}{A_1'} = \frac{26.74}{3.5 \times 2.4} = 3.18 \text{ m/sec} \right.$

$\Delta Z' = 0.198 \text{ m}.$

Probs

Water flows at a depth of 1.6 m and velocity of 1.1 m/sec in a open channel of Rect. section of width 4 m. At a certain section width is red[uced] to 3.5 m and the bed is raised by 0.35 m through a smooth flat hump. Calculate wa[ter] surface elevation at the contracted section aswell as the U/S section. Neglect losses.

At section (2) depth $(y_2) = 1.155 \text{ m}$ $[y_2 > y_c \therefore$

$y_1 = 1.6 \text{ m}$

At section (1) elevation is = raised

b) $\Delta y = y_1 - \Delta z - y_2$

$= 1.524 - 0.312 - 0.914$

$= 0.294\ m$

Prob 4 A rect. channel 3.5 m wide laid at a slope of 0.0036, uniform flow occurs at a depth of 2 m. Find how high a bump can be raised on the channel bed without causing a change in u/s depth. If the u/s depth is to be raised to 2.4 m what should be the height of bump. Assume Manning's N = 0.015.

$A_1 = 3.5 \times 2.0 = 7\ m^2$

$P_1 = 3.5 + 2 \times 2 = 7.5\ m$

$R_1 = A_1/P_1 = 0.938$

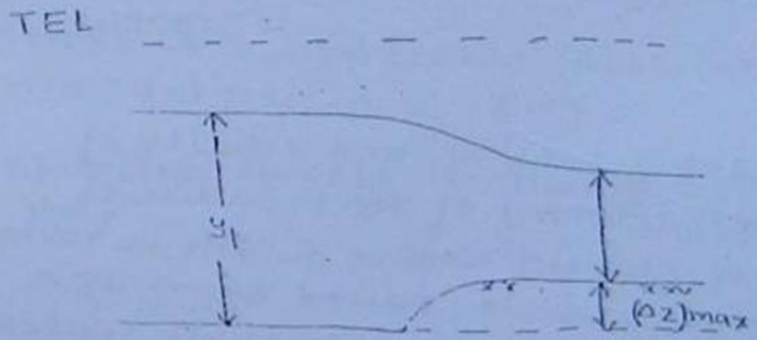
$V_1 = \frac{1}{N} R_1^{2/3} S^{1/2}$

$= 3.82\ m/sec$

check For Froud Number

$F_1 = \frac{V_1}{\sqrt{g y_1}} = \frac{3.82}{\sqrt{9.81 \times 2}} = 0.86 < 1$

↳ subcritical flow



a) If u/s depth is not to be changed than at equilibrium

$$\boxed{E_1 = (\Delta z)_{max} + E_{min}}$$

$(\Delta z)_{max} = E_1 - E_{min}$

$Q = V_1 \times A_1 = 3.82 \times 7$

$Q/B_1 = q = 3.82 \times 7 / 3.5 = 7.64\ m^3/sec/m$

$\Rightarrow y_2 = 1.8 - 0.3 - 0.15 = 1.35\ m$

By using eqn (ii) ...

$$\frac{Q^2}{2gA_2} - \frac{Q^2}{2gA_1} = 0.15$$

(324)

$$\Rightarrow \frac{Q^2}{2g}\left[\frac{1}{A_2} - \frac{1}{A_1}\right] = 0.15$$

$\Rightarrow Q = 6.418\ m^3/sec$

$\left[A_1 = 3.6 \times 1.8, \quad A_2 = 2.4 \times 1.35 \right.$

2008, 5/2005 **

A wide rect. channel carries a flow of $2.76\ m^3/sec$. The depth of flow is 1.524 m.

a) calculate the min. rise of flow at a section required to produce critical flow conditions

b) what is corresponding fall in the water Le

Given

$q = 2.76\ m^3/sec/m$

$y_1 = 1.524\ m$

$\Delta Z_{max} = ?$ (For critical flow condition)

At critical Flow condition at section (2)

$$E_1 = \Delta Z_{Max} + E_{Min}$$

$$V_1 = q/y_1 = \frac{2.76}{1.524} = 1.81\ m/sec$$

$$\therefore E_1 = y_1 + \frac{V_1^2}{2g} = 1.524 + \frac{1.81^2}{2 \times 9.81} = 1.69\ m$$

$E_{min} = 3/2\,(y_c)$ $\left[y_c = (q^2/g)^{1/3} = 0.919\ m \right.$

$$\Delta Z_{Max} = E_1 - E_{Min} = 1.69 - 1.5 \times 0.9{\cdot}5 = 0.312\ m$$

$$\left(F_2/F_1\right)^{2/3} = \frac{2+F_2^2}{2+F_1^2}$$

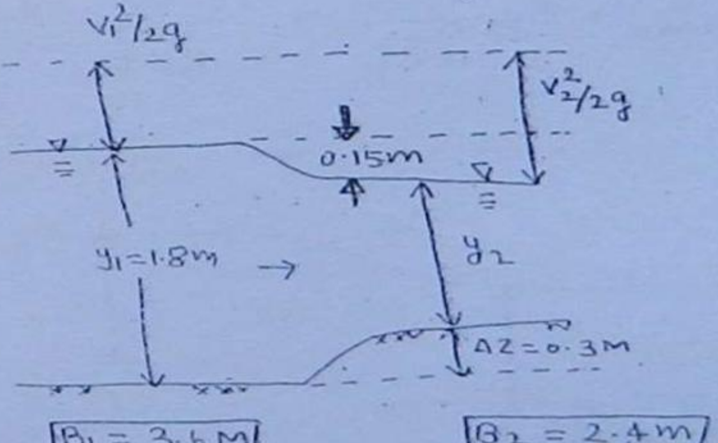
$$F_1 = \frac{V_1}{\sqrt{g y_1}}, \quad F_2 = \frac{V_2}{\sqrt{g y_2}}$$

$$\therefore \; y_1^3 = \frac{Q^2}{B^2 g F_1^2}$$

$$y_2^3 = \frac{Q^2}{B^2 g F_2^2} \qquad \therefore \; y_1/y_2 = \left(F_2/F_1\right)^{2/3}$$

$$\left(F_2/F_1\right)^{2/3} = \frac{2+F_2^2}{2+F_1^2}$$

Prob2 A 3.6 M wide rect. wide channel carries a water a depth of 1.8M. In order to measure the discharge channel width is reduced to 2.4m and hump of a is provided in the bottom. calculate the disc if the water surface in the contracted surf drop by 0.15m assume no Losses.



$$E_1 = \Delta Z + E_2$$

$$y_1 + \frac{V_1^2}{2g} = \Delta Z + y_2 + \frac{V_2^2}{2g} \quad \text{--- (1)}$$

Imp $\dfrac{V_2^2}{2g} - \dfrac{V_1^2}{2g} = 0.15\,m$ ——— (2)

From (2) in Eqn (1)

Q. In a Flow through a rect. channel for a certain discharge the Fraud No. corresponding to two alternate depths are F_1 & F_2 than prove

$$\left(F_2/F_1\right)^{2/3} = \frac{2+F_2^2}{2+F_1^2}$$

(322)

$$F_r = \frac{V}{\sqrt{gY}} = \frac{V}{\sqrt{gD}}$$

$$E_1 = E_2$$

$$y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g}$$

$$\Rightarrow y_1\left[1+\frac{V_1^2}{2gy_1}\right] = y_2\left[1+\frac{V_2^2}{2gy_2}\right]$$

$$\therefore y_1/y_2 = \frac{1+F_2^2/2}{1+F_1^2/2} = \frac{2+F_2^2}{2+F_1^2}$$

Now
$$F_1 = \frac{V_1}{\sqrt{gY}}$$
$$= \frac{q}{By_1\sqrt{gy_1}}$$
$$= q/B\sqrt{gy_1^3}$$

Similarly
$$F_2 = \frac{q}{B\sqrt{g\,y_2^3}}$$

$$y_1^3 = \frac{q^2}{B^2 g F_1^2}$$

$$y_2^3 = \frac{q^2}{B^2 g F_2^2}$$

$\therefore A = \frac{(2B + 1.5y)}{2} \times y$

$\therefore A = (B + 0.75y) \times y$

$\therefore B = A/y - 0.75y$

For Given Area perimeter should be Minimum.

$\therefore P = A/y - 0.75y + 2.8y$

$\therefore dP/dy = -A/y^2 - 0.75 + 2.8 = 0$

$\Rightarrow y^2 = \frac{A}{2.05} \Rightarrow \boxed{A = 2.05y^2}$

$\therefore \boxed{B = 1.3y}$

By applying Manning's Equation

$Q = \frac{1}{N} \cdot A \cdot R^{2/3} S^{1/2} \Rightarrow$ Get $(y) = ?$

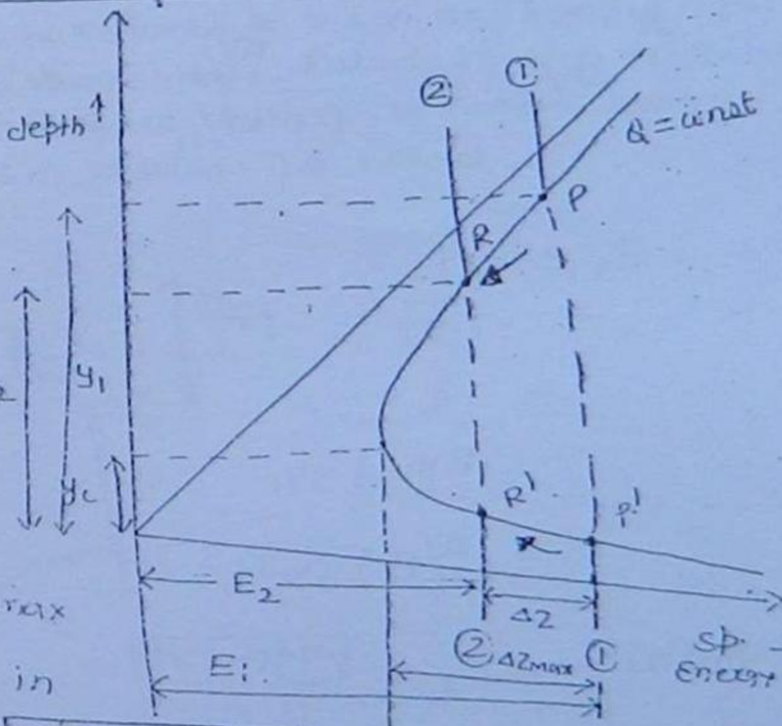
---

channel with a hump:

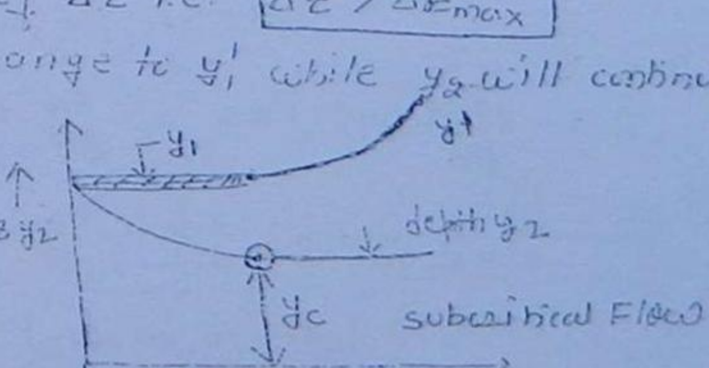
a) **Subcritical Flow:**

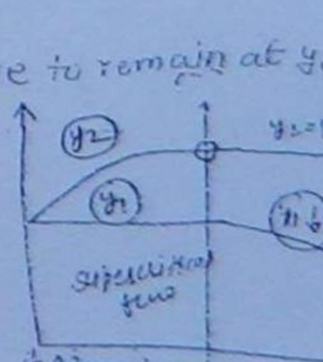
when $\boxed{0 < \Delta Z < \Delta Z_{max}}$ the U/S water level remains stationary at y_1 while the depth of flow at section 2 decreases with ΔZ reaching at minimum value of y_c at $\Delta Z = \Delta Z_{max}$

with further increase in the value of ΔZ i.e. $\boxed{\Delta Z > \Delta Z_{max}}$



y_1 will change to y_1' while y_2 will continue to remain at y_c





A trapezoidal channel of base width 8m and side slope of 2H: 1V carries a flow of 60 m³/sec at a depth of 2.5 m. There is a smooth transition to a rect. section 6m wide accompined by a gradual lowering of channel bed by 0.6 m.

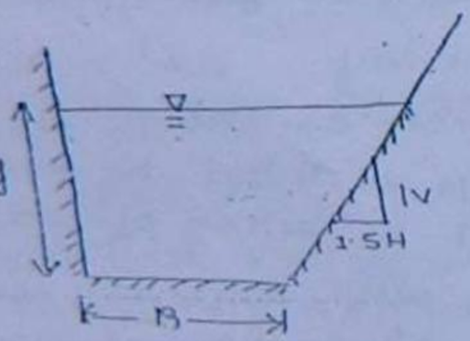
1) Find the depth of water in the rect. section & change in water surface level.

2) In-case the drop of water surface level is to be restricated to 0.20 m what is the amount of bed must be lowered.

(320)

Prob 2 [Uniform Flow Problem]

. A Lined channel (N = 0.014) is of trapezoidal section with one side vertical and other side on slope (1.5H: 1V) If the channel is to be deliver 9 m³/sec when laid on a slope of 0.0002. calculate the dimensions of efficient section which requires minimum lining. Also calculate corresponding mean velocity.



$$\left[\begin{array}{l} nH : 1V \\ n = 1.5 \end{array} \right.$$

For Minimum Lining, P should be Minimum

$$P = y + B + y\sqrt{n^2+1}$$

$$= B + y\left[1 + \sqrt{3.25}\right]$$

$$Q =$$

$$A = \frac{B + (B + ny)}{2} \times y$$

(319) $(y_2 < y_1)$

$$E_1 = \Delta Z + E_2$$
OR
$$E_1' = \Delta Z + E_2'$$

→ If flow $Fr > 1$ → $\{y_1' < y_c\}$

$(y_2' > y_1')$

→ The Maxm height of hump ($\Delta Z = Max$) will be obtain when point (2) in the sp. energy curv or when depth of section (2) coincides with critical depth at that section. ($y_2 = y_c$) Thus flow over raised section will be critic

Than
$$E_1 = (\Delta Z)_{Max} + E_{min}$$
$$E_2 = E_{min}$$

$$\therefore (\Delta Z)_{Max} = E_1 - E_{min}$$

NOTE: If the height of hump is further increas beyond ΔZ, Let's say $\Delta Z' > (\Delta Z_{max})$ than flow at given sp. energy E_1 & at given depth y_1 will not be possib which will result in piling of water Hence depth y_1 will increase, cau an increase in sp. energy of approa flow.

Water Level at section (1) will cont to rise until at section (2) flow becomes critical.

The increased sp. energy E_1'' at (1) is obtained as

$$E_1'' = E_{min} + \Delta Z'$$
$$= \frac{3}{2} y_c + \Delta Z'$$ → For Rect. channe

flow is subcritical. (Fr<1) (38)

If flow is transform such that V_2 decreases than Flow will tend to become critical and depth will tend to become critical hence Lowering of water surf and type-2 curve will be formed

Case II :- If flow is supercritical at section (1)-(1). than at section (2), flow tend to become critical hence flow will rise will be observed. in actual curve

If flow is through smooth transition and there is no change in bed Level than $E_2 = E_1$

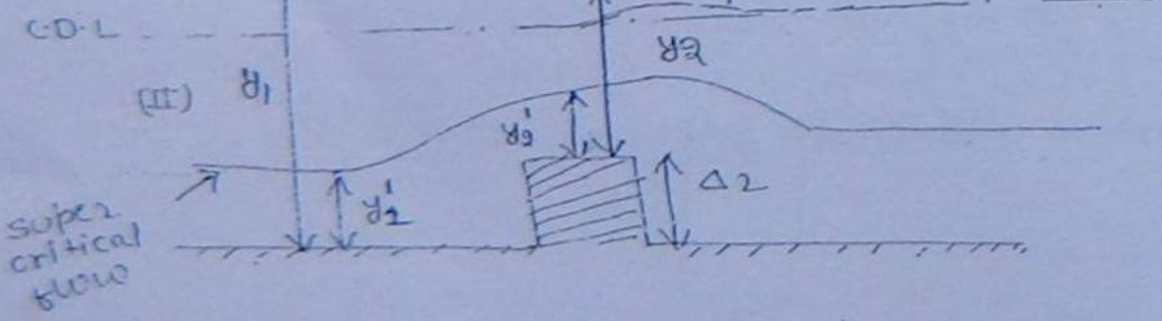
NOTE :- If B_2 is further contracted even after E_2 has reached E_{min} (corresponding to critical stage) than piling of water in U/s will occure and flow will not be possible at original depth y_2.

Imp

Flow over Local rise in the channel slope:

Flow over Local rise is called 'hump flow'.

Let's consider a rectangular channel having its bottom raised by an amount Δ.



Applications of sp. Energy :-

1) Analysis of flow through the channels when one section is transformed into another sec[tion] such channels are called transition channel[s]

2) a Flow over raised channel bottom slope.
Ex: Broad crested weir

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3) Flow through sluice gate opening.

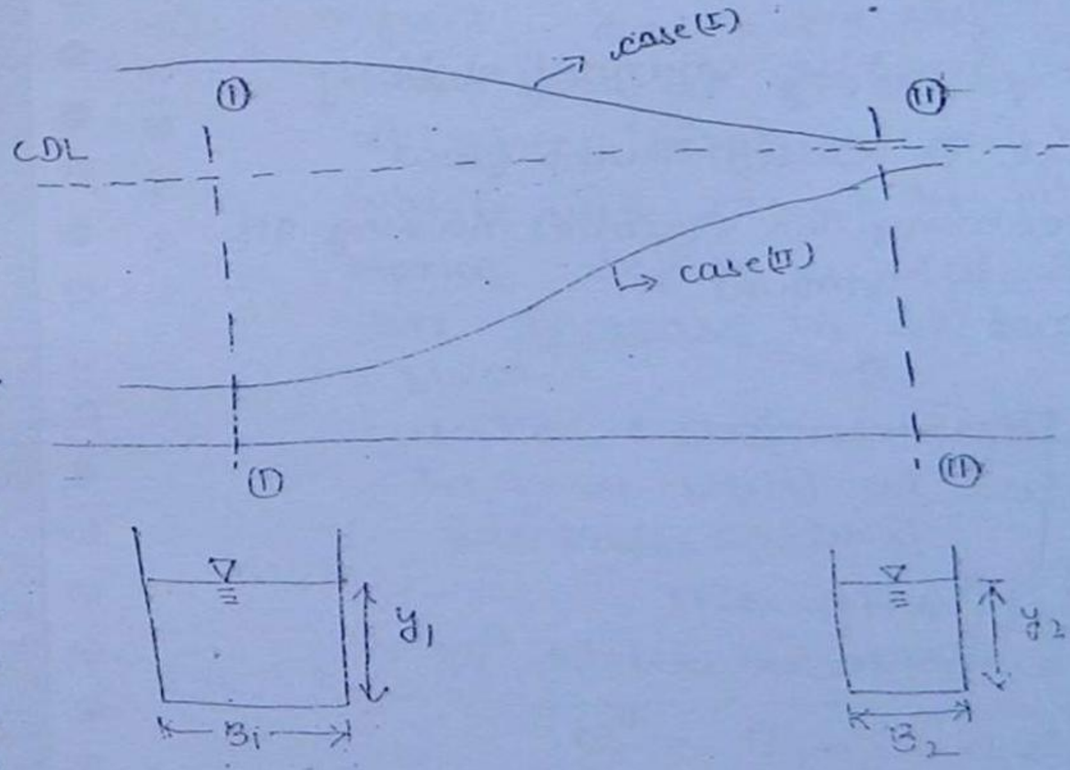
Flow through Rectangular channel Transition :-

when the width of the channel is reduced, it ca[n be] done by

a) sudden contraction

b) Gradual contraction

In suddenly contraction Loss of Energy is much m[ore] than Gradual contraction therefor all practical p[urposes] Gradual contraction is preferred.



$= 1.6 + \frac{1.875^2}{2 \times 9.81}$

$= 1.779$

$\left[\frac{\quad}{1.6 \times 10} \right.$

(316.)

At Mid depth

$$y = \frac{1.6 + 2.0}{2} = 1.8\,M$$

$$Q = \frac{1}{N} A R^{2/3} S_e^{1/2}$$

$$30 = \frac{1}{[0.015]} \times [10 \times 1.8] \left[\frac{10 \times 1.8}{10 + 3.6} \right]^{2/3} \times S_e^{1/2}$$

$$\Rightarrow S_e = 0.00043$$

$$\therefore \Delta x = \frac{E_2 - E_1}{S_0 - S_e} = \frac{2.11 - 1.779}{0.0001 - 0.00043} = (-)\,1003$$

$\therefore \Delta x = 1.003$ KM $\rightarrow$ U/S to section (1)

ob2

Choking ↓ :

In the case of a channel with a hump and also in the case of a width constriction, it is observed that the U/S water-surface elevation is not affected by the conditions at section (2) till a critical stage is first achieved.

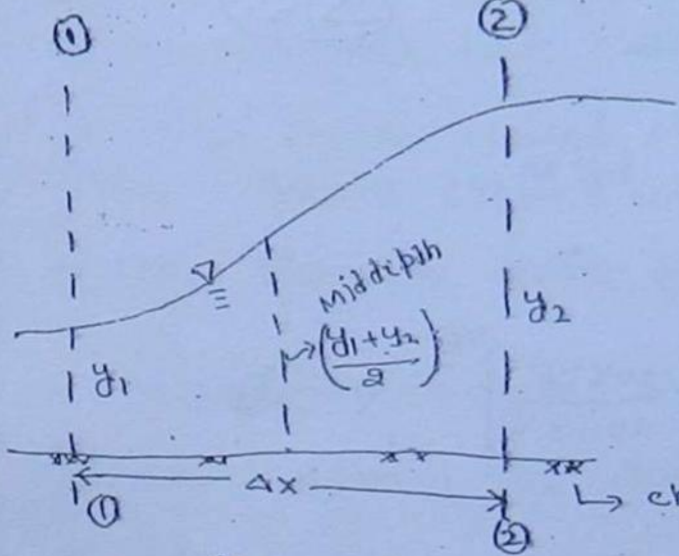
So in the case of a hump for all $\Delta Z \leq \Delta Z_{max}$, the U/S water depth is constant and for all $\Delta Z > \Delta Z_{max}$ the U/S depth is different from y_1. Similarly in the case of width constriction for $B_2 \geq B_{2min}$ the U/S depth y_1 is constant; while for all $B_2 < B_{2min}$ the U/S depth undergoes a change.

This critical condition at section (2) is known as choking.

Thus for all cases with $\Delta Z > \Delta Z_m$ & $B_2 < B_{2m}$ are known as choked conditions.

Approximate Method to determine distance b/w two depths in G.V.F. ↓

(315)



↳ channel slope = S_0

$E_1 = y_1 + \frac{V_1^2}{2g}$

E_2 = Sp. Energy at section ②

$= y_2 + \frac{V_2^2}{2g}$

$$\boxed{\Delta x = \frac{E_2 - E_1}{S_0 - S_e}}$$

slope of Energy Line at mid section

At Mid section $y = y_1 + y_2 / 2$

∴ S_e is given by

$$Q = \frac{1}{N} A R^{2/3} S_e^{1/2}$$

$A = B \cdot y$ → depth at mid section

$P = B + 2y$, $R = A/P$.

Ref. Ex:

$E_2 = y_2 + V_2^2/2g$

$= 2.0 + \frac{1.5^2}{2 \times 9.81}$

$= 2.11$ m

$\left[V_2 = Q/A_2 = \frac{30}{10 \times 2.0} = 1.5 \right.$

1) Normal depth [illegible]

(3) 4

$\therefore A = 10\, y_n$

$Q = \frac{1}{N} A R^{2/3} S_0^{1/2}$

$30 = \frac{1}{0.015} (10 y_n) \left[\frac{10 y_n}{10 + 2y_n} \right]^{2/3} (0.0001)^{1/2}$

$\therefore y_n^{5/2} = 1.909\,(y_n + 5)$

$\Rightarrow y_n = 2.97\ m$ (By trial & bit Method)

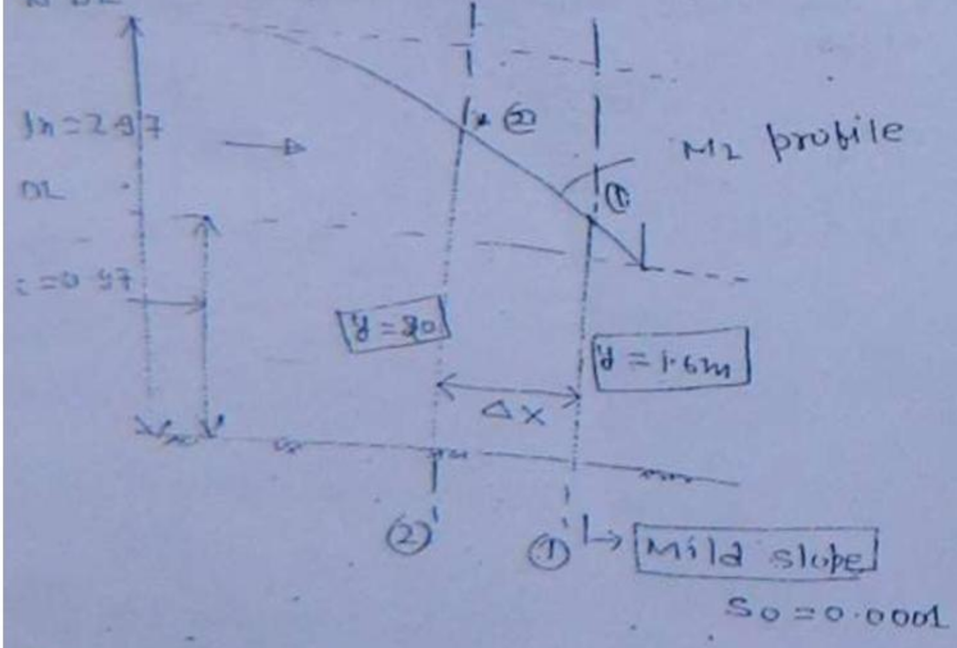
2) Find critical depth

$q = Q/B = 30/10 = 3\ m^3/sec/m$

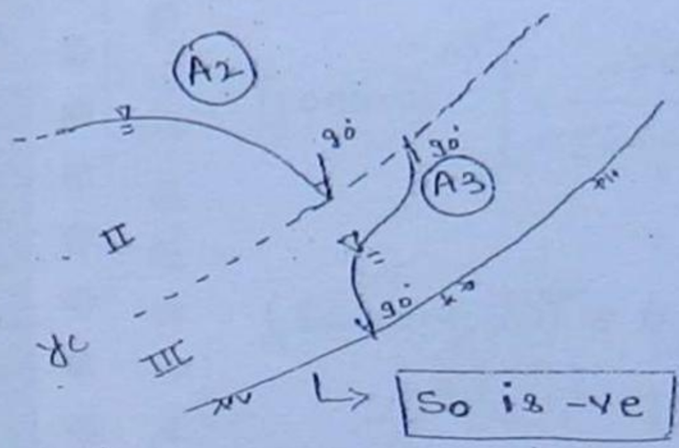
$\therefore y_c^3 = (q^2/g) \longrightarrow$ For Rectangular

$\therefore y_c = \left(\frac{3^2}{9.81}\right)^{1/3} = 0.97\ m$

since $y_n > y_c$ the given slope is Mild slope and since actual depth of flow are b/w y_c & y_n therefor surface profile will be M_2.



Adverse slope:



A2 & A3 * yn will be imaginary so Normal depth Line does not exist.

* A1 zone will not exist and only A2 & A3 will e

Prob 1 A Rectangular channel 10m wide, carry a dischar
** 30 M3/sec. It is Laid at a slope of 0.0001. a section in this channel the depth of flow is Find whether upstream or downstream from Section, the depth of flow is 2M. Also dete the surface profile type. Assume N = 0 Also determine the distance b/w two de along the chanel slope.

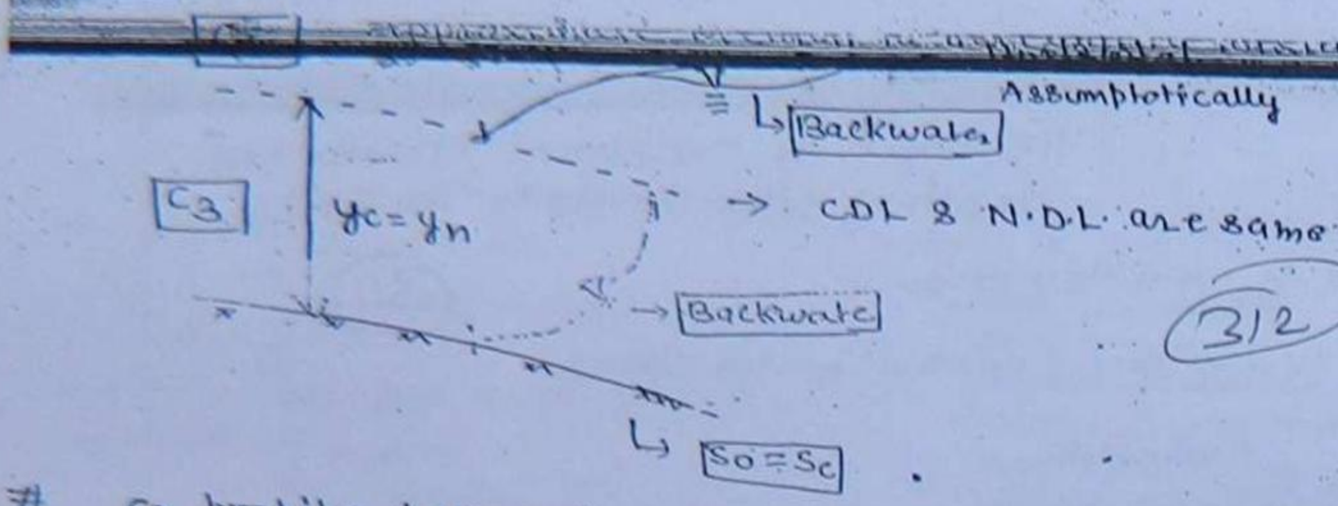
Find Normal depth of flow]

$Q = 30 \; M^3/sec$

$B = 10 \; m$

Section 1 $y = 1.6m$

At section 2. $y = 2m$



C_2 profile does not exist.

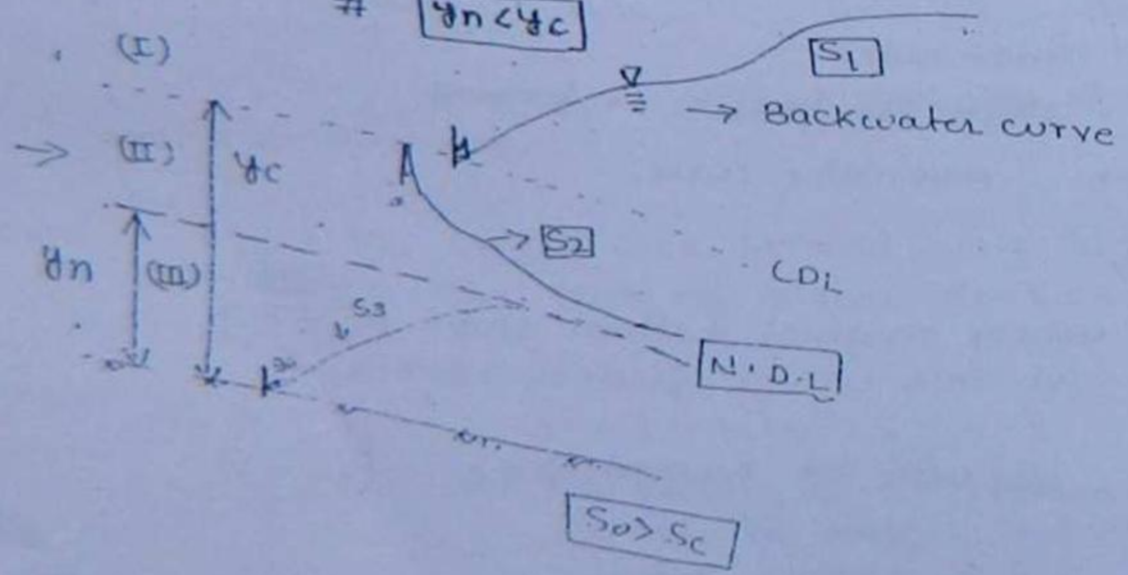
If $y > y_n$ $(= y_c)$ $\Rightarrow$ C_1 profile $\Rightarrow$ Backwater curve

If $y < y_n$ $(= y_c)$ $\Rightarrow$ C_3 profile $\Rightarrow$ ~~drawdown~~ Backwater curve.

steep slope :-

≠ $S_0 > S_c$ imp.

$y_n < y_c$



S_1 profile $\Rightarrow$ when $y > y_c$

S_2 profile $\Rightarrow$ when $y_n \le y \le y_c$

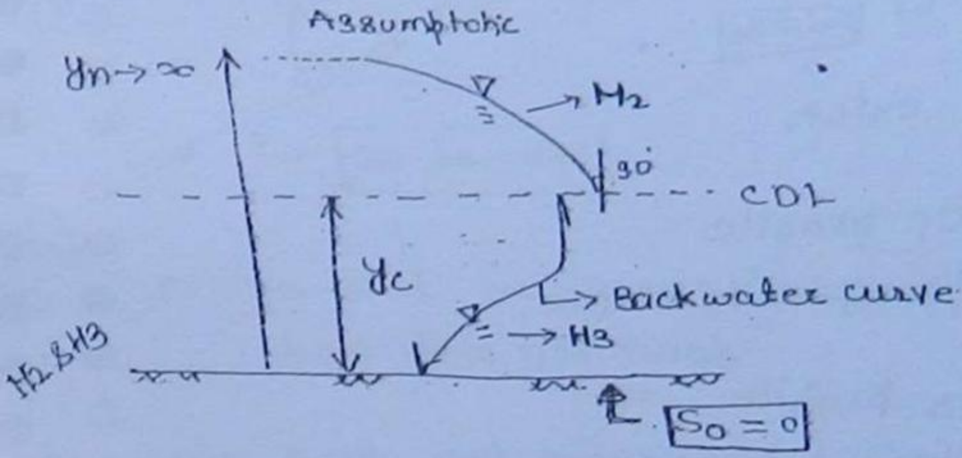
S_3 profile $\Rightarrow$ when $0 < y < y_n$

2) Horizontal slope:

If slope is horizontal than normal depth of flow tends to infinity

$Q \propto y_N A R^{2/3} S^{1/2} \to 0$ (311)

$\Rightarrow$ $\boxed{y_n \to \infty}$ (For horizontal slope)



H_1 profiles are not formed and H_1 zone does exist

If $\boxed{y_c \le y \le y_n}$ → than H_2 profile is formed
→ drawdown curve.

If $\boxed{y < y_c}$ → than H_3 profile is formed.
→ Backwater curve.

3) critical slope:

1) when channel bottom slope $S_0 = S$... at this stage flow is critical

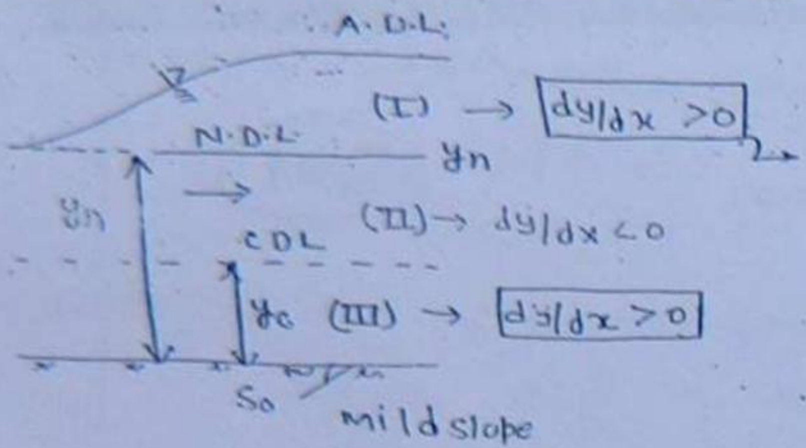
(Q&C)

2) y_n will be Equal to y_c. $\boxed{y_n = y_c}$

In Mild slope

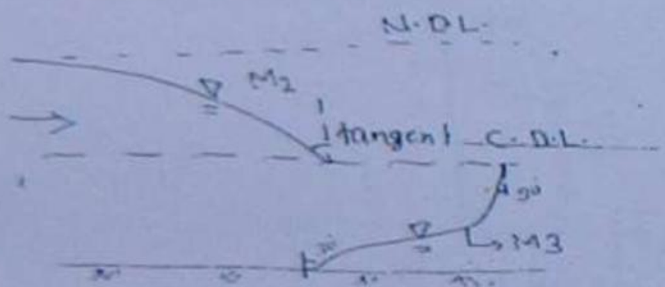
$S_0 < S_c$

3/0



curve is Backwater in the direction of flow.
i.e. M1 profile Meets asymptotically t NDL and Rises in the direction of flow.

When $y_c \leq y \leq y_n$, than M2 profile is formed



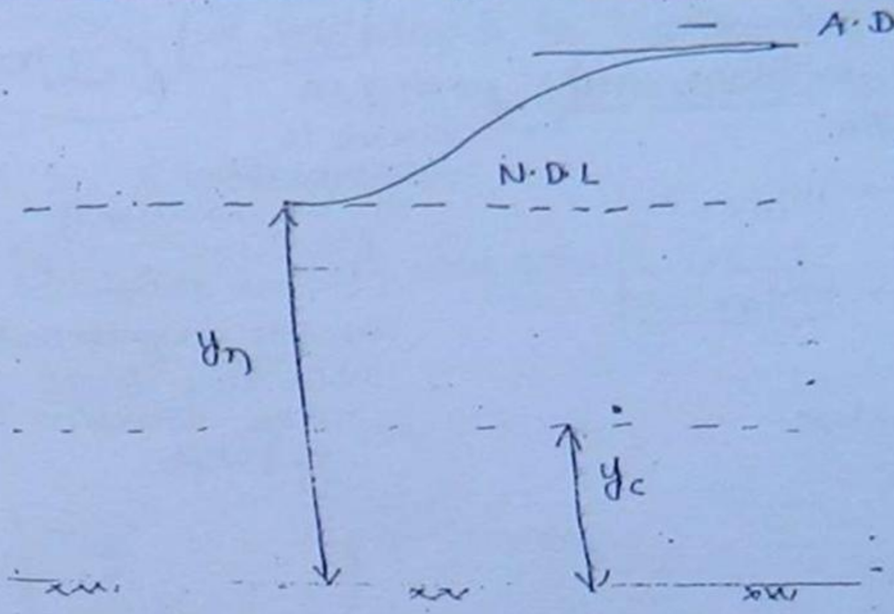
M2 profile Meets asmtotatically to N.D.L. and Meets norma to C.D.L. The curve is draw down in the direction of flow.

NOTE: M_1 & M_2 profile are formed when flow are of stable type having Fraud No. Less than 1

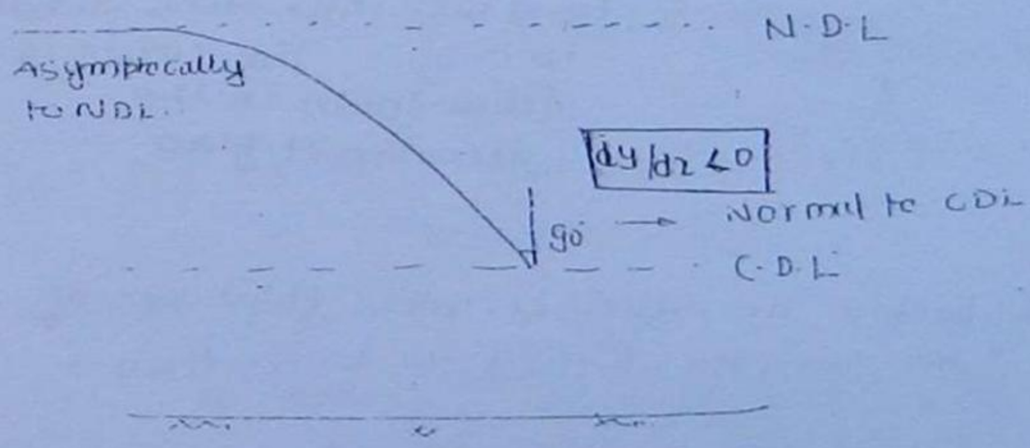
When $0 < y \leq y_c$ → M3 profile is formed

→ M3 profile is backwater curv which is normal to channel bottom ~~slope~~ slope & C.D.L.

→ M3 curve is formed when flow is supercritical



If. $y_c \leq y \leq y_n$ → M_2 profile will be formed
↳ Means asymptocally to normal depth and Normally to critical depth in direction of flow. The curve is dr



** M_1 & M_2 curve profile are formed when $Fr < 1$

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1. Determine normal depth of flow by y_n.

$$Q = \frac{1}{N} \cdot A R^{2/3} S^{1/2}$$

OR

$$Q = C \cdot A \cdot R^{1/2} S^{1/2}$$

2. determine critical depth of flow y_c.

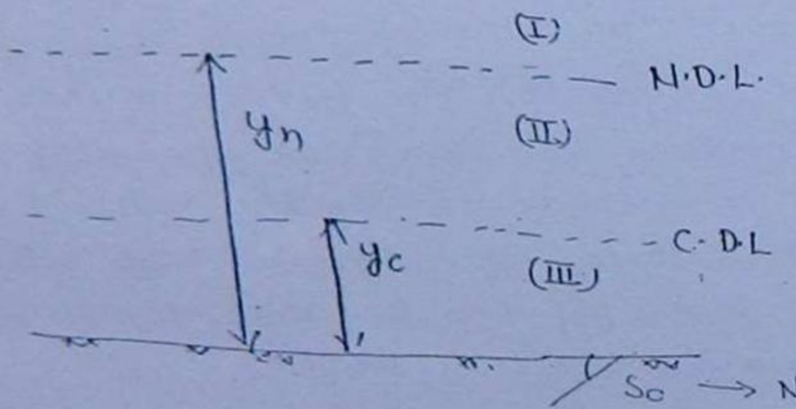
$\boxed{Q^2/g = A^3/T}$ → In General

$\boxed{q^2/g = y_c^3}$ → For Rectangular channel

3. Actual depth of flow y.

(a) Mild slope :

when $\boxed{y_n > y_c}$



$\boxed{S_0 < S_c}$

If actual depth of flow y is such that

~~$y_c < y < y_n$~~ $\boxed{y > y_n > y_c}$

↳ Than surface profile is M_1 ty

M_1 profile Means normal depth Line is asympotically and tend to become horizontal in d/s towards actual depth Line. The curv water is backwater and rising hence

CRITICAL DEPTH

→ Constant discharge situation:

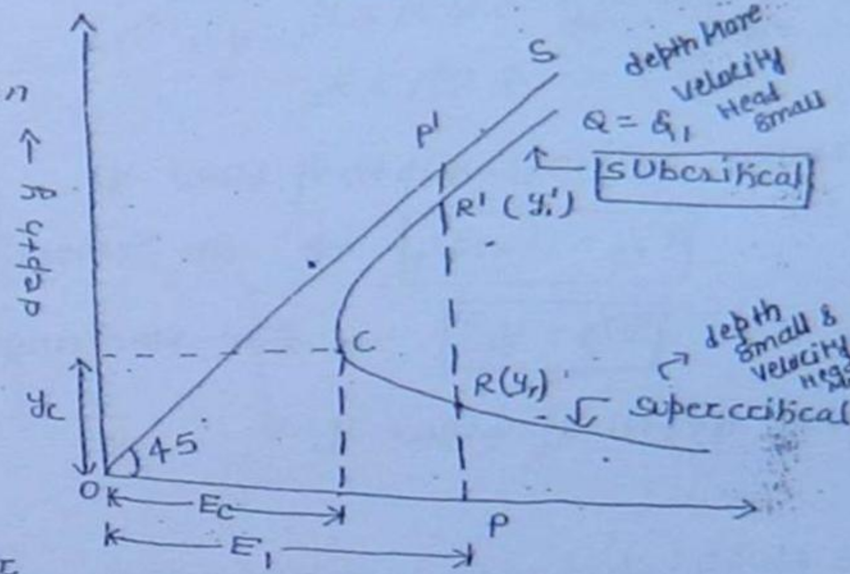
(307)

$$E = y + \frac{Q^2}{2gA^2}$$

* For a channel of known geometry

$E = f(y, Q)$

Keeping Q = constant $Q = Q_1$ the variation of E with y is represented by a cubic parabola.



That at any particular discharge Q_1 can be passed in a given channel at two depths & still maintain the same sp. energy E.

The depth of flow can be either $PR = y_1$ or $PR' = y_1'$. These two have same sp. energy. The intercept $P'R'$ or $P'R$ represents the velocity head. depth ($PR = y_1$) is smaller and has a large velocity head while other ($PR' = y_1'$) has a larger depth and consequently a smaller velocity head.

→ For a given Q, as the sp. energy is increased the difference b/w the two alternate depth increases.

→ If E is decreased, the difference $(y_1' - y_1)$ will decrease and at a certain value $E = E_c$

→ At the lower limb CR of the sp. energy curve the depth $y_1 < y_c$ As such $V_1' > V_c$ and $F_1 > 1.0$

↳ supercritical Flow Region

→ In the upper limb CR', $y_1' > y_c$ as such $V_1' < V_c$ and $F_1' < 1.0$ ⇒ Subcritical flow Region.

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$\therefore \frac{V^2}{gy} \neq 1$

iv) If $\frac{V^2}{gy} = 1$, $F_r = 1$

$\boxed{\frac{dV}{dx} = \infty}$ → Since in G.V.F $[dy/dx]$ is small, depth of flow change over a larger length hence this condition beyond the assumption of G.V.F.

For a given discharge normal depth of flow can be calculated as follows:↓

Normal depth of flow:↓
↓
[depth of flow at which a given discharge flows as uniform flow in a given channel.]

For given values of Mannings N and chezy, C and for given value of Q and channel bottom slope 'S_0' there will exist one depth of flow (y_n) at which the uniform flow will be maintained; such a depth of flow is called Normal depth of flow.

- Choking:- (1) U/s, water surface elevation is not affected by the conditions at section (2) till a critical stage is just achieved.

(2) In case of Hump, for all $\boxed{\Delta z \le \Delta z_{max}}$ — U/s water depth is constant
For all $\boxed{\Delta z > \Delta z_{max}}$ → y_1 increases in subcritical flow
→ y_2 decreases in super critical flow

(3) In case of width contraction:-
$\boxed{B_2 \ge B_{2m}}$ → U/s depth y_1 is constant
while for $\boxed{B_2 < B_{2m}}$ → U/s depth goes under a change

→ Onset of critical condition at (2) is prerequisite to choking.

→ All cases $\boxed{\Delta z > \Delta z_{max}}$, $\boxed{B_2 < B_{2m}}$ ⇒ known as choked condition

→ In subcritical flow, water surface will drop due to decrease in sp. energy
or supercritical flow, depth of flow increases due to reduction in sp. energy.

According to Manning's Eqn:]

$$\frac{dy}{dx} = S_0\left[\frac{1-(y_n/y)^{10/3}}{1-(y_c/y)^{10/3}}\right]$$

(30)

$y \rightarrow$ Actual depth of flow

$y_n \rightarrow$ It is that depth of flow at which flow i[s] uniform

$dy/dx \rightarrow$ Rate of change of depth of flow w.r.t channel bottom

If $\frac{dy}{dx} > 0 \rightarrow$ depth of flow increasing in direction of fl[ow]

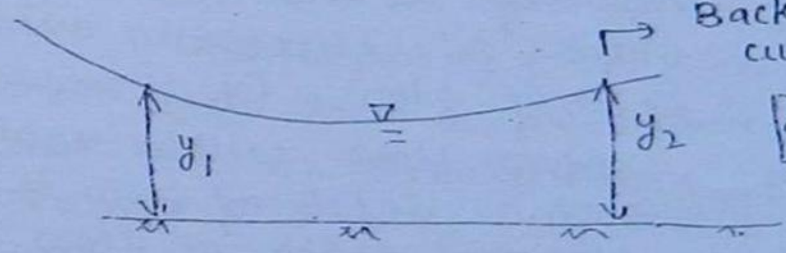
↳ Backwater flow curve

$dy/dx = 0 \rightarrow$ depth of flow is constant.

$dy/dx < 0 \rightarrow$ depth of flow is decreasing

↳ drawdown curve.

1)



$dy/dx > 0$

$$dy/dx = \frac{S_0 - S_f}{1 - \frac{V^2}{gy}} \quad ; \quad dy/dx > 0 \text{ If}$$

$\rightarrow$ channel slope > Energy slope

$\rightarrow$ Flow is subcritical.

$$\left[\begin{matrix} S_0 > S_f \\ \& \\ 1 > \frac{V^2}{gy} \end{matrix}\right]$$

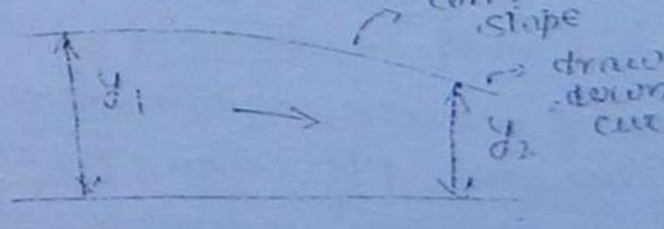
2)

$S_0 < S_f$

$1 < \frac{V^2}{gy}$

$dy/dx < 0$

↑ [supercritical flow]



[drawdown curve]

↳ convex shape.

$$\frac{d}{dx}\left[\frac{Q^2}{2gB^2y^2}\right] = \frac{Q^2}{2gB^2} \times \frac{-2}{y^3} \cdot \frac{dy}{dx} \qquad [A = By$$

$$= \frac{Q^2}{gB^2y^2} * \frac{1}{y}\,\frac{dy}{dx}$$

(304)

$$= -\frac{V^2}{gy} \cdot \frac{dy}{dx}$$

$$\therefore \frac{dE}{dx} = \frac{dz}{dx} + \frac{dy}{dx} - \frac{V^2}{gy} \cdot \frac{dy}{dx}$$

$$\frac{dy}{dx}\left[1 - \frac{V^2}{gy}\right] = \frac{dE}{dx} - \frac{dz}{dx}$$

$$\therefore \frac{dy}{dx} = \frac{-S_f - (-S_0)}{1 - V^2/gy}$$

$$\therefore \boxed{\frac{dy}{dx} = \frac{S_0 - S_f}{1 - V^2/gy}} \rightarrow$$ dynamic eqn for G.V.F Rectangular section.

$$\boxed{\frac{dy}{dx} = \frac{S_0 - S_f}{1 - F_r^2}} \rightarrow$$ For Rectangular channel

For All sections:

$$\boxed{\frac{dy}{dx} = \frac{S_0 - S_f}{1 - \frac{Q^2}{g}\frac{T}{A^3}}}$$

$$\left[F_r = \frac{V}{\sqrt{gy}}\right.$$

$$\boxed{S_0 - S_f = \frac{dE}{dx}}$$

↑ differential energy eqn of G.V.F

Energy slope

$$\boxed{S_f = h_f/L}$$

According to chezy's eqn

$$\boxed{\frac{dy}{dx} = S_0\left[\frac{1 - (y_n/y)^3}{1 - (y_c/y)^3}\right]}$$

V.Imp (obj)

$y_c \rightarrow$ critical depth of flow

$y_n \rightarrow$ Normal " "

Dynamic Eqn for Gradually Varied Flow:-

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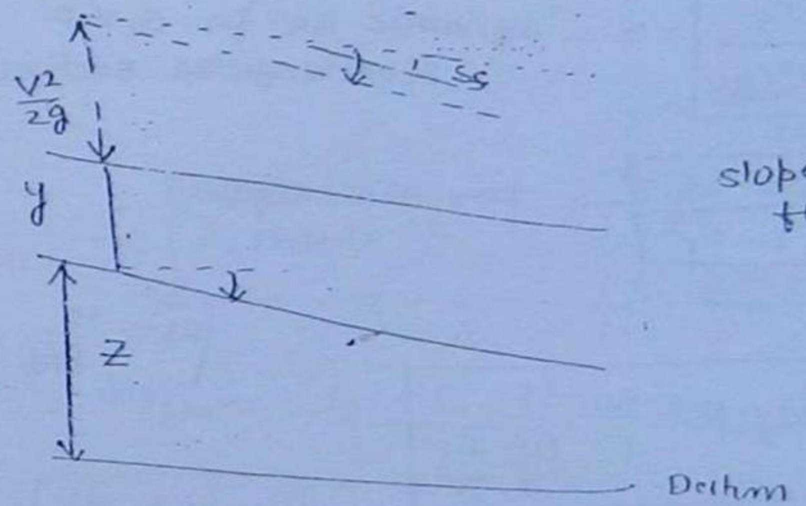
Assumptions:-

1) Chezy's Formula & Manning Formula is used (with S_0 as Energy slope.)
2) Bottom slope of the channel is very small
3) channel is prismatic.
4) Energy correction factor is 1
5) Pressure distribution is only hydrostatic
6) Discharge is constant, flow is steady.
7) Roughness coeff. of channel is independent of depth of flow and taken constant through the Length of channel.



slope is falling flow direction.

channel slope $dz/dx = -S_0$

If total Energy is E

$$dE/dx = \text{Energy slope} - S_f$$

$$E = z + y + V^2/2g$$

$$dE/dx = dz/dx + dy/dx + d/dx\left[\frac{V^2}{2g}\right]$$

$$\therefore \; d/dx\left(\frac{V^2}{2g}\right) = d/dx\left[\frac{Q^2}{2gA^2}\right]$$

$$\therefore \frac{V}{\sqrt{gD}} = 1$$

$\therefore$ For Rect section $D = A/T = \frac{B\cdot y}{B} = y$

$$\therefore \boxed{V_c = \sqrt{g y_c}}$$

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For Triangular section

$$D = A/T = y/2$$

$$\therefore \boxed{V_c = \sqrt{g y_c/2}}$$

For Parabolic section

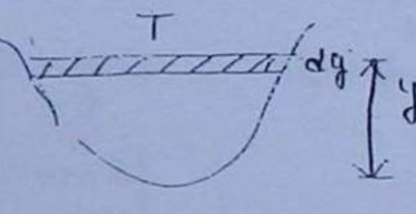
$$D = A/T = 2/3\, y$$

$$\therefore \boxed{V_c = \sqrt{\frac{2 g y_c}{3}}}$$

critical depth for Non-uniform channel:-

$$dA = T\,dy$$

$$\therefore dA/dy = T$$



$$E = y + \frac{Q^2}{2gA^2}$$

For critical Flow $dE/dy = 0 = 1 + \frac{Q^2}{2g}\left(-2/A^3\right) d$

$$\therefore \frac{Q^2}{g} = \frac{A^3}{(dA/dy)} = A^3/T$$

$$\therefore \boxed{\frac{Q^2}{g} = A^3/T}$$ → For critical Flow
Applicable for Rectangular or Non-uniform section.

imp

$y_c = 2/3\,E_{min}$ For Rectangular

$= 3/4\,E_{min}$ For Parabolic.

$= 4/5\,E_{min}$ For Triangular

→ At critical flow it may be proved that discharge is Maxm. For a Rectangular section.

$\therefore\ E = y + \frac{q^2}{2g}\cdot\frac{1}{y^2}$

(301)

$\therefore$ For E_{min}, $dE/dy = 0$

$\Rightarrow\ 1 + \frac{q^2}{2g}\left(-2/y^3\right) = 0$

$\Rightarrow\ y^3 = (q^2/g)$

$\therefore$ At E_{min}, $y = y_c$

$\therefore\ \boxed{y_c^3 = (q^2/g)}$ → Valid For Rectangular section.

$\therefore$ If $y = y_c$, $E = E_{min}$

$\therefore$ at $y = y_c$, $E_{min} = y_c + \frac{y_c^3}{2} \times 1/y_c^2$

$\therefore\ \boxed{E_{min} = 3/2\, y_c}$

At critical flow, for Rectangular section kinetic head is half of potential head.

* For parabolic section: ↓

$$E_{min} = 4/3\, y_c = y_c + y_c/3$$ → Kinetic Head

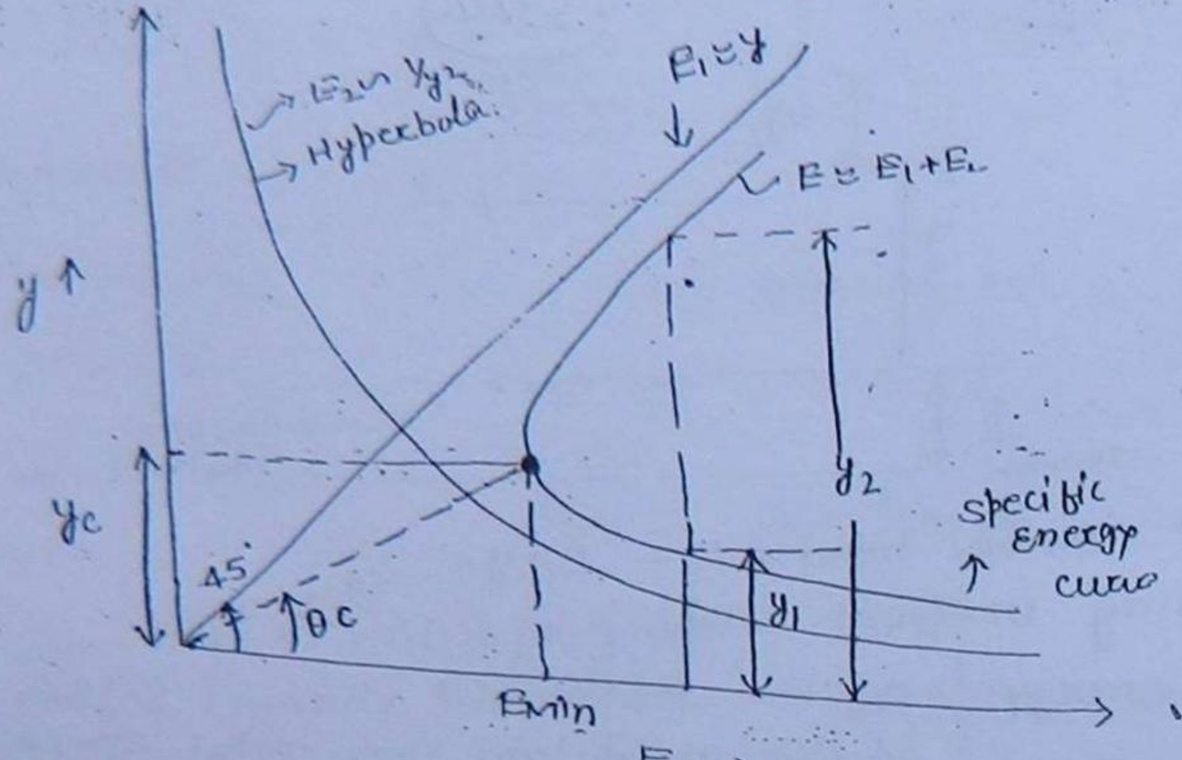
Triangular section: ↓

$$E_{min} = 5/4\, y_c = (y_c) + y_c/4$$ → Kinetic Head.

$E_1 = E_P = y$

$E_2 = E_K = q^2/2g * 1/y^2$

300



$$\tan\theta = y_c / E_{Min}$$

$$= \frac{\frac{2}{3} E_{min}}{E_{min}}$$

$\Rightarrow$ $\theta_c = 33.7°$ For Rectangular
$= 38.65°$ For Triangular
$= 36.8°$ For Parabolic

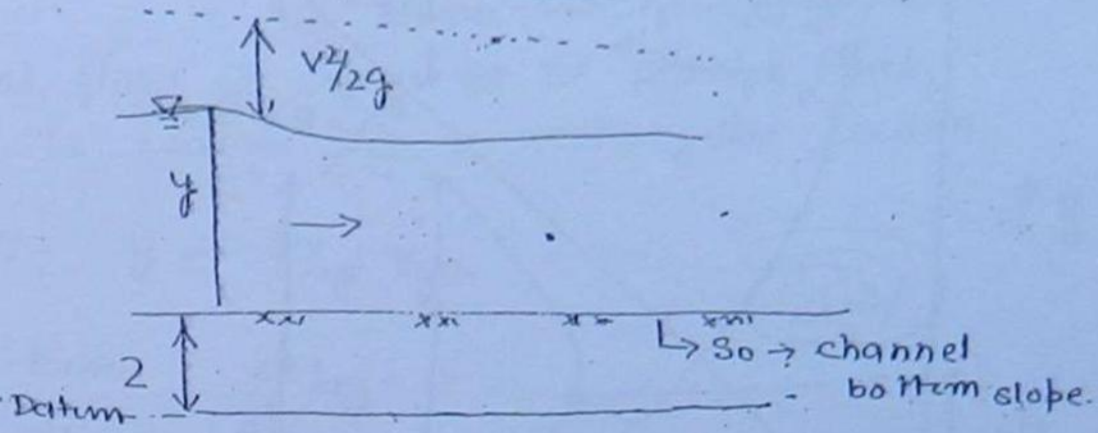
imp.

For G.V.F. Minimum specific Energy occurs at which there is only one depth of flow called critical depth of flow (y_c). It Means at critical flow specific energy is minimum.

For other sp. energy there will be two depth of flow y_1 & y_2 known as alternate depths. For Rectangular section y_c is critical depth 2/3 of Emin

G.V.F. :

(299)



Total Energy head = E = $Z + y + \frac{V^2}{2g}$

Assuming uniform velocity of section $\alpha = 1$

Specific Energy: If the channel bottom is taken as datum than total energy per unit wt. is called specific Energy.

∴ For G.V.F. specific energy is constant

$$E = y + V^2/2g$$

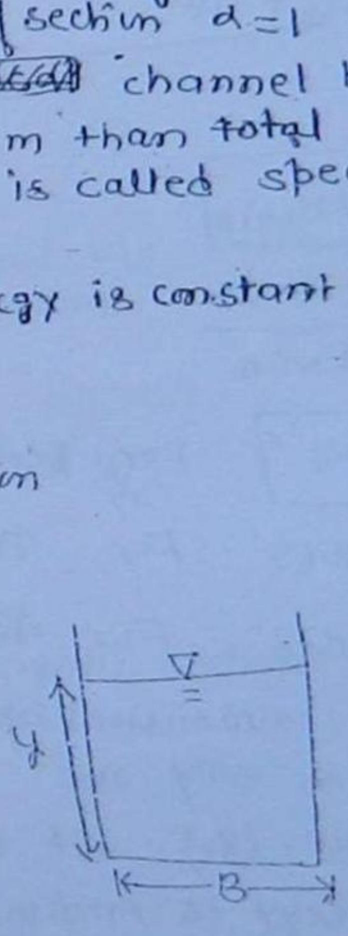
Case: Ist: For Rectangular section

specific Energy

$$\boxed{E = E_p + E_k}$$

$$E = y + V^2/2g$$

$$= y + \frac{Q^2}{2gA^2}$$



∴ Let discharge per unit width $q = Q/B$

$$\therefore E = y + q^2/2gy^2 = y + (q^2/2g) \times 1/y^2$$

mp

$R_{Max} = 0.60R$
$= 0.30D$

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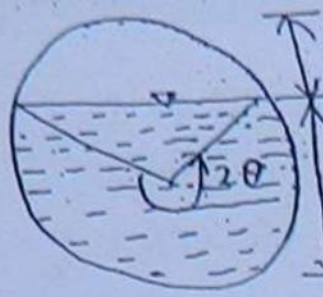
For V_{Max}: ↓

$2\theta = 257^\circ 30'$
$y = 0.81D$
$R_{Max} = 0.3D$



ondition For Maxm discharge: ↓

> using chezy's eqn:

$Q = CA\, R^{1/2} \cdot S^{1/2}$

For $Q_{Max} \Rightarrow (AR)^{1/2}_{Max}$

$\therefore \frac{d}{d\theta}\left[A R^{1/2}\right] = 0$

$\Rightarrow \frac{d}{d\theta}\left[\frac{A^{3/2}}{P^{1/2}}\right] = 0$

$\Rightarrow$

$2\theta = 308^\circ$
$y = 0.95D$
$R = 0.29D$

B> using Manning eqn: ↓

$Q = \frac{1}{N} \cdot A\, R^{2/3}\, S^{1/2}$

$Q_{Max} = (A R^{2/3})_{max}$

$\therefore$

$2\theta = 302^\circ 20'$
$y = 0.938D$
$R = 0.29D$

COMMENT: → From techanical consideration Manning result are more relalistic because Mannings N based on surface grea roughness which can be computin directly whereas chezy's C is given arbitary.

$\therefore$ $\boxed{R = y/2\sqrt{2}}$

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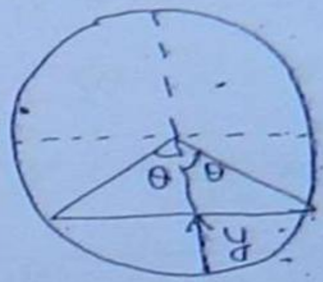
CIRCULAR SECTION: ↓

1) For Maxm. velocity condition

2) For Maxm. discharge condition



$V \propto (R = A/P)^{1/2}$
$\propto R^{2/3}$

$Q \propto A \cdot R^{2/3}$ ↳ Manning's eqn
$\propto A \cdot R^{1/2}$ chezy's eqn.

$\therefore$ For V_{max} – R should be Maxm.

$\therefore A = R^2\left[\theta - \frac{\sin 2\theta}{2}\right]$

$P = 2\theta R$

$\therefore dR/d\theta = 0 \Rightarrow \frac{\partial}{d\theta}(A/P) = 0$

$$\frac{dA}{d\theta} = R^2[1 - \cos ...$$
$$dP/d\theta = 2R$$

$$= \frac{P \cdot \left(\frac{dA}{d\theta}\right) - A \cdot \frac{dP}{d\theta}}{P^2} = 0$$

$$\Rightarrow \frac{PR^2[1-\cos 2\theta] - A(2R)}{P^2} = 0$$

$$\Rightarrow 2R\theta[1-\cos 2\theta]R^2 - R^2\left[\theta - \frac{\sin 2\theta}{2}\right] \times 2R = 0$$

$$\Rightarrow \boxed{2\theta = \tan 2\theta}$$

V. Imp: $\boxed{\tan\alpha = \alpha \quad \alpha = 4.5 \text{ rad}}$ → Trial & Hit

$$\boxed{2\theta = 4.5 \text{ rad} = 257^\circ \cdot 30'}$$

$$= \frac{y}{AC} = \frac{y}{y\sqrt{n^2+1}} = \frac{OB}{\left(\frac{B+2ny}{2}\right)}$$

$(B+2ny/2)$

$$\therefore \boxed{OB = y}$$

Condition: For an economical trapezoidal section side slope will be at nH: 1V

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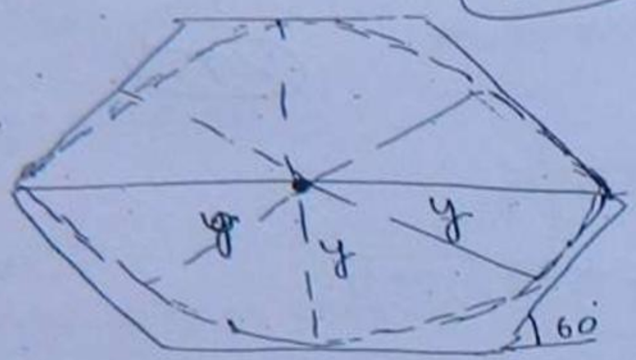


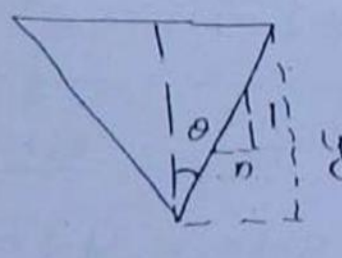
$\boxed{\theta = 60^\circ}$ → channel is Most Economic

$\boxed{1H : 3V}$

Trapezoidal section is a part of Hexagon whose centre at Middle of top width.

Triangular section:

$$A = ny^2$$
$$P = 2y\sqrt{1+n^2}$$
$$R = A/P$$



∴ For Maxm R, Pmin

$$\partial P/\partial n = 0$$

$$P = 2 \times \frac{\sqrt{A}}{\sqrt{n}} \sqrt{n^2+1}$$

$$P = 2\sqrt{A}\sqrt{1+1/n} \Rightarrow P^2 = 4A\,(n + 1/n)$$

$$2P\left(\frac{dP}{dn}\right) = 4A\,(1 - 1/n^2)$$

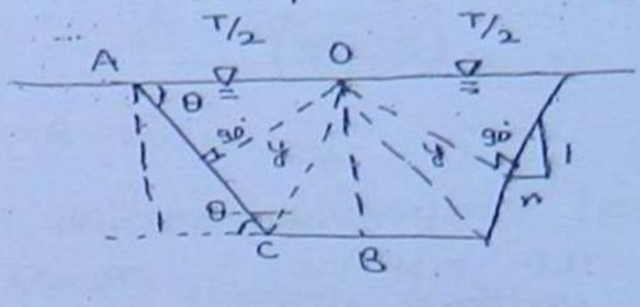
$$\boxed{\frac{dP}{dn} = 2\sqrt{A}}$$

$$\frac{dP}{dn} = 0, \quad n = 1 \Rightarrow \boxed{\theta = 45^\circ}$$

i. Triangular section to be most economical $\theta = 45$ and $\boxed{R = \frac{y}{2\sqrt{2}}}$

Trapezoidal section

case I: → side slopes are constant



$$A = (B+ny)y$$
$$P = B + 2y\sqrt{1+n^2}$$
$$T = B + 2ny$$

For Maxm Q at given area

P should be Minimum

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$$\therefore \ dP/dy = 0$$

$$P = B + 2y\sqrt{n^2+1}$$

$$= A/y - ny + 2y\sqrt{n^2+1}$$

$$\therefore \ dP/dy = -A/y^2 - n + 2\sqrt{n^2+1}$$

$$= -\left(\frac{(B+ny)y}{y^2}\right) - n + 2\sqrt{n^2+1} = 0$$

$$= -(B+ny) - ny + 2y\sqrt{n^2+1} = 0$$

$$\therefore \boxed{y\sqrt{n^2+1} = \frac{B+2ny}{2}}$$

$$T/2 = \frac{B+2ny}{2}$$

$$\text{side} = y\sqrt{n^2+1}$$

∴ For Most Economical channel

$\boxed{1/2 \text{ top width} = \text{one of sloping side Length}}$ imp

$$\therefore R = A/P = \frac{(B+ny)y}{B+2y\sqrt{n^2+1}}$$

$$= \frac{(B+ny)y}{B+2\frac{(B+2ny)}{2}} \Rightarrow \boxed{R = y/\ldots}$$

Economical section: ↓

A section of a channel is said to be economical when its cost of constr... is Least or for a given discharge and given area.

For a given sectional Area, dimension of section des... in such a way that discharge carrying capacity is Maximum.

ectangular section: ↓

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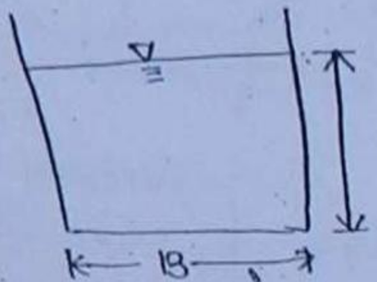
$A = By =$ constant



For Maxm Q

we know that

$Q \propto V \propto R^{1/2} \rightarrow$ chezy's

$\propto R^{2/3} \rightarrow$ Manning

$q_{Max} \rightarrow R$ should be Maxm

For a given area $R = A/P$

For $R_{max} \rightarrow P$ should be ~~Maximum~~ Minimu...

wetted perimeter $P = B + 2y$

$P = A/y + 2y$

$\therefore$ For P_{min} $dP/dy = 0$

$-A/y^2 + 2 = 0$

$\Rightarrow \boxed{y = B/2}$ gap

$\therefore$ $\boxed{\text{depth of flow} = \tfrac{1}{2}\text{ width}}$ gap

Hydraulic Radius $R = A/P = \dfrac{By}{B+2y} = \dfrac{B \cdot B/2}{B + 2 \cdot B...}$

$\boxed{R = B/4 = y/2}$ gap

Prob. Find the discharge for the channel section shown in figure whose bed slope is .0001 and Manning's N = 0.018

$S = 0.0001$
$N = 0.018$ → [0.012 to 0.025]
↑ For smooth lined channels. ↑ For very rough earthen channels

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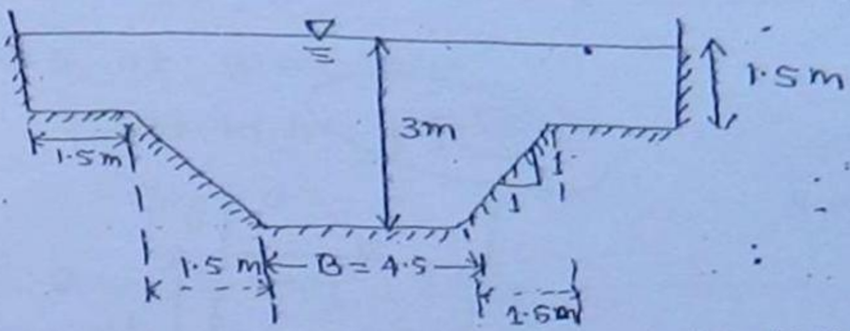


Open channel
- Steady
  - uniform → Flow in a prismatic channel with constant velocity
  - GVF → (i) Backing up of water in a stream; (ii) dropping of water surface due to drop in canal bed
  - RVF → A hydraulic jump occurring below a spillway
  - Spatially varied → Flow over a bottom rack
- Unsteady
  - Gradually varied → Passage of flood wave
  - Rapidly varied → A surge moving up a channel; Bore travelling up a river
  - Spatially varied. → Surface runoff due to rainfall.

* In GVF, frictional resistance plays an important role.

* In GVF, RVF no flow is externally added or taken out of the channel.

→ Spatially varied flow — either some flow is added or abstracted from the system.

→ Specific force is sum of the pressure force + momentum flux per unit wt. of the fluid at a section.

- Sp. force is constant in a horizontal, frictionless channel.

- Critical flow condition is governed by the channel geometry and discharge; other channel properties such as the bed slope and roughness do not influence the critical flow condition for any given discharge.

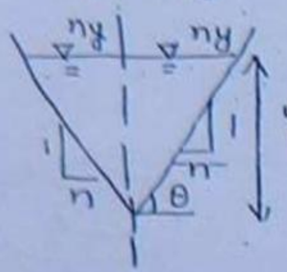
side slopes

[n H : 1 V]

$E_c = \frac{5}{4} y_c$

$y_c = \left(\frac{2Q^2}{g m^2}\right)^{1/5}$

$F = \sqrt{2} \cdot \frac{V}{\sqrt{gy}}$



$\tan\theta = 1/n$

$A = ny^2$

$T = 2ny$

$R = A/P = \frac{ny}{2\sqrt{1+n^2}}$

$P = 2y\sqrt{1+n^2}$

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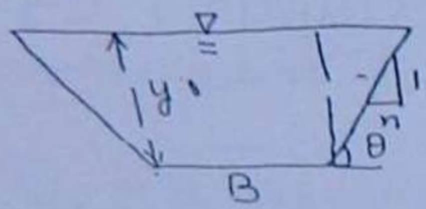
d) Trapezoidal section:



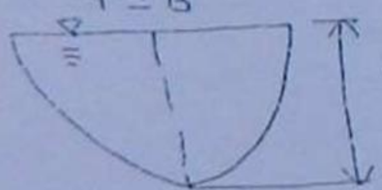
$T = B + 2ny$

$A = \left(\frac{B+T}{2}\right) y = \left(\frac{B+B+2ny}{2}\right) y$

$\boxed{A = (B+ny)\,y}$ ✓

Wetted perimeter $\boxed{P = B + 2y\sqrt{1+n^2}}$

e) Parabolic channel:



Hydraulic depth

$\boxed{D = A/T = \frac{2}{3}y}$

- Section Factor

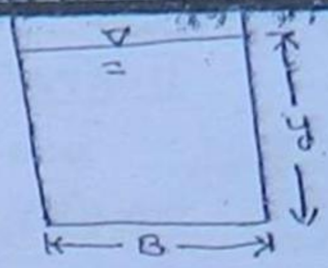
$Z = \frac{2}{9}\sqrt{6}\, B y^{3/2}$

$A = \frac{2}{3} T y = \frac{2}{3} B y$

Wetted perimeter $P = B + \frac{8}{3}\frac{y^2}{B}$

$= 3B^2 + 8y^2$

A> Rectangular section:



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$A = By$

Wetted Perimeter $= B + 2y$

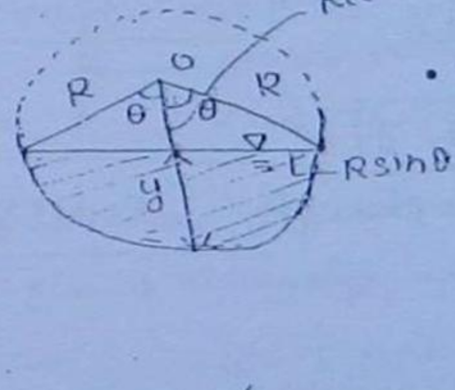
$R = A/P = \frac{By}{B+2y}$

$D = $ Hy. depth $= A/T = y$

imp: Section Factor $= \sqrt{A^3/T}$

$= \left[\frac{(By)^3}{B}\right]^{1/2} = B \cdot y^{3/2}$

B> circular section:



• Area of Flow

$= \theta R^2 - 2\sqrt{R^2(\ldots}$

$\frac{1}{2} \times (\ldots$

$[\theta \rightarrow \ldots$

$= R^2\left[\theta - \frac{1}{2}\sin \ldots\right.$

$A = R^2\left[\theta - \frac{\sin \ldots}{}\right.$

- Top width $T = 2R\sin\theta$ ✓
- Wetted Perimeter $P = 2\theta R$

$$C = \frac{23 + \frac{0.00155}{S} + 1/n}{\left[1 + \left[\left(23 + \frac{0.00155}{S}\right)\right] \frac{n}{\sqrt{R}}\right]}$$

Bazin's eqn: ↓

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$$C = \frac{157.6}{1.81 + K/\sqrt{R}}$$

· K = Bazin's coeff

$$C = \frac{187}{1 + M/\sqrt{R}}$$

$$C = \frac{m/sec}{\sqrt{m}} = L^{1/2} T^{-1/2}$$

Average or Mean velocity is findout

Manning's Equation: ↓

$$V = \frac{1}{N} R^{2/3} S^{1/2}$$

N = Manning's Rugosity con

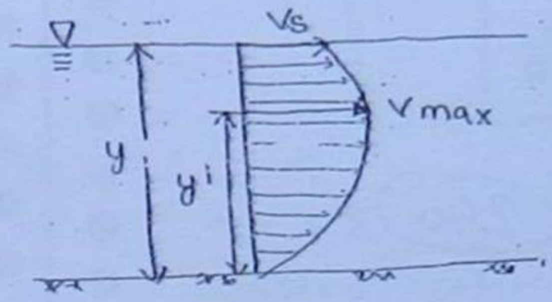
$$N = L^{-1/3} T^{1}$$

$$C = \frac{1}{N} R^{1/6}$$

V. Imp.

$$C = \sqrt{8g/f} = \frac{1}{N} R^{1/6}$$

Velocity distribution in open channel :→



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y' = distance of Vmax from bottom ≃ 0.8y to 0.95y **imp**

$$\boxed{V_s \simeq 0.91\ V_{max}}$$ **imp** → (May be b/w 0.85 to 0.95 Vm

↳ velocity at surface

$$\boxed{V_{Mean} = Q/A}$$

VMean ≃ velocity at 0.6y from ~~bottom~~ (Freesurface) to

$$\simeq \frac{V_{at\ 0.2y} + V_{at\ 0.8y}}{2}$$

UNIFORM FLOW :→

Methods to determine velocity & disc

(a) chezy's eqn :→

$$V = C\sqrt{RS}$$

$$\boxed{Q = AC\sqrt{RS}}$$

[S = slope of the chann bottom
A = Area of flow
R = Hydraulic Radiu [Effective length Perimeter]]

chezy's constant can be calculated by the Kutter's or Bazin's eqn and c depends upon the surface roughness

C = chezy's constant

$$\boxed{C = L^{1/2}T^{-1}}$$ **imp**

$$C = \frac{23 + \frac{0.00155}{S} + 1/n}{1 + [(23 + \frac{0.00155}{S})] \frac{n}{\ \ }}$$

n = Kutter's rugosity c = Roughness o channel sur

If $F_R < 1$

Subcritical | Tranquil | Streaming | stable flow
(Velocity Low, depth of flow high)

Critical Flow: ↓

If $F_R = 1 \Rightarrow$ critical Flow.

Supercritical Flow: ↓

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If $F_R > 1 \Rightarrow$ supercritical Flow | shooting | Rapid | unstable flow.
($V\uparrow$, depth of flow Low)

$$\boxed{F_R = \frac{V}{\sqrt{gD}}}$$

$V \rightarrow$ Mean velocity $= Q/A$

$D \rightarrow$ Hydraulic depth

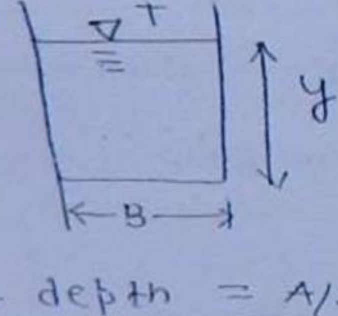
$$\boxed{D = A/T}$$

T = top width

A = Area of flow

For eg: ↓

1)



$\therefore$ Hyd. depth $= A/T$

$= By/B = y$

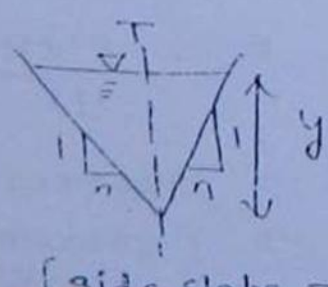
$=$ depth of flow { In case of Rect. channel

2) $T = 2ny$

$A = \frac{1}{2} \times y \times 2ny = ny^2$

$\therefore$ Hydraulic depth $= A/T$

$= y/2$



OPEN CHANNEL FLOW

O.C.F → Uniform → $V = \text{const}$, d (depth) $= \text{const}$, $A = \text{const}$, $Q = \text{const}$ [chan is pris

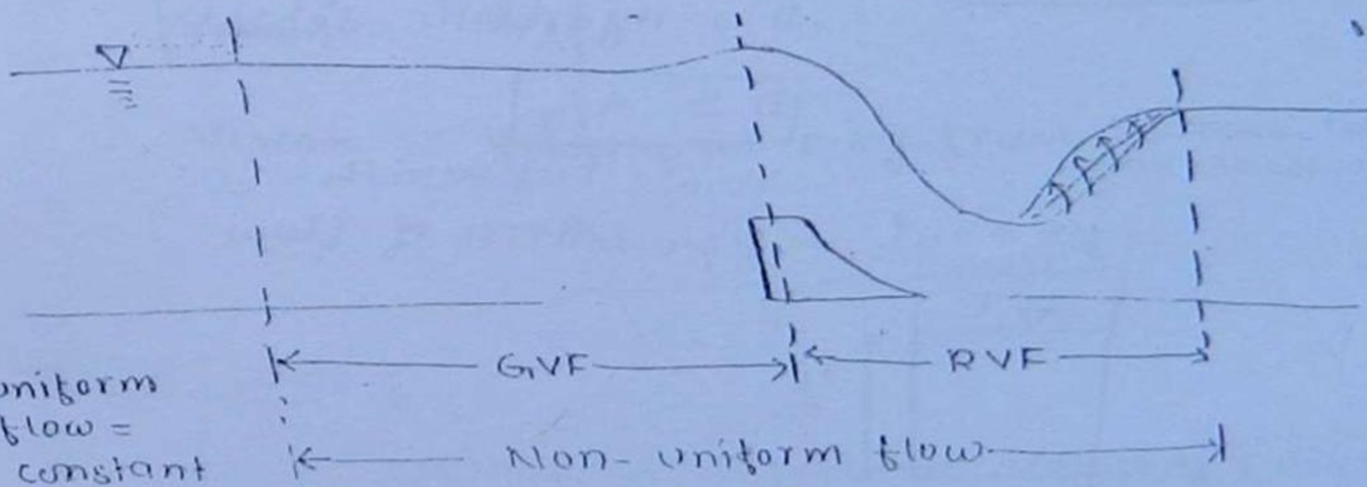
O.C.F → Non-uniform → GVF, RVF

(282)

GVF → depth of flow changes over a lon distance

→ No Loss of energy if friction Los are Negligible.

RVF → depth of flow changes suddenly & Energy dissipation takes place at point of Jump formation.



uniform flow = constant depth.

* For Laminar Flow in open channel

$\boxed{Re \leq 500}$ → Laminar

$\boxed{Re > 2000}$ → Turbulent

$$Re = \frac{\rho V R}{\mu} = \frac{V R}{\nu}$$

R → Hydraulic Radius $= A/P$ → wetted perime

→ Hydraulic Mean

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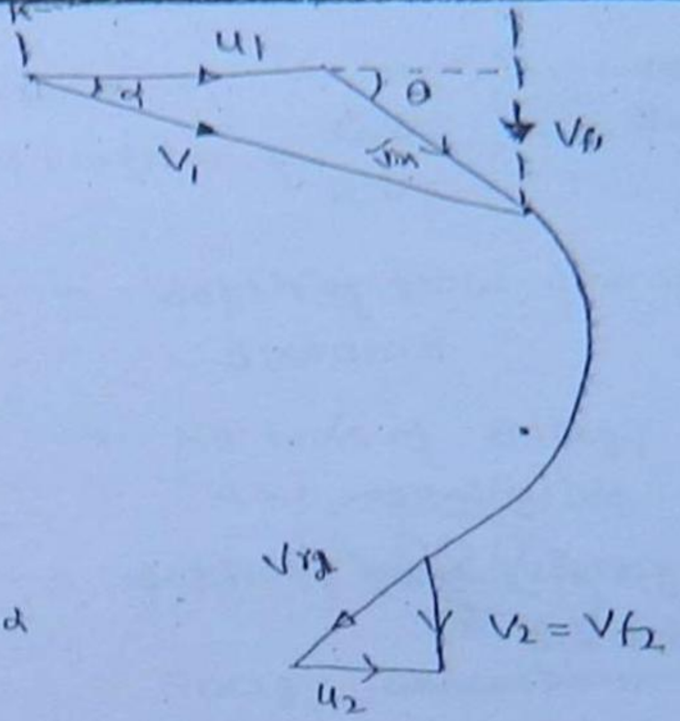

(285)

$V_{f_1} = V_{f_2} = V_2$

$V_{w_2} = 0$

$\cot\theta = \frac{V_{w}...}{V...}$

$\therefore u_1 = V_{w_1} ...$

$\therefore u_1 = V_{f_1}[\cot ...$

$$\boxed{\frac{V_{w_1}}{V_{f_1}} = \cot\alpha}$$

$\therefore V_{w_1} = V_{f_1}\cot\alpha$

$$\boxed{V_2 = V_{f_1}}$$

$\therefore V_1^2 = V_{f_1}^2 + V_{w_1}^2$

$\therefore V_1 = \sqrt{1+\cot^2\alpha} \cdot V_{f_1}$

$$\therefore \boxed{V_1 = V_{f_1}\sqrt{1+\cot^2\alpha} = V_{f_1}\operatorname{cosec}\alpha} \text{ — (i)}$$

$$\therefore \quad \rho = 1 + \frac{V_{f_1}^2 - V_{f_1}^2\operatorname{cosec}^2\alpha}{2V_{f_1}\cot\alpha \times V_{f_1}(\cot\alpha - \cot\theta)}$$

$$\rho = 1 + \frac{V_{f_1}^2(1-\operatorname{cosec}^2\alpha)}{2V_{f_1}^2\cot\alpha(\cot\alpha - \cot\theta)}$$

$$= 1 - \frac{\cot^2\alpha}{2\cot\alpha(\cot\alpha - \cot\theta)}$$

$$= 1 - \frac{\cot\alpha}{2(\cot\alpha - \cot\theta)}$$

$\Downarrow$

$$\boxed{\rho = \frac{1}{2}\left[1 - \frac{\cot\theta}{(\cot\alpha - \cot\theta)}\right]}$$

velocity of flow from inlet to exit remains constant
If the turbine discharges radially so that the degree
of reaction (ρ) can be expressed as

$$\rho = \frac{1}{2}\left[1 - \frac{\cot\theta}{\cot\alpha - \cot\theta}\right]$$

(284)

where θ is the runner vane angle at inlet
α is the guide blade Angle &
$\rho \rightarrow$ degree of rxn. defined as ratio of pressure head droped to the hydraulic work-done in the runner

Assume that Losses in the runner are negligible

$$\rho = \frac{\text{Pressure head drop b/w inlet \& outlet of Runner}}{\text{work-done by the water on the runner / sec. / unit of water}}$$

$$= \frac{p_1/w - p_2/w}{\left(\frac{V_{w_1}u_1 - V_{w_2}u_2}{g}\right)}$$

($V_{w_2} \rightarrow 0$)

Apply the B-eqn b/w inlet & exit of runner

$$p_1/w + z_1 + \frac{V_1^2}{2g} = p_2/w + \frac{V_2^2}{2g} + z_2 + \frac{V_{w_1}u_1}{g}$$

$$(p_1/w - p_2/w) = \left(\frac{V_2^2}{2g} - \frac{V_1^2}{2g}\right) + \frac{V_{w_1}u_1}{g}$$

[No Losses are considered]

$$\rho = \frac{\left[\frac{V_2^2}{2g} - \frac{V_1^2}{2g}\right] + \frac{V_{w_1}u_1}{g}}{\left(\frac{V_{w_1}u_1}{g}\right)}$$

$$\rho = 1 + \left(\frac{V_2^2 - V_1^2}{2V_{w_1}u_1}\right)$$

CS/2004 ES/2001 A C.P. has an impeller of ... when running at 600 r.p.m. discharges 8000 L... against a head of 8.5 m.

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Prob 2

The cylinder bore dia. of a single acting reciprocating pump is 150 mm and stok... is 300mm. The pump runs at 50 rpm. and w... is Lifted to a height of 25 m. The Le... of delivery pipe is Ld = 22 mm and d_d = 100 mm.

Find the theoretical discharge & powe... required to running the pump, if actual discharge = 4.2 l/s. Find the slip. Also determine accln head at th... begining and middle of stroke.

$A = \pi/4 \, D^2$

$D = 150$ mm

$L = 2r = 300$ mm

$N = 50$

$l_s = 25$

$l_d = 22$

$$\boxed{Q_{th} = \frac{ALN}{60}} = \frac{\pi/4 (0.15)^2 \times 0.3 \times 50}{60} \quad (m^3/...)$$

$= 4.42 \times 10^{-3}$ m3/sec.

$= 4.42$ l/sec

$Q_a = 4.2$ l/se.

$\therefore C_d = 4.2/4.42 = 0.95$

$\therefore$ % slip $= \frac{4.42 - 4.2}{4.42} \times 100 = 4.95$ %

Accln head = pressure head due to accln

Accln head in suction pipe :

$$h_{as} = (l_s/g) \times A/a_s \times r\omega^2 \cos\theta$$

$\left[\omega = \frac{2\pi N}{60} \Rightarrow r = L/2 = 150 \right.$

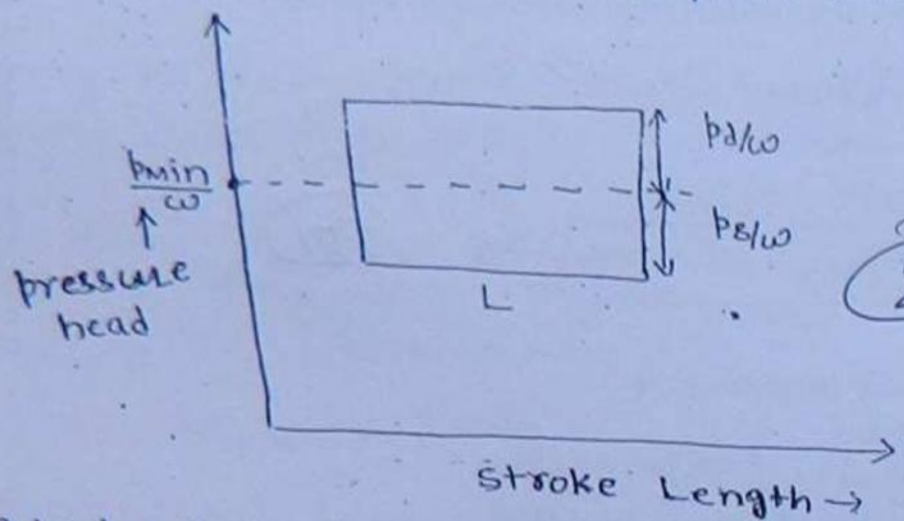
$\to \theta = 0$ & 90

Accln head in delivery pipe :

$$h_{ad} = \frac{l_d}{g} \times \frac{A}{a_d} \times r\omega^2 \cos\theta$$

$\to [\theta = 180$ & $270]$

distance travelled by the piston in complete revolution of crank.



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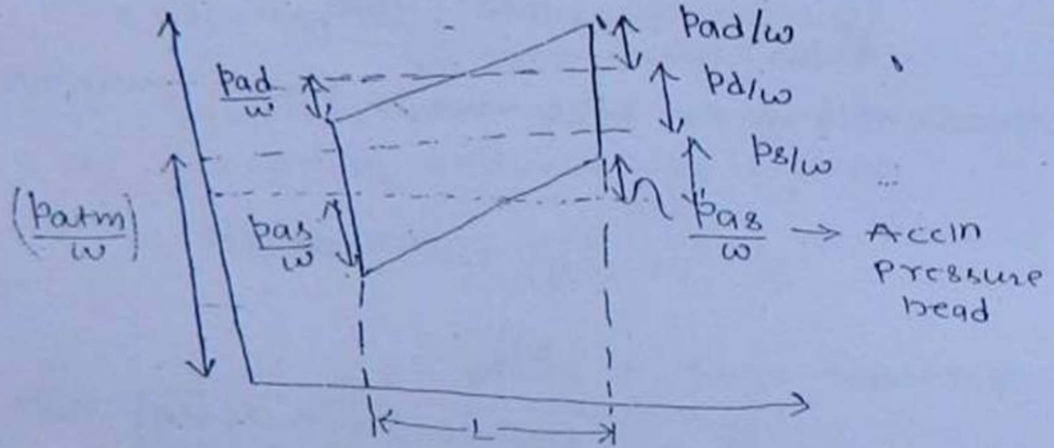
Ideal Indicator diagram when hf is neglected & effect of accln. also neglected.



Significance :

(1) Area of Indicator diagram is directly proportion to discharge and Q ∝ Power hence If a Indicator diagram of a pump is given than discharge output and power consumed can be compared of two pumps

$v = (A/a)\, r w \sin\theta \rightarrow$ velocity of water

$\therefore \frac{dv}{dt}$ = accleration of water in pipe

$= (A/a) \times r w \cos\theta \, (d\theta/dt)$

$\therefore \alpha$ = Accl^n, in pipe

$$\boxed{\alpha = (A/a)\, r w^2 \cos\theta}$$ imp (281)

α_{Max} at $\theta = 0°$ & π

- Force required in suction water / pipe water

$= \text{Mass} \times \text{accl}^n$

$= (\rho a l) \times A/a \, r w^2 \cos\theta$

$$\boxed{F = \rho l A \, r w^2 \cos\theta}$$

- Pressure head in pipe due to piston movement

$= F/a$

$= \rho l \, (A/a)\, r w^2 \cos\theta$

$\therefore$ pressure head $= p/\rho g$

$$\boxed{h = (l/g) \times (A/a) \times r w^2 \cos\theta}$$ imp

- Friction head on suction | Delivery pipe

$$\boxed{h_{f_s} = \frac{f l_s v^2}{2 g d_s}}$$ [d → dia of suction pipe

$$= \frac{f l_s \left[\left(\frac{A}{a}\right) r w \sin\theta \right]^2}{2 g d_s}$$

$$\boxed{(h_f)_{max} = \frac{f \, l_s \left[(A/a)\, r w \right]^2}{2 g d_s}}$$

Power Required: $\boxed{P \propto Q}$

∴ Power required get doubled

It may be noted that though the operating cost is doubled but increased in installation cost is marginal

Slip: → (%)

$$= \frac{Q_{theoretical} - Q_{actual}}{Q_{theoretical}} \times 100$$

(2.80)

$$= (1 - C_d) \times 100$$

[C_d: coefficient of discharge

−ve slip: → when $\boxed{Q_{actual} > Q_{theoretical}}$

If some of the water coming from suction pipe directly enters into delivery pipe without entering into piston chamber.

−ve slip occurs when

(i) piston is moving at very high speed
(ii) Length of delivery pipe is small

Effect of Accln of piston on the velocity of suction and delivery pipe: ↓

$$x = r(1 - \cos\theta)$$

∴ velocity of piston

$$V = \frac{dx}{dt} = r\sin\theta\left(\frac{d\theta}{dt}\right)$$

$$= r\omega\sin\theta$$

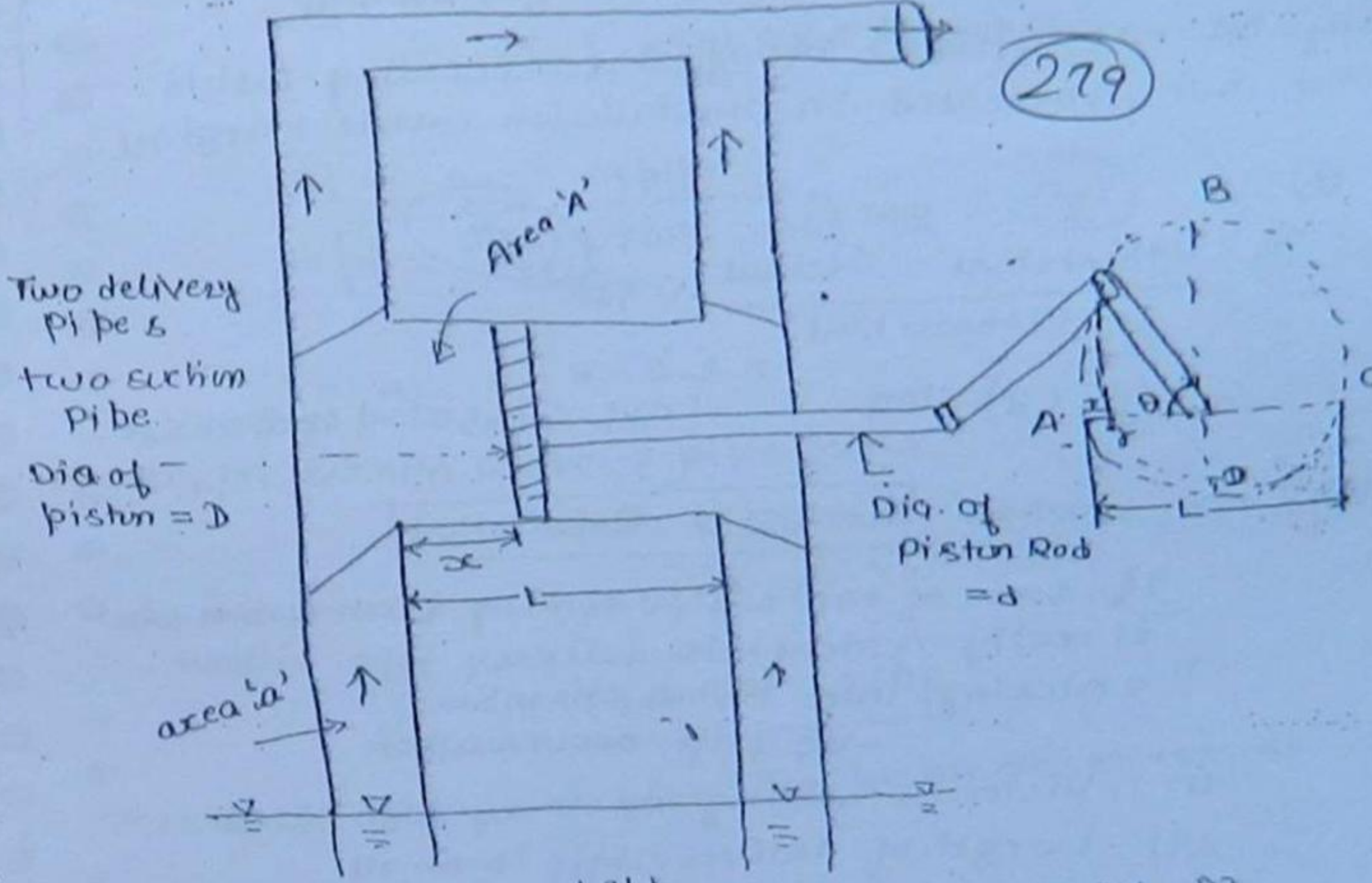
$$\boxed{\frac{dx}{dt} = r\omega\sin\theta}$$ Imp

V_{max} occurs at $\theta = \pi/2$

Let v be the velocity of water in suction/delivery and a be the area of that pipe

$$\boxed{av = AV}$$ Imp

DOUBLE ACTING RECIPROCATING PUMP



Area on the Left of the piston $= \pi/4\, D^2$

Area " " Right " $= \pi/4\, (D^2 - d^2)$

Length $\boxed{L = 2r}$

So, Total volume of water delivered in one revolution of crank

$$V = \left[\pi/4\, D^2 + \pi/4\, (D^2 - d^2)\right] \times L$$

Volume of water delivered in one minute

$$= \left[\pi/4\, D^2 + \pi/4\, (D^2 - d^2)\right] L \cdot N$$

$$\text{Discharge/sec} = \frac{\pi/4\, \left[D^2 + (D^2 - d^2)\right] LN}{60}$$

→ If area. $d << D$ then

imp $\boxed{Q = \dfrac{2 \times \pi/4\, D^2 \times LN}{60} = \dfrac{2ALN}{60}}$ → discharge get double

$t = 16 hr$

$\therefore Q = \frac{18000}{16 \times 60 \times 60} = 0.3125 \ m^3/sec$

$H_s = 21 m$

$h_f = h_{fs} + h_{fd}$

$h_{fs} = \frac{4 f L_s Q^2}{12.1 D^5}, \quad h_{fd} = \frac{4 f L_d Q^2}{12.1 D^5}$

$\therefore h_f = \frac{4 f L_s Q^2}{12.1 D^5} + \frac{4 f L_d Q^2}{12.1 D^5}$.

$= \frac{4 \times 0.01 \times (40+150) \times (0.3125)^2}{12.1 \times (0.5)^2} = 1.96 m$

$\therefore H_m = H_s + h_f$

$= 21 + 1.96 = 22.96 \ m$

$\therefore$ Manometric power $= wQH_m \rightarrow KW$

$= \frac{\rho Q H_m}{75}$ (H.P.)

$= \frac{1000 \times 0.3125 \times 22.96}{75}$

$= 95.67$ H.P.

$\eta_o = \frac{\text{Mano. Power (H.P)}}{\text{S.H.P.}}$

$\text{S.H.P.} = \frac{95.67}{0.80} = 119.58$ (B.H.P)

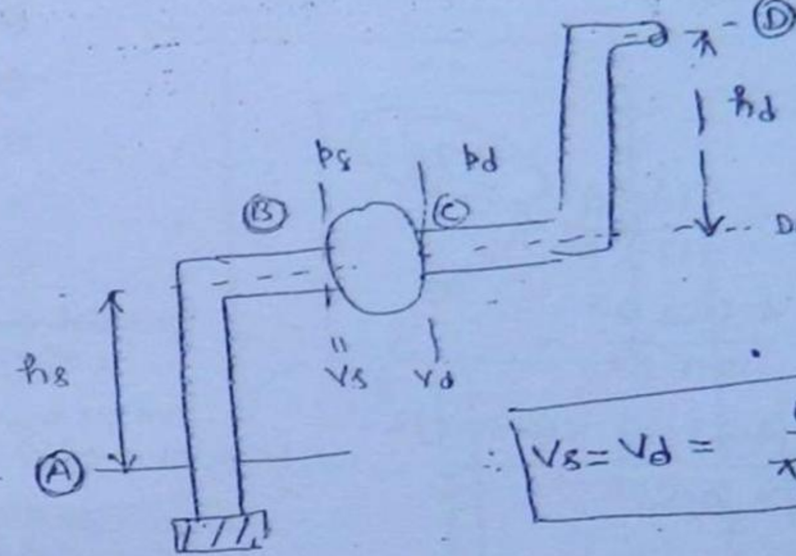
No. of pump required $= \frac{\text{Total B.H.P}}{\text{B.H.P of one pump}}$

$= \frac{119.58}{30} \simeq 4$

~~since V_{f1}~~

hence $V_{f1} = V_1 = Q/A_{f1}$

(277)



$$\therefore \boxed{V_s = V_d = \frac{Q}{\pi/4\, d^2}} = \frac{0.237}{\pi/4\,(0.33)^2}$$

$= 2.46$ m/sec.

Apply B. Eqn b/w (A) and (B)

$$\boxed{\left(\frac{p_{atm}}{\omega}\right) = \frac{p_s}{\omega} + \frac{V_s^2}{2g} + [h_s + h_{fs}]}$$

h_{fs} → Loss in suction pipe

in terms of water → $10.3 = \frac{p_s}{\omega} + \frac{2.46^2}{2\times 9.81} + 3 + 2$

$\Rightarrow \boxed{\frac{p_s}{\omega} = 5} > 2.5$ m of vapour pressure at 20°C

O.K.

Apply B. Eqn b/w (C) and (D)

$$\frac{p_d}{\omega} + \frac{V_d^2}{2g} + 0 = \frac{p_{atm}}{\omega} + \frac{V_d^2}{2g} + (h_d + h_{fd})$$

h_{fd} → Loss in delivery pipe

$p_d/\omega = 10.3 + 3.7 + 6 = 53.3$ m

prob4 In a pumping station 18000 m3 water is to be lifted per day from a intake well to a sedimentation tank under a static head of 21 m. Length of suction & delivery pipes are 40 m & 150 m respectively. dia of pipes is constant = ... There are two shifts of working each of 8 h. If the efficiency of pump & motor combined is 80% and friction coeff is 0.01. Recommend the unit of pumps each having B.H.P of (=30) pipe bend

a) Discharge through pump: ↓

Let N be the r.p.m. of crank

1 ~~pipe~~ one revolⁿ. of crank

Vol. of water discharged = AL (276)

If in crank, there are N revⁿ.

than discharge in one Minute is = ALN

∴ discharge in one sec.

Imp $$\boxed{Q = \frac{ALN}{60}}$$ N → R.P.M

$$\boxed{A = \frac{\pi D^2}{4}}$$

b) Power Required: ↓

$$\boxed{P = wQ\, H_{required}}$$

$$H_{required} = (h_s + h_d) + h_{fs} + h_{fd}$$

↳ If Neglected

than $H = h_s + h_d$

$$\therefore \boxed{P = wQ\,(h_s + h_d)}$$

COMMENTS: ↓

1) The discharge through the pump is not continuous in nature therefore power required is fluctating

Imp 2) Reciprocating pumps are suitable for high suction head & Low delivery head & Low discharge.

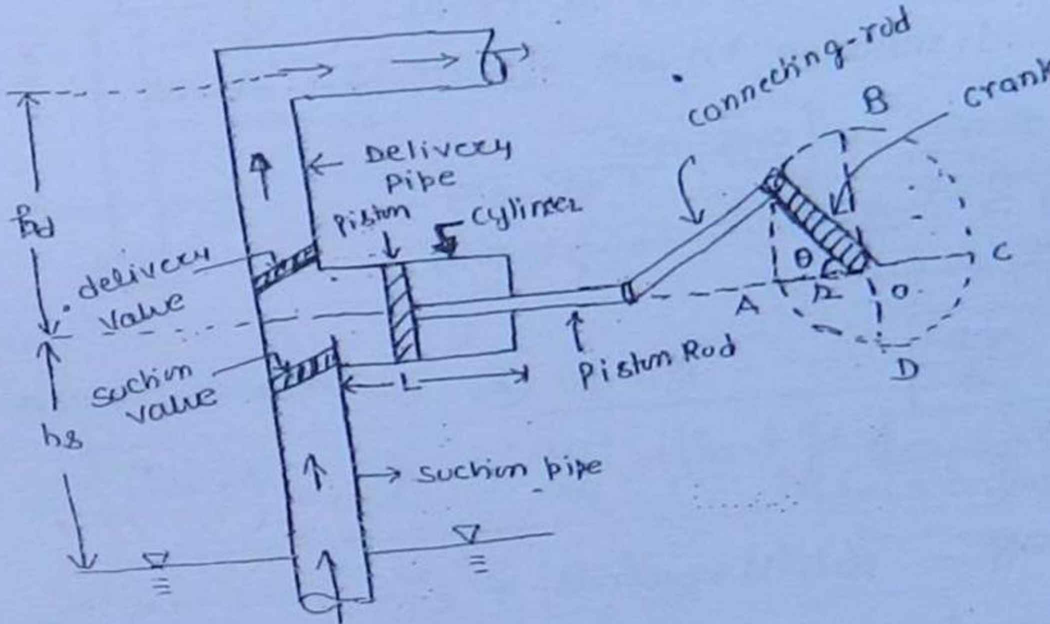
3) In order to make the more continuous supply of water double acting pump may be used.

2) Reciprocating pump:

These work on the principle of creating suction head.

Main parts:

(275)



Working:

The crank is rotated by an external source of power. When the crank is at A, suction stroke started and when θ = 0 – 180° suction s... completes. The piston is moving in the cyl... forward & backward.

A → Area of cylinder = Area of piston

L = Length of cylinder chamber

$L = 2r$

when θ = 0° to 90°, acc^n takes place and when θ = 90° to 180°, deacc^n & at θ = 90° the velocity of piston is maximum.

for delivery pipe →
- for θ = 180° to 270° ⇒ Acc^n of delivery s...
- for θ = 270° to 360° ⇒ Deacc^n of delivery
- at θ = 270° ⇒ velocity is Max

It may be noted that while suction stroke only suction valve is open & delivery valve is closed

2000 — when running at 600 r.p.m. discharges at the rate of 8000 Lit/min against a head of 8.5 m. The water enters the impeller without whirl & shock. The inner dia. is 0.25 m & the vanes are set back at outlet at an angle of 45° & area of flow which is constant from inlet to outlet of the impeller of $0.06 m^2$. determine

(i) Manometric efficiency of pump

(ii) The vane Angle at inlet → 39°

(iii) Minimum speed at which the pump commences to work.

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Prob 3 — A C.P lifts water under a static Lift of 40 m of which 3m is suction Lift. The suction & delivery pipes are of 30 cm dia. both. The friction Loss in suction pipe is 2m & in delivery pipe is 6m. The impeller is 0.5m dia. & 3 cm. wide at outlet & runs at a speed of 1200 r.p.m. The exit blade angle is 20° and $\eta_{mano.} = 85\%$. Find

a) The discharge

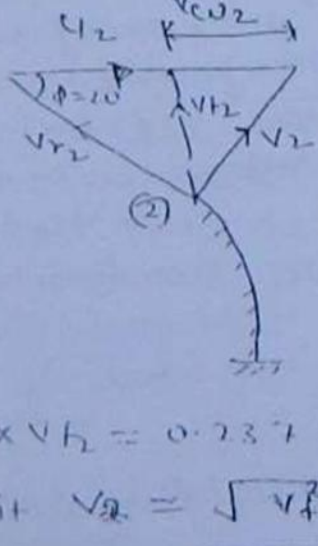
b) Pressure at the suction and at delivery point

1) $H_m = h_s + h_d + h_{fs} + h_{fd}$

$= 40 + 2 + 6$

$= 48 m$

2) $\eta_{manometric} = \frac{g H_m}{V_{w2} u_2}$ ← calculate $V_{w2} = 17.6$



using exit velocity diagram

3) $\tan 20° = \frac{V_{f2}}{u_2 - V_{w2}}$

$\Rightarrow V_{f2} = 5.02 m/sec$

$Q = A_{f2} \times V_{f2} = (\pi d_2 b_2) \times V_{f2} = 0.237 m^3/sec$

Absolute velocity at exit $V_2 = \sqrt{V_{f2}^2 + V_{w2}^2}$

$= \sqrt{(5.02)^2 + (17.63)^2}$

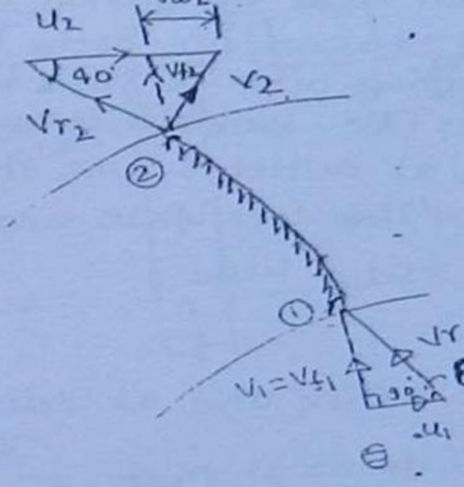
$= 18.33 m/sec$

Problem: A centrifugal pump having outer dia. equal to two times the inner dia. & running at 1000 r.p.m works against a total head of 40m. The velocity of flow through impeller is constant & at 2.5 m/sec. The vanes are set back at an angle of 40° at outlet. If the outer dia of impeller is 50 cm & width of outlet is 5 cm than determine
a) Vane Angle at inlet
b) work done by Impeller/sec on water
c) Manometric efficiency

(275)

$N = 1000$ r.p.m
$H_m = 40m$
$V_{f_1} = V_{f_2} = 2.5$ m/sec
$\phi = 40°$
$d_2 = 0.5m$
$d_1 = 0.25m$
$b_2 = 0.05m$

→ water enters into pump without whirl & shock. $[V_{w1} = 0]$



$\tan 40° = \frac{V_{f_2}}{u_2 - V_{w_2}}$

$\Rightarrow \boxed{V_{w_2} = 23.19 \text{ m}}$

B) $\tan\theta = \frac{V_{f1}}{u_1}$

$\Rightarrow \boxed{\theta = 10.81}$

A) $u_2 = \frac{\pi d_2 N}{60}$

$= \frac{\pi \times 0.5 \times 1000}{60}$

$= 26.17$ M/sec

C) Manometric efficiency

$= \frac{g H_m}{V_{w_2} u_2} =$

$= \frac{\text{Manometric efficiency}}{I.P}$

$Q = A_{f_2} \times V_{f_2} = (\pi d_2 b_2) \times V_{f_2}$

$= \pi \times 0.5 \times 0.05 \times 2.5$

$= 0.1966 \ m^3/sec$

work done by Imp./sec. (I.P)

$= \frac{wQ}{g}\left[V_{w_2} u_2\right] = \frac{9.81 \times 0.1966 \times 23.19}{9.81}$

$= 119.9$ KW.

(1) $\left(\frac{N\sqrt{Q}}{Hm^{3/4}}\right)_m = \left[\frac{N\sqrt{Q}}{(Hm)^{3/4}}\right]_p$

(2) $\left(\frac{Hm}{D^2N^2}\right)_m = \left(\frac{Hm}{D^2N^2}\right)_p$ (272)

(3) $\left(\frac{Q}{ND^3}\right)_m = \left(\frac{Q}{ND^3}\right)_p$

(4) $\left(\frac{P}{N^3D^5}\right)_m = \left(\frac{P}{N^3D^5}\right)_m$

9> specific speed of pumps: ↓

$$N_s = \frac{N\sqrt{Q}}{(Hm)^{3/4}}$$ (Q → output)

Turbine: $$N_s = \frac{N\sqrt{P}}{(H)^{5/4}}$$

10> Cavitation & Thoma Number: ↓

In centrifugal impeller the pressure is minimu on the underside of vane at entry where vapour pressure may be form, these vapour pressure carried to a region of high pr. to exit where bubble collapse causing pit & sever demage to metal surface. apper entry vane tips at exit are the most suspitable for water hammer attack. Th harmful effect of cavitation are:

1> pitting & erosion of surface due to conti hammering

2> sudden drop in head & decrease in the Efficiency in the pump

3> Noise & vibration

4> corrosion problem

6> Mean speed required to start the pumping of water

Minimum speed should be such that head developed should be greater than Hm.

$$\therefore \boxed{\frac{\omega^2 r_2^2}{2g} - \frac{\omega^2 r_1^2}{2g} \geq H_m}$$ (gate)

$\omega \rightarrow$ Rad. sec

$r_1 \rightarrow d_1/2$

$r_2 \rightarrow d_2/2$

especial: For a given value of ω & H_m it is possible to work-out minimum dia. of impeller (outer dia) which will be required for pumping of water.

$$\Rightarrow \frac{\omega^2}{2g}\left[\frac{d_2^2}{4} - \frac{d_1^2}{4}\right] \geq H_m$$

[Take $d_2 = 2d_1$ $\Rightarrow \boxed{d_1 = d_2/2}$]

$$\therefore \frac{d_2^2}{4}\left[1 - 1/4\right] \geq \frac{2gH_m}{\omega^2}$$

$$\Rightarrow \boxed{d_2 = \frac{10.23}{\omega}\sqrt{H_m}}$$ (gate)

7> Multi-stage centrifugal pump:

(a) To produce high head, impeller should be connected in series. If n no. of impellers are connected in series & each lifts manometric heads equal to (H_m) than

For series connections [Q = const.]

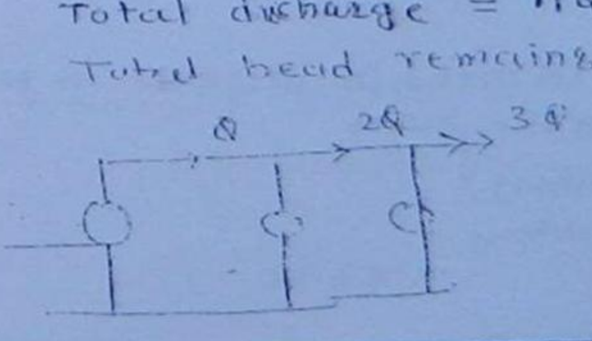
Total head lifted = $n H_m$

Here total discharge remains constant

(b) Parallel connection: – [Head = const.] Impellers or pumps are mounted in parallel to increase the discharge

Total discharge = nQ

Total head remains constant

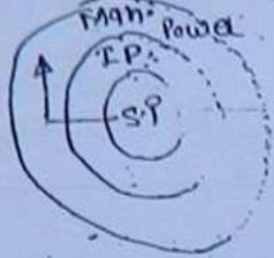


→ Manometric power $= \omega Q H_m$

1.> Mechanical Efficiency (η_{cy}) :

$$\eta_{Mech.} = \frac{I.P.}{S.P}$$

(220)



[Reverse calculati

define
[n_o → than n
n_m →

2> Manometric Efficiency :

$$\eta_{Mano.} = \frac{\text{Mano. power}}{\text{Imp. power}}$$

$$= \frac{\omega Q H_m}{\frac{\omega Q}{g}\left[V_{w_2} u_2\right]}$$

$$= \frac{g H_m}{V_{w_2} u_2}$$

3> overall Efficiency :

$$(\eta_o) = \frac{\text{Man. power}}{S.P}$$

$$= \eta_{Mech.} \times \eta_{Man.}$$

NOTE: If Leakage Losses are also accounted than Volumetric Efficiency

$$\eta_v = \frac{\text{Discharge at delivery point}}{\text{Discharge at Inlet}}$$

$$= Q/(Q+\Delta Q)$$

$\Delta Q =$ Loss of water through casing

It May be noted that Loss of water takes after Leaving the Impeller plates

overall Efficiency

$$\eta_o = \eta_{Mech.} \times \eta_{Man.} \times \eta_{Volumetric}$$

Manometric head: ...

Imp — This is the head against which pu[mp] has to work.

work-done by pump / sec / unit wt of water = Manometric he[ad] + Loss[es]

⇒ A) $\frac{V_{w_2} U_2}{g} = H_m + \text{Losses}$ Imp [Assuming V_{w_1} = ...

— If Losses are negligible

$$H_m = \frac{V_{w_2} U_2}{g}$$

(269)

B) H_m = Total energy head at outlet − Total energy head at inlet

$$= \left[\frac{p_o}{w} + z_o + \frac{V_o^2}{2g}\right] - \left[\frac{p_i}{w} + z_i + \frac{V_i^2}{2g}\right]$$

$V_o \rightarrow V_d$ (velocity in delivery pipe)

$V_i \rightarrow V_s$ (velocity in suction pipe)

$z_o \simeq z_i$, $p_o = p_d$, $p_i \simeq p_s$

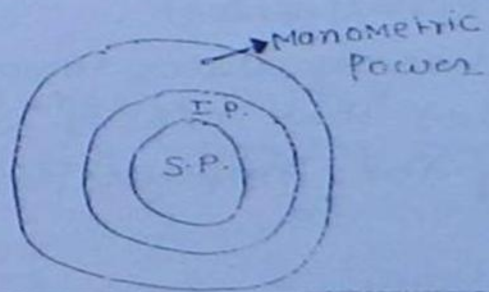
C) $H_m = (h_s + h_d) + (h_{fs} + h_{fd}) + \left(\frac{V_d^2}{2g}\right)$

↓ Negligi[ble]

$H_m = (h_s + h_d) + (h_{fs} + h_{fd})$ Imp

Static Head (H_s) ↑ Friction Head ↑

6) Efficiency & Powers of Pump: ↓



S.P > I.P. > Manometric power (water) Imp

$= -$ [work done per second in case of Turbine]

$$= -\frac{wQ}{g}\left[V_{w_1}u_1 - V_{w_2}u_2\right]$$

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$$\therefore \text{work/sec.} = \frac{wQ}{g}\left[V_{w_2}u_2 - V_{w_1}u_1\right]$$

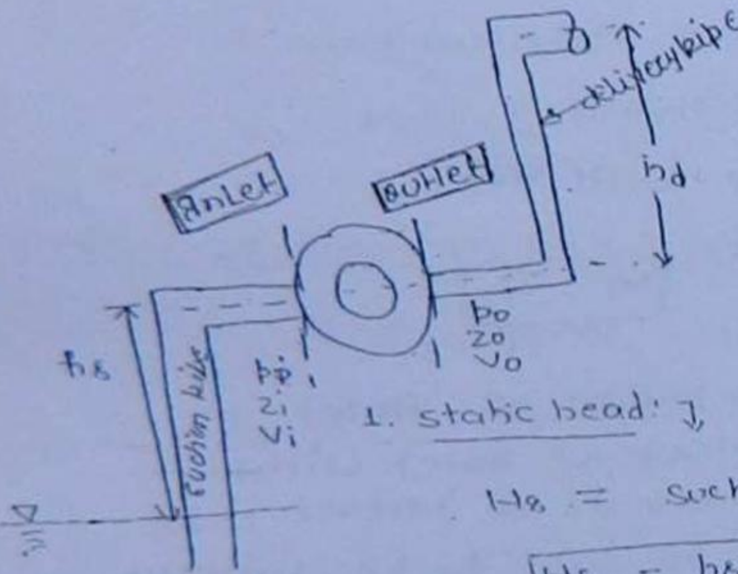
For Maxm power $V_{w_1} = 0$

work-done by Impeller on water/sec

$$= \frac{wQ}{g}\left[V_{w_2}u_2\right]$$

= Impeller power | Rotor power

Important Definitions:



1. static head:

Hs = suction head + delivery head

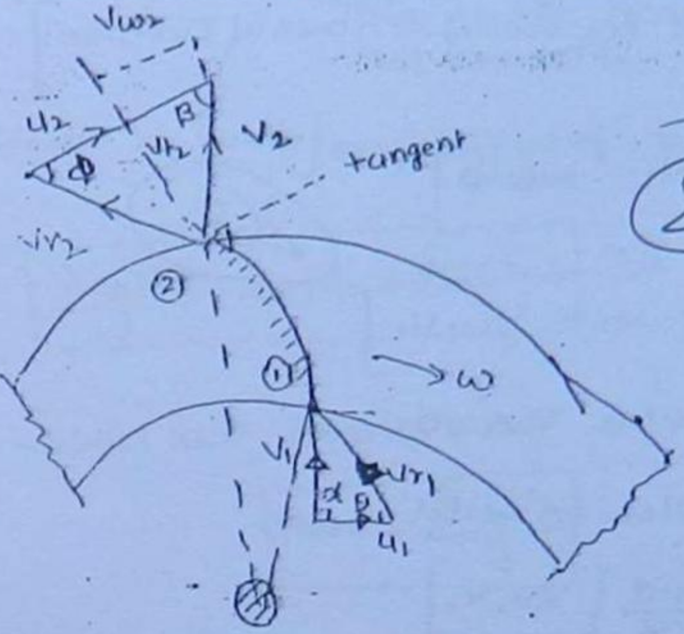
$$\boxed{H_s = h_s + h_d}$$

2. Friction head (h_f)

$$\boxed{\text{Total friction head} = h_{fs} + h_{fd}}$$

↓ friction head in suction pipe

4> Velocity diagram :-



u_1 & u_2 → Tangential or peripherial velocities

ϕ → Vane Angle at exit

$\phi < 90°$, vanes called backward curved

$\phi = 90°$ vanes are radial at exit

$\phi > 90°$ vanes forward curved

$\alpha = 90°$ {Angle betn u_1 & V_1}

Then $\boxed{V_{w1} = 0}$ $\boxed{V_1 = V_{f1}}$

→ Hence discharge is radial at inlet, It means water enters at inlet without whirl and if there is no impact loss then discharge is said to be without whirl & shock

b_2 be the outlet width "

Following points May be Noted: ↓

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(1) Area of flow:

$$A_{f_1} = \pi d_1 b_1 \rightarrow \text{when thickness of vanes is negligible}$$

$$= (\pi d_1 - nt) b_1 \rightarrow \text{If thickness of each vane is } t \text{ \& there } n \text{ vanes.}$$

similarly at exit

$$A_{f_2} = \pi d_2 b_2$$

$$= (\pi d_2 - nt) b_2$$

(2) Tangential velocity or peripherial velocity:

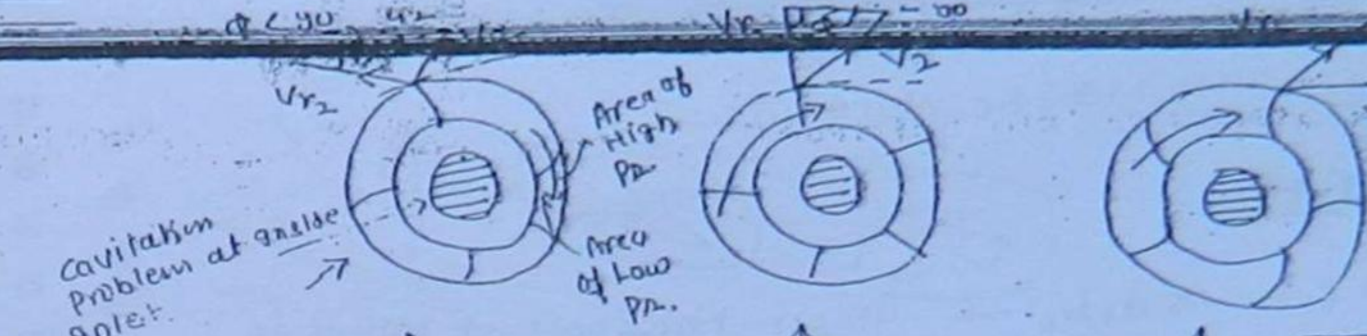
$$u_1 = \frac{\pi d_1 N}{60} \qquad \Rightarrow \boxed{\frac{u_1}{u_2} = d_1/d_2}$$

$$u_2 = \frac{\pi d_2 N}{60}$$

(3) Discharge through the pump:

$$Q = A_{f_1} \cdot V_{f_1} \qquad V_{f_1} \,\&\, V_{f_2} \rightarrow \text{Radial com[ponent] of abs. vel[ocity]}$$

$$= A_{f_2} \cdot V_{f_2}$$



Backward Vanes	Radial vane	Forward Vanes or Gurad Vane
Minimum Power	Medium Power	Maxm Power
* Less efficient		* Most efficient

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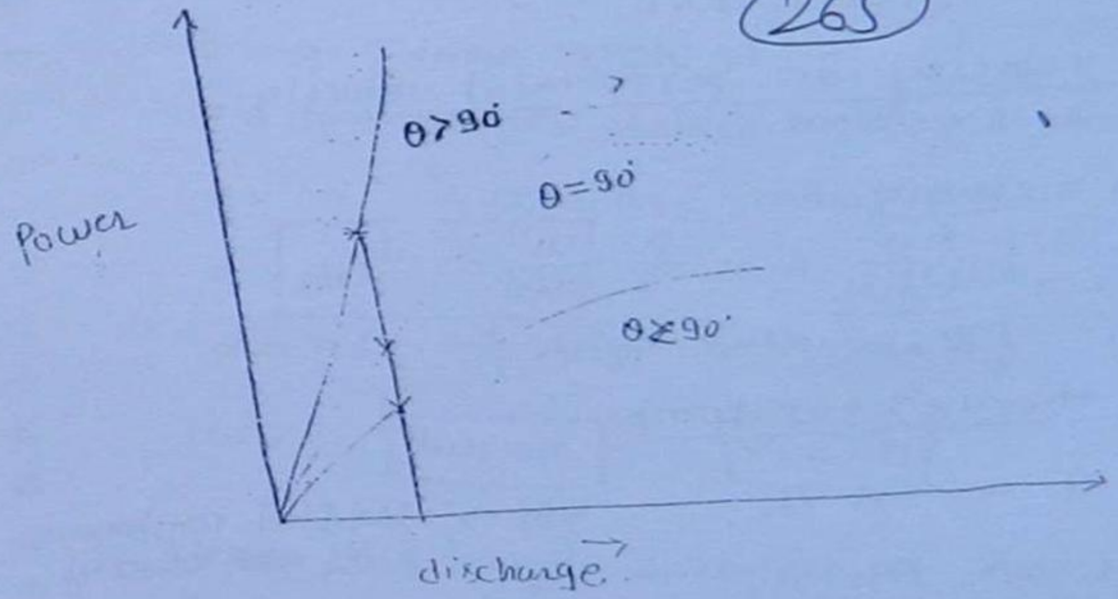

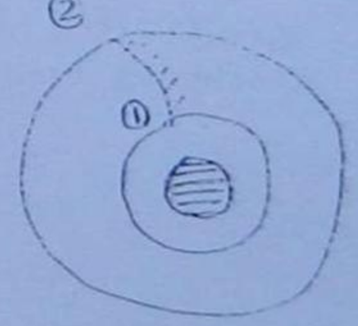

① → Entry point
② → Exit point

d_1 → inner dia (inlet dia)

d_2 → Exit dia (outer dia)

Generally

$d_1 \simeq \frac{1}{2} d_2$

* size of impeller
  – means outer dia $\simeq d_2$

→ In order to prevent cavitation phenomenon & water hammer problem. ($p_{min} = p_s$)

Imp parts of pump: ↓

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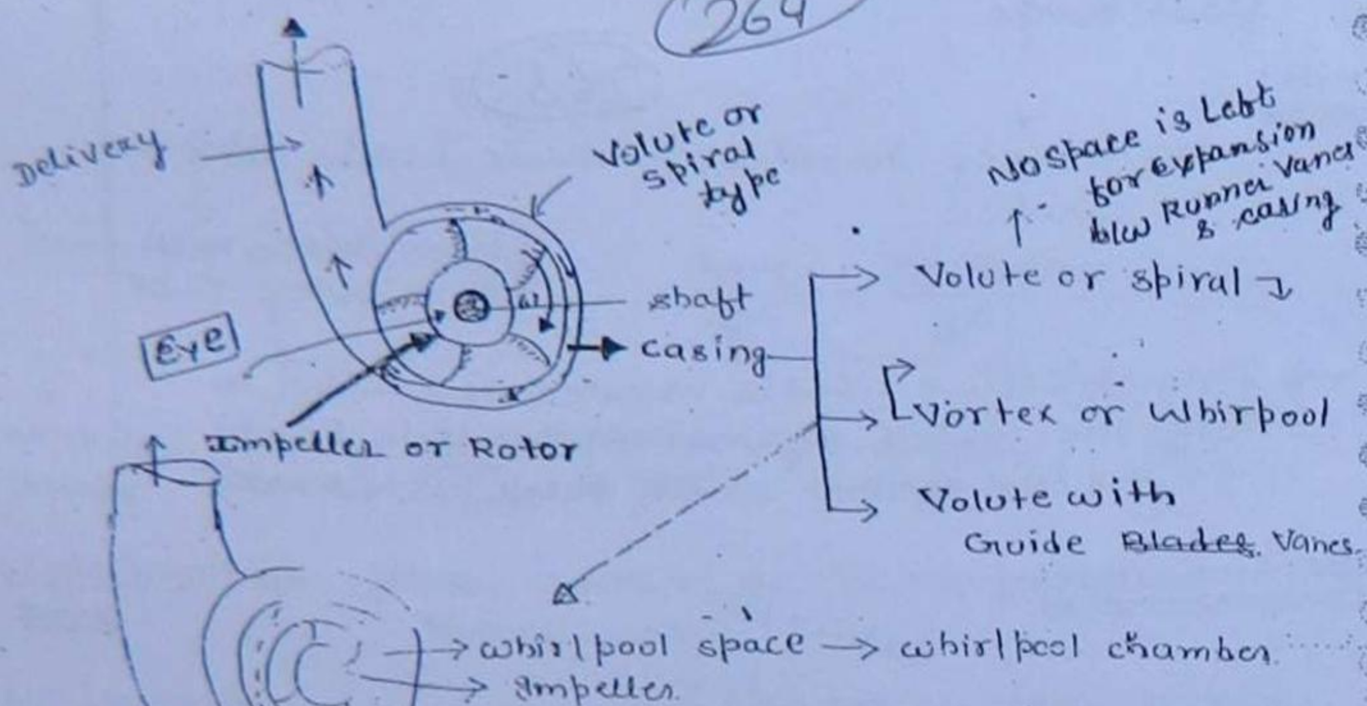

— In whirlpool chamber an Annular spaced is provided b/w casing & impeller, this arrangement prevent the formation of eddies and gives an improved performance.

* In case of volute with Guide vanes, guides are provided to divert the water properly such pumps are called diffuser pump or turbine pump. These are adopted when impeller pumps are connected in series for multi stage pumping.

→ These have Maximum Efficiency but Less satisfactory when opertating conditions are flactuating (Power or head)

* **Impeller:** ↓

It is the rotating unit of a pump similar to runner unit of turbine

→ Impeller has 6 to 12 curved vanes.

* The No. of vanes on Rotating unit [illegible] are 6 to 12.
* centrifugal pumps are exectly inverse of Francis turbine It Means these are outward radial flow pumps.

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Principle: ↓

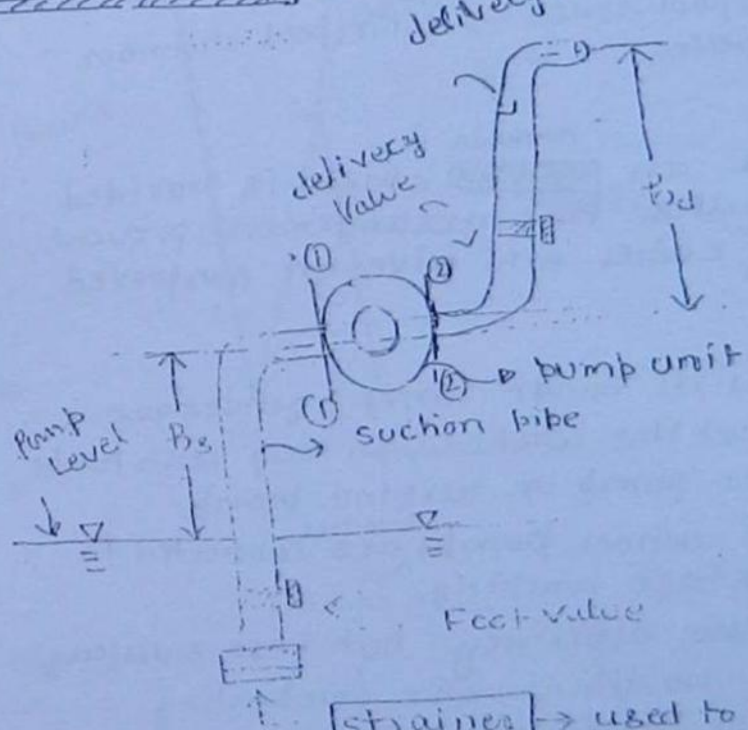
By rotating impeller, pressure head difference is created.

$$= \frac{\omega^2 r_2^2}{2g} - \frac{\omega^2 r_1^2}{2g}$$

[$r_1 \rightarrow$ inner radii, $r_2 \rightarrow$ outer radii]

→ This pressure head is created is utilized to Lift the water against Manometric head (it is the head against which pump has to work)

IMPORTANT UNIT: ↓



strainer → used to prevent entry of blockage material

$$H_s = h_s + h_d$$

Static head = suction head + delivery head

Pressure in suction pipe is always below atmospheric pressure

→ minimum pressure exist at (1)-(1) i.e. entry of pump

→ This pmin should not falls vapour pressure of water

PUMPS :

* These utilize Mechanical power supplied by the shaft or utilize Man-power to convert it into hydraulic power or water power.

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- PUMP
  - Dynamic pressure pump
    - centrifugal pumps
    - Turbine pumps
    - Jet Pumps
    - Propeller pumps
  - Displacement pump
    - Reciprocating Pump
    - Rotary

centrifugal pump ⇒ These works on the principle of forced Vortex-Motion

Reciprocating pump → works on the principle of suction pressure

*1) Centrifugal pump: ↓

1) These have high output & high efficiency ~~& are~~ used for Low head & high discharge.

a) when Head is Less than 15m these are called Low Head pump

b) 15m < H < 45 m → Medium Head pump

c) H > 40m → High head pump

→ Head here means suction head primarily

NOTE: when head is > 40 m, single state centrifugal pump is not desirable therefor Multistage pump in series should be used. It is practically observed that when head is b/w 12 to 8 m, centrifugal pump are most efficient

Loss in guide tube to runner

$$= 0.04\left(\frac{V_1^2}{2g}\right) = 0.04H$$

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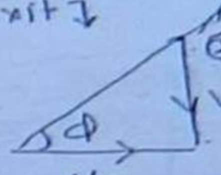
Loss in Runner vanes

$$= 0.06\left(\frac{V_2^2}{2g}\right) = 0.06\left[0.96H\right]$$

Loss in Draft tube

$$= 0.05\left(\frac{V_3^2}{2g}\right)$$

At exit ↓



u_2

$V_{w1} = 1$

$u_1/u_2 = D_1/$

$\Rightarrow u_2 = 4$

Apply B. Eqn b/w (2) & (3)

$$\left(\frac{V_2^2}{2g} + \frac{p_2}{w} + 3\right) = \frac{p_{atm}}{w} + \frac{V_3^2}{2g} + 0 + h_L$$

$$+ 0.05x$$

$$=$$

$$\Rightarrow 0.95x = \frac{p_{atm}}{w} + \frac{V_3^2}{2g}$$

$$= 10.3 + \frac{2.2^2}{2\times 9.81}$$

$$\Rightarrow x = \frac{10.5}{0.95} = 11.10$$

∴ Total head at the exit diameter $= 11.10$

Total Head at inl

$24 = 2 + P_1/w +$

$= 3 + \frac{P_{1}}{w} + \frac{10}{2}$

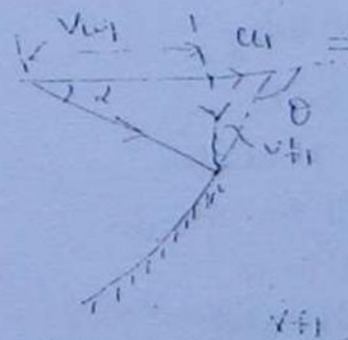
$\therefore P_1/w = 14.92$

B. Eqn B/w inlet & outlet of Runner

Head at inlet (Y) = Head at outlet + work-done on Runner / by + Losses

$$Y = 11.10 + \frac{\frac{w a}{g}\left[V_{w1} u_1\right]}{w g} + 0.06Y$$

$$0.94Y = 11.10 + \frac{V_{w1} u_1}{g}$$



$$\Rightarrow \frac{V_{w1} u_1}{g} = 24 - 11.10$$

$$\Rightarrow V_{w1} = 10.409 \text{ m/sec}$$

since $V_{w1} < u_1 \Rightarrow \theta > 90$

$$\tan\alpha = \frac{V_{f1}}{V_{w1}} = \frac{3.3}{10.409}$$

$$\tan(180-\theta) = \frac{V_{f1}}{u_1 - V_{w1}}$$

$$\Rightarrow \boxed{\alpha = 17.59}$$

$$\boxed{V_1 = \sqrt{V_{f1}^2 + }}$$

total head of 25 M. The centre line of the machine is 3M above the water level, in the tail rest. The abs. velocity of flow leaving the vanes on the runner wheel is in the radial direction. the outlet dia = 0.45 x inlet dia. The tangential velocity at exit of runner the rim is 10.8 m/sec & velocity at entry is 3.3 M/sec. And velocity at the exit of the draft tube is 2.2 M/sec. Assuming that flow enters without shock (the runner wheel).

determine

1) outlet Angle of the guide blades (α)
2) inlet & outlet angle (θ & ϕ)
3) The pressure head at inlet & outlet of the runner

Assume that loss due to friction in the guide blade, runner blade plate & the draft tube 4%, 6% & 5% respectively of the available head.

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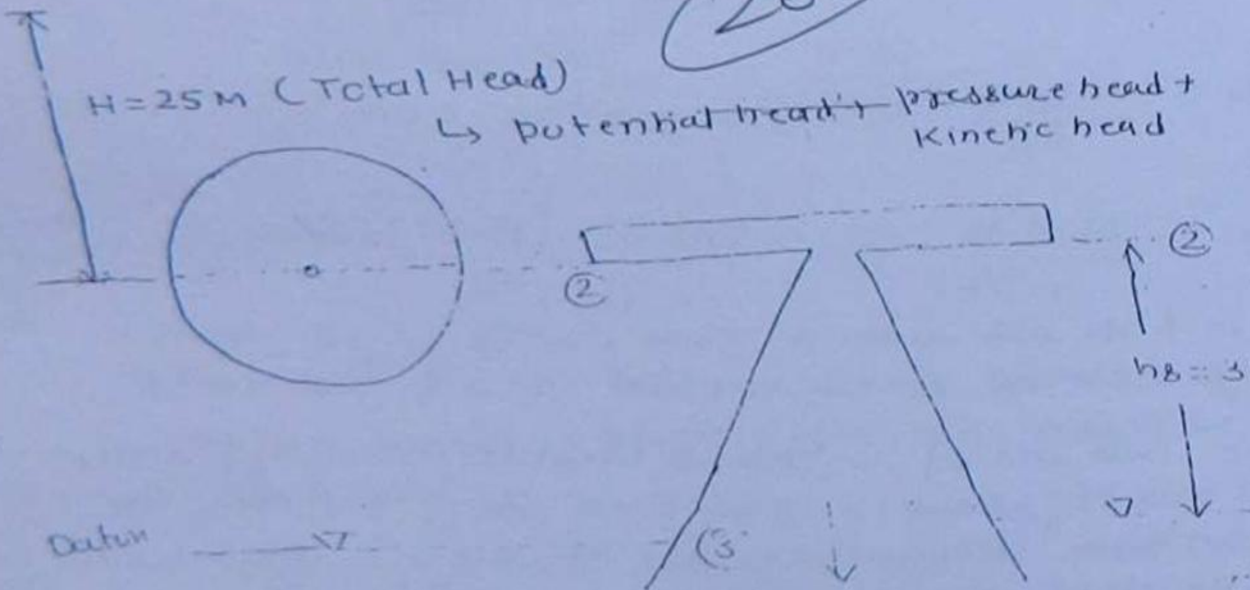

H = 25 M

p_1/w & p_2/w = ?

V_1 = 10.8 m/sec

$$\frac{\quad}{gH} \quad \text{---} ①$$

$$V_{f_1} = \frac{Q}{\pi/4\,(D_o^2 - D_b^2)(\,)} = 6.12 \text{ m/sec}$$

$$= V_{f_2} = V_2$$

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$$\boxed{H = \frac{V_2^2}{2g} + \frac{V_{w_1} u_1}{g}}$$

$$\Rightarrow H = \frac{6.12^2}{2 \times 9.81} + 0.9H$$

$$\Rightarrow H = 19.1 m$$

$$S.P. = \underline{H.P.} \times \eta_o = wQH \times \eta_h \times \eta_m$$

$$S.P = 10,972 \text{ KW}$$

$$\phi = \frac{u_1}{\sqrt{2gH}} \Rightarrow u_1 = 2.0 \times \sqrt{2 \times 9.81 \times 19.1}$$

$$u_1 = 38.71 \text{ m/sec}$$

$$u_1 = \frac{\pi D_o N}{60} \Rightarrow N = 184.76 \text{ rpm}$$

$$N_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{184.76\sqrt{10,972}}{(19.1)^{5/4}} \quad = \underline{\underline{S.P}}$$

Ns (specific speed) = 454.31 (SI unit)

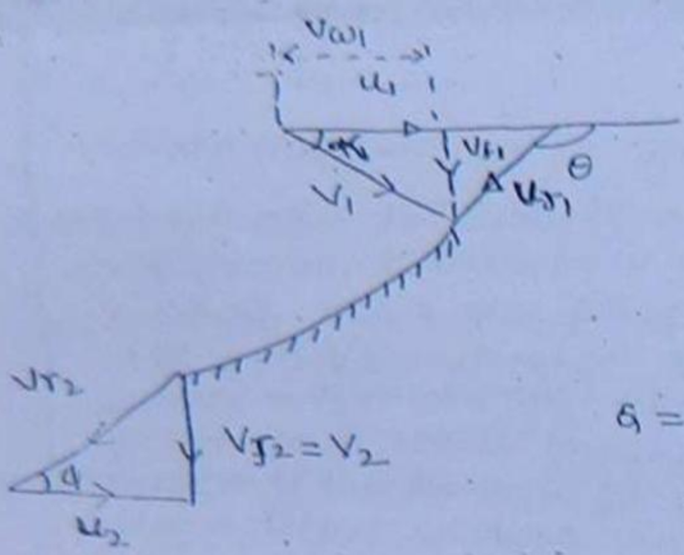
prob3 — The hub dia. of a kaplan turbine working under a head of 12 m is 0.35 times dia of runner. The turbine is running at 100 r.p.m. If the angle of extreme edge at outlet is 15°, and Flow ratio is 0.26.

a) Find dia. of runner → Do = 6.55 m

b) Find dia. of boss →

c) discharge through runner → 271.77 m³/sec

d) Assume velocity of whirl at outlet is ...



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$$Q = \pi/4 \left(D_0^2 - D_b^2 \right) \times V_{f_1}$$

$$\Rightarrow V_{f_1} = 8.90 \text{ m/sec}$$

$$V_{f_1} = V_{f_2} = V_2 = 8.90 \text{ m/sec.}$$

$$\tan(180-\theta) = \left(\frac{V_{f_1}}{u_1 - V_{w_1}} \right) = \frac{8.90}{(25.525 - 7.58)}$$

$$\tan(180-\theta) = $$

$$\Rightarrow \boxed{\theta = 153.6^\circ}$$

From exit velocity diagram

$$\tan\phi = \frac{V_{f_2}}{u_2} = \frac{8.95}{25.525}$$

$$\Rightarrow \boxed{\phi = 19.22^\circ}$$

Case IInd. Repeat the calculation for $d = D_0$

NOTE

When it is given that runner dia is d m then it is the outer dia. of the runner & in case of the Pelton wheel pitch circle dia. should be taken.

Prob2 A kaplan turbine has a runner dia. of 4 m. And hub dia. 2 meter. The discharge through turbine is 70 m³/sec. The η_h & η_m can be taken as 0.9 & 0.93 respectively. Assuming absence of whirl at outlet & discharge is free from friction estimate the Net head available in the turbine & the power developed. Speed Ratio is 2... Also estimate specific speed.

5) Under assumptions B.Eqn may be applied at Inlet and exit point

when $V_{r_2} = C$, friction on the blades is negligible

Probl XXIII A propeller runner turbine runner has outer dia 4.5m & dia. of hub is 2M. It is required to develop power 20600 KW when running at 150 r.p.m. under a head of 21 M. Assuming hydraulic efficiency 94% & overall efficiency of 88%. Determine the runner vane Angle at Inlet & outlet at the Mean exit of vane. Assume velocity of wirl at outlet is zero. Also determine the vane Angle at outlet & Inlet at outer dia.

(257)

calculation at Mean diameter:

$$D_m = \frac{D_o + D_b}{2}$$

$$= 3.25 \text{ m}$$

$$u_1 = u_2 = \frac{\pi D_m N}{60}$$

$$= \frac{\pi \times 3.25 \times 150}{60}$$

$$= 25.525 \text{ M/sec.}$$

Shaft Power = 20600 KW

$$\eta_o = 0.88$$

$$\eta_o = \frac{S.P}{H.P.}$$

$$\omega Q H = \frac{20,600}{0.88}$$

$$\Rightarrow 9.81 Q \times 21 = \frac{20,600}{0.88}$$

$$\Rightarrow Q = 113.63 \text{ m}^3/\text{sec.}$$

Hydraulic efficiency $(\eta_h) = \frac{V_{w_1} u_1}{gH} = 0.94$

$$\Rightarrow V_{w_1} = 7.58 \text{ m/sec.}$$

$\Rightarrow V_{f1} =$ [illegible]

ii> $Q = A_{f1} \cdot V_{f1}$

$= A_{f2} \cdot V_{f2}$

$\Rightarrow V_{f1} = V_{f2}$

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iii> If friction Losses are negligible than

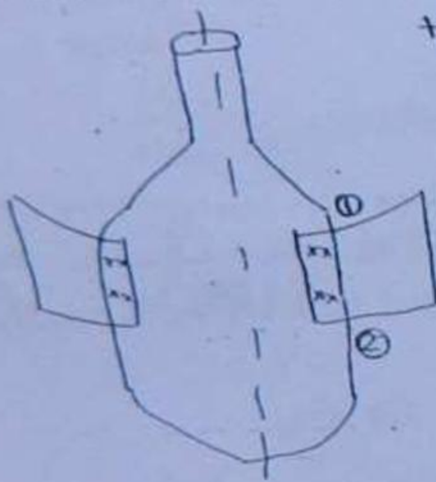
$$\boxed{V_{r1} = V_{r2}}$$

iv> Vane angle from Do to Db May change..

$$\therefore \boxed{u_1 = u_2 = \frac{\pi D N}{60}}$$

$\left.\begin{array}{l} u_1 \text{ at } D = D_0 \\ u_2 \text{ at } D = D_b \end{array}\right\}$ $\left\{ D = D_{Avg} = \frac{D_0 + D_b}{2} \right\}$

* Power & Efficiency calculation are similar to Francisis turbine & velocity diagram also similar to Francisis turbine.



$$\boxed{H = \frac{V_2^2}{2g} + \frac{V_{w1} u_1}{g}}$$

NOTE:-

1) Imp If Entry & Exit points are not clearly Maintain than calculations should be made at outer dia. $\boxed{d = D_0}$

2) Velocity of flow through runner remains constant, i.e. $\boxed{A_{f1} = A_{f2}}$

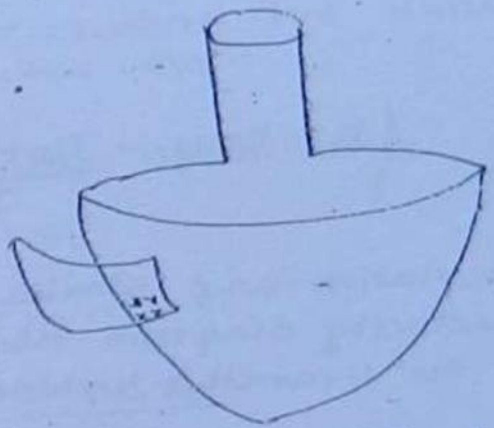
3) The Inlet Vane Angle θ, normally > 90. $\boxed{\text{No of Blades is Normally 3 to 6}}$

4) Ignoring friction resistance, $\boxed{V_{r1} = V_{r2}}$ May be taken

3) Kaplan & Propeller Turbine:

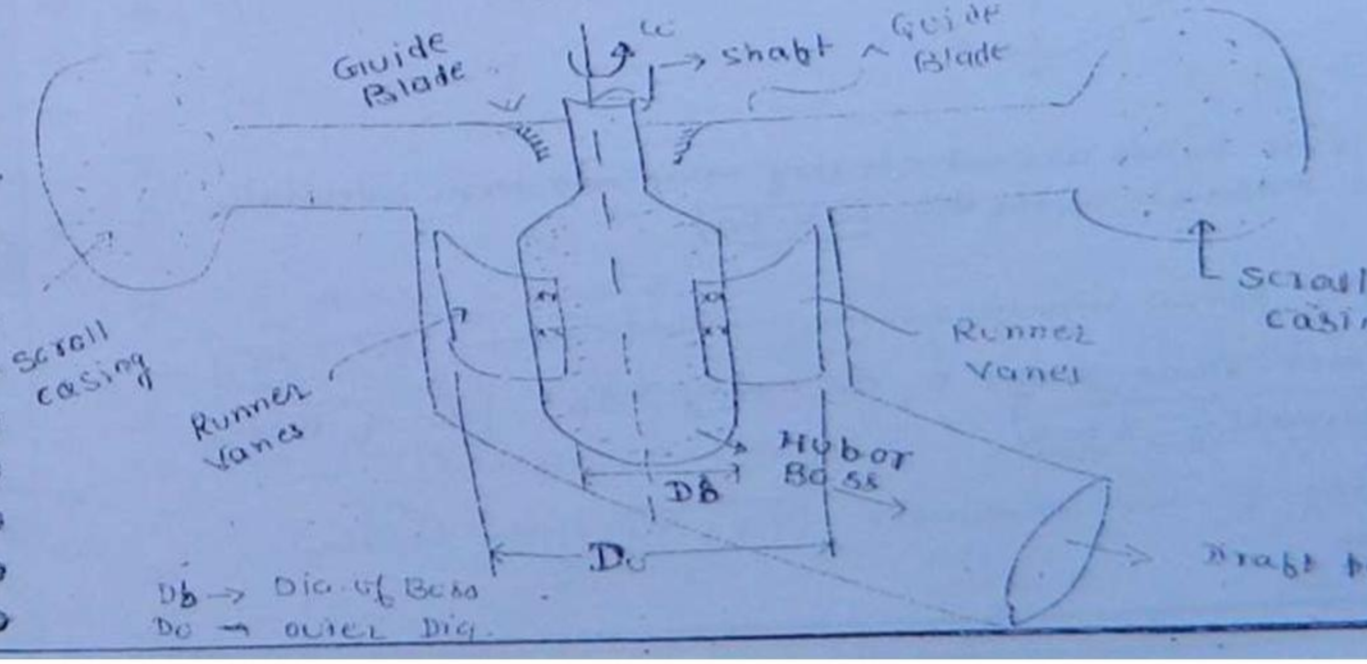
(255)

- Axial flow Rxn turbines
- Propeller turbines & Kaplan turbines are si[milar] in principal except that kaplan had impro[ved] over propeller w.r.t. direction of the blades are Flexible i.e. Propeller turbines has fix[ed] vanes connected through rivets permanane[ntly] where Kapaln has provided bolts & an additional bolt hole.



Important unit of propeller turbines:

a) For the axial flow reaction turbine the sha[ft] of the turbine is vertical, the Lower end o[f] the shaft is made Larger which is known a[s] Hub or Boss.



for a turbine to run under a
head of 1m

$$Q_U = \frac{Q}{\sqrt{H}}$$

(254)

> Unit power: It is the theoritical power which a turbine would produce under a head of 1m.

$$P_U = \frac{P}{H^{3/2}}$$

model quantities: ⤵

When the results obtain from the e
conducted on the model are appl
to the prototype in the field fol
similarity exists:

a) $\frac{H}{N^2 D^2}$ = costant

i.e. $\frac{H_M}{N_M D_M^2} = \frac{H_P}{N_P D_P^2}$

b) $\frac{P}{N^3 D^5}$ = constant

$\Rightarrow \frac{P_M}{N_M^3 D_M^5} = \frac{P_P}{N_P^3 D_P^5}$

c) $\frac{Q}{N D^3}$ = constant

$\Rightarrow \frac{Q_M}{N_M D_M^3} = \frac{Q_P}{N_P D_P^3}$

Specific speeds for various turbines:-

[M.K.S. Un...
P → H.P...

a) Pelton wheel

→ Single Jet $N_s = 10$ to 30

→ Multi Jet $= 30$ to 60

(253)

b) Francis turbine $N_s \Rightarrow 60$ to 300

c) Kaplan turbine $N_s \Rightarrow 300$ to 1000

Unit quantities:-

A turbine operates most efficientl[y] at its design points at a particu[lar] combination of H, Q & N. But in practice these variable do not remain constant therefore conce[pt] of unit quantity is important to

(i) Predict the behaviour of turbine workin[g] at different condition

(ii) To make the comparison of performance [of] turbine of the same type but diff. si[ze]

(iii) It may be used to compare the performa[nce] of turbine of different type.

(iv) To correlate the use of experimental data

a) unit speed: It is the theoritical speed at which a given turbine would operate unde[r] a head of 1M.

$$N_u = \frac{N}{\sqrt{H}}$$ r.p.m

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

P → H.P (Power)
H → Head

L = 1200 m
no. of turbine = 3
H = 360 m
f = 0.02

(252)

NOTE: For multiple jet pelton wheel the sp. speed is based on break power per jet.

$\eta = 0.85 = \frac{S.P.}{\text{water available at the base of nozzle}}$

$\left[\eta_M = \frac{S.P.}{R.P.} \right.$

$0.85 = \frac{55.06}{wQH}$.

$\Rightarrow Q = 1.834 \ m^3/sec.$

Total discharge supplied by pipe = 18.34

∴ Discharge through each nozzle

$= \frac{1.834}{3} = 0.611 \ m^3/sec$

$V_1 = C_v \sqrt{2gH} = 0.98 \sqrt{2 \times 9.81 \times 360}$

∴ $V_1 = 82.36$ m/sec.

~~discharage~~ dia. of each Jet/nozzle is

$\pi d^2/4 = \frac{0.611}{82.36} \Rightarrow d = 0.097 \ m$
$= 97 \ mm$

$$\boxed{h_f = \frac{fLQ^2}{12.1 D^5}} = \frac{0.02 \times 1200 \times 18.34^2}{12.1 \ D^5}$$

$= 12$

$$\Rightarrow \boxed{D = 0.88 \ m}$$

Power at Nozzle = $\rho g Q H$ = 9.81 × 700 × 0.1 [illegible]

$= 686.7\ kW$

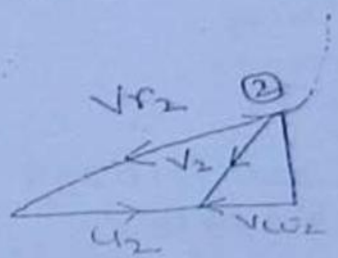
$$\eta_H = \frac{V_{w_1} u_1 + V_{w_2} u_2}{gH}$$ { Losses at Nozzle are negligible

$V_{w_1} = V_1 = 117.19$

$V_{r_1} = V_1 - u_1 = 117.19 - 52.35 = 64.83$

Incoming bucket to be frictionless

$V_{r_2} = V_{r_1} = 64.83\ m/sec.$



$|u_2| + |V_{w_2}| = |V_{r_2} \cos$ [illegible]

$= 64.83 \cos$ [illegible]

$\therefore V_{w_2} = 10.261\ m/s$

$\therefore \eta_H = 97.18\ \%$

Prob 4

A pipline 1200 m Long supply water t[o] three simple pelton wheel. The head o[n] the nozzle is 360 M. CV = 0.98, fo[r] factor for the pipe = 0.02. The tur[bine] efficiency based on the head of th[e] nozzle is 0.85. If specific speed [based] on the base of nozzle is 15.3 [Ns = ...] such that n = r.p.m, P = kW, H = ... If head loss due to friction in the [pipe] line is 12 M and operating speed o[f] [tur]bine is 3[illegible] r.p.m. determine

(i) [Total] power developed

(ii) The Dia of pipe line

(iii) The dia of pipe each nozzle.

(iv) Discharge

$$= \frac{wQ}{g}\left[V_{w_1}u_1 + V_{w_2}u_2\right]$$

$$= \frac{9.81 \times 0.75}{9.81}\left[25.68 + 0.855\right] \times 12$$

(280)

Efficiency: ↓

Hydraulic efficiency $\eta_{cy} = \frac{R.P.}{K.E./second}$

$$K.E./second = \frac{1}{2} \times \left(\frac{wQ}{g}\right) \times V_1^2$$

$$= \frac{1}{2} \times \frac{9.81 \times 0.75}{9.81} \times 25.68^2$$

$$= 247.29 \text{ KW}$$

$$\therefore \eta_R = \frac{238.8}{247.29} \times 100\ \%$$

$$= 96.56\ \%$$

Prob3 (S/2004) A pelton wheel has mean bucket dia. of 1M a[nd] is running at 1000 R.P.M. The net head o[n] the pelton wheel is 700 m. If the side [...] clearance angle is 15° and discharge thr[ough] the nozzle 0.1 m^3/sec. Find

a) Power available at the nozzle

b) Hydraulic Efficiency of turbine, take C_v [...]

$$u_1 = u_2 = \frac{\pi DN}{60} = \frac{\pi \times 1 \times 1000}{60} = 52.35 \text{ m/s}$$

Net head on the peltonwheel = 700 m (H)

$\phi = 15°$

$Q = 0.1 \text{ m}^3/\text{sec}$, $C_v = 1.0$

$$V_1 = C_v\sqrt{2gH}$$

$$= 1.0\sqrt{2 \times 9.81 \times 700}$$

$$= 117.19 \text{ m/sec}$$

$\phi = \frac{u_1}{\sqrt{2gH}} = 0.45$ — Speed ratio can not be applied to calculate u_1

A Pelton wheel has a mean bucket speed of 12 m/s
is supplied with water at a rate of 750
under a head of 35 M. If the buckets def
the jet by an angle of 160°. Find the
power & efficiency of the bucket takin
$C_v = 0.98$ & Neglecting the friction in the

$u_1 = u_2 = 12$ M/sec

$Q = 750$ l/sec

$= 0.75$ m^3/sec

$H = 35$ M

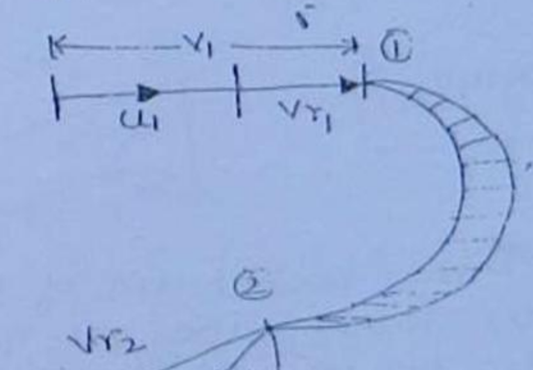
Defln Angle $= 180 - \phi$

$= 160°$

(249)

∴ side clearance angle or runner vane angle $(\phi) = 20°$

$C_v = 0.98$



$V_{r_1} = V_1 - u_1$

$= 25.68 - 12$

$= 13.68$ m/sec

$V_1 = C_v \sqrt{2gH}$

$= 0.98 \sqrt{2 \times 9.8}$

$= 25.68$ m/s

$V_{r_1} = V_{r_2} = 13.68$ m/sec

$|V_{r_2} \cos\phi| = |u_2| + |V_{w_2}|$

$\Rightarrow 13.68 \cos 20 = 12 + V_{w_2}$

$\Rightarrow V_{w_2} = 0.855$ m/sec

ES/2001

Pelton wheel

i) Head at the base of Nozzle = 32 M (H)

ii) discharge of the Nozzle = 0.18 m^3/sec (Q)

iii) area of Jet = 7500 mm^2 (a)

iv) Power available at the shaft = 44 KW (S.P.

v) Mech. efficiency = 94 %. ($\eta_M = 0.94$)

Calculate the power Loss

a) In the Nozzle

b) In the Runner

c) In the Mech. friction

$\eta_M = \frac{S.P.}{R.P.}$

(248)

$R.P. = \frac{S.P}{\eta_M} = \frac{44}{0.94} = 46.8$ KW

velocity of Jet = $Q/a = \frac{0.18}{7500 \times 10^{-6}} = 24.0$ m/sec

K.E per second of the Jet = $\frac{1}{2} \times \left(\frac{wQ}{g}\right) \times V_1^2$

$= \frac{1}{2} \times \frac{9.810 \times 0.18}{9.81} \times (24)^2 = 51.84$ KW

Power available at the base of Nozzle

$= wQH$

$= 9.81 \times 0.18 \times 32 = 56.5$ KW

Loss at Nozzle

$= 56.5 - 51.84 = 4.66$ KW

Loss in Runner

$= 51.84 - 46.8 = 5.04$ KW

Mechanical Losses = 46.5 - 44 = 2.5 KW

= R.P. - Losses

= S.P. shaft losses.

Volumetric Efficiency :-

If entire volume of Jet is not striking to the vane than volumetric efficiency

$$\eta_v = \frac{Q'}{Q}$$

[Q' = total volume of water striking the Jet per sec.

Q =

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specification for design of Pleton wheel :-

(a) speed ratio $\phi = \frac{u_1}{\sqrt{2gH}}$ [ϕ is also called side clearance angle

= 0.45 to 0.47

(b) Angle of defln of Jet through the bucket is ≃ 165° [If not given]

(c) Jet ratio = $\frac{\text{Dia. of pitch circle}}{\text{Dia. of Jet}} = D/d = m$

≃ 11 to 15 & commonly It is adopted 12.

(d) No. of buckets on the runner should be as Less as possible in order to minimize friction losses.
But In-order to Maximize Volumetric Efficiency Optimum No. of Buckets are given by

$$Z = 15 + \frac{D}{2d} = 15 + 0.5\,m$$ [m = 12

≃ 21 [Range 18 to 25]

(e) No. of Jets (n) = $\frac{\text{Total discharge}}{\text{Discharge through one Jet}}$ ⊁ 6

(f) width of bucket may be taken as height times dia of Jet & vertical depth of bucket may be taken as 1.5 times dia of Jet

a) Efficiency of Nozzle: ↓

$$\eta_N = \frac{K.E./sec}{\text{Power at the base of Nozzle}} = \frac{\frac{1}{2}\frac{wQ}{g} \times V_1^2}{wQH}$$

(246)

$$= \frac{V_1^2}{2gH} = \frac{C_v^2(2gH)}{(2gH)} = C_v^2$$

$\therefore$ $\eta_N = C_v^2$

b) Hydraulic efficiency: ↓

$$\Rightarrow \eta_h = \frac{R.P.}{K.E./sec \text{ of Jet}}$$

$$= \frac{\frac{wQ}{g}\left[V_{w1}u_1 + V_{w2}u_2\right]}{\frac{wQ}{2g} \times V_1^2}$$

NOTE:- If hydraulic efficiency is calculated on the basis of power available at the base of nozzle then

$$\eta_h = \frac{R.P.}{\text{Power available at the base of Nozzle}}$$

$$= \frac{\frac{wQ}{g}\left[V_{w1}u_1 + V_{w2}u_2\right]}{wQH}$$

$$\eta_h = \frac{V_{w1}u_1 + V_{w2}u_2}{gH}$$

It means energy loss at the base of nozzle is neglected

c) Mechanical efficiency ↓

$$\eta_m = S.P./R.P.$$

d) Overall efficiency:- Accounting the Nozzle Loss

$$\boxed{\eta_o = \eta_N \times \eta_h \times \eta_m}$$

Work done by water on the runner (per second)

$$= \frac{\omega Q}{g}\left[V_{\omega_1} u_1 - [-V_{\omega_2}] u_2\right]$$

$$= \frac{\omega Q}{g}\left[V_{\omega_1} u_1 + V_{\omega_2} u_2\right]$$

Discharge through turbine:

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$$= n \times \left(\frac{\pi d^2}{4}\right) \times V_1$$

[where $n \to$ No. of van
$d \to$ dia. of Je
$V_1 \to$ velocity of
$= C_V \sqrt{2g.H}$
$H \to$ Net head a

Power available at the base of Nozzle: base of Nozz

(1) $\underset{(H.P)}{W.P.} = \omega Q H$ [Power available at the base of No.

(3) $R.P. = \frac{\omega Q}{g}\left[V_{\omega_1} u_1 + V_{\omega_2} u_2\right]$ [$(u_1 =$

(2) Power available at the inlet of Jet/v

$= K.E.$ of Jet per second

$= \frac{1}{2} \times$ Mass flowing per second $\times V_1^2$

$= \frac{1}{2} \times \rho Q \times V_1^2$

$= \frac{1}{2}\left(\frac{\omega}{g}\right)(aV_1) \times V_1^2$ [$a \to$ area of Jet

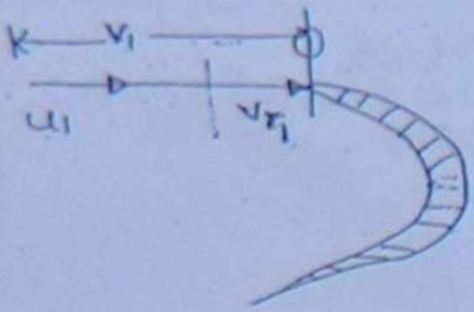
$= \frac{\omega a V_1^3}{2g}$

(4) Power available at the shaft

S.P. or Break Power

$= R.P. -$ Losses

Inlet velocity diagram:



$$\boxed{V_{r_1} = V_1 - u_1}$$

$$\boxed{\begin{aligned}\theta &= 0^\circ \\ \alpha &= 0^\circ\end{aligned}}$$

$V_{w_1} = V_1 \cos\alpha = V_1$

$V_{f_1} = 0$ {radial velocity at inlet}

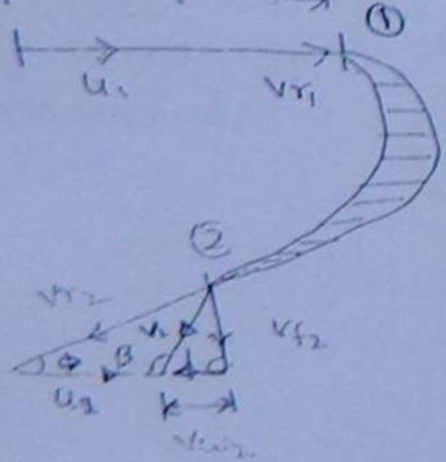
(244)

If Loss of friction on the surface of vane is negligible than $\boxed{V_{r_1} = V_{r_2}}$

$\boxed{V_{r_2} = V_{r_1}}$ ---------- when friction Loss is negligible

$\boxed{V_{r_2} = K V_{r_1}}$ ---------- If friction Losses are accounted. $(K < 1)$

Exit velocity diagram:



$$\boxed{\overline{V_{r_2}} + \overline{u_2} = \overline{V_2}}$$

$$u_2 = u_1 = \frac{\pi D N}{60}$$

$$\boxed{\tan\phi = \frac{V_{f_2}}{u_2 - V_{w_2}}}$$

where $\boxed{V_{w_2} = -ve}$

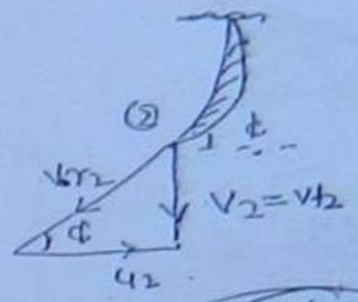
$$u_1 = u_2 = \frac{\pi D N}{60}$$

d = dia of jet.
D = Dia. of Buckets (mean dia

V_{r_1} = Relative velocity at inlet

$= V_1 - u_1$

$$\overline{V_{r_1}} + \bar{U_1} = \bar{V_1}$$



At exit

$$\overrightarrow{V_{r_2}} + \overrightarrow{u_2} = \overrightarrow{V_2}$$

(243)

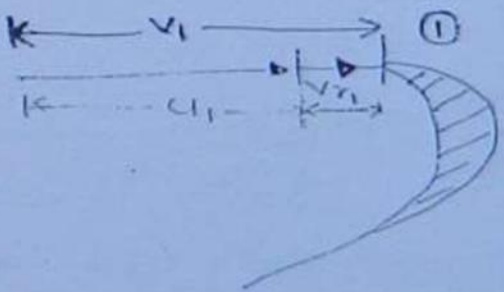
Defln Angle = $180 - \phi$

ϕ = Vane angle at exit

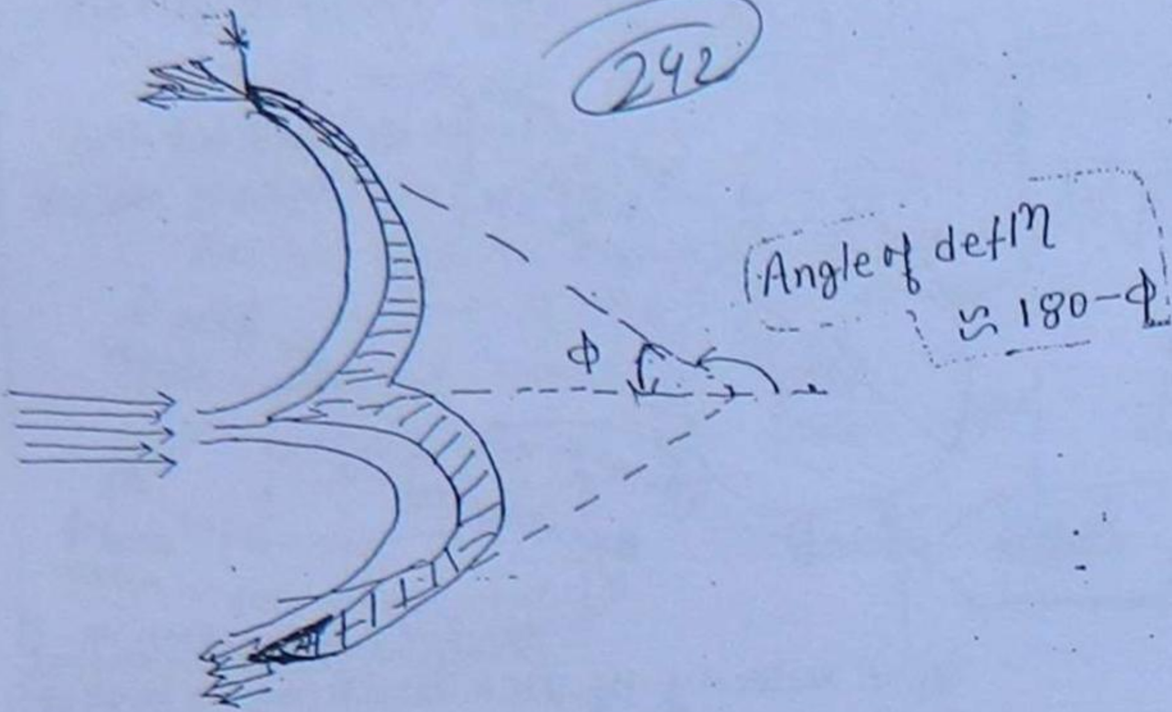
θ = Angle b/w u_1 & V_{r_1}
↓
Vane angle at inlet

Velocity triangle at inlet:]

Since u_1, V_{r_1}, V_1 are in same direction
∴ inlet vel. triangle reduces into a straight line.



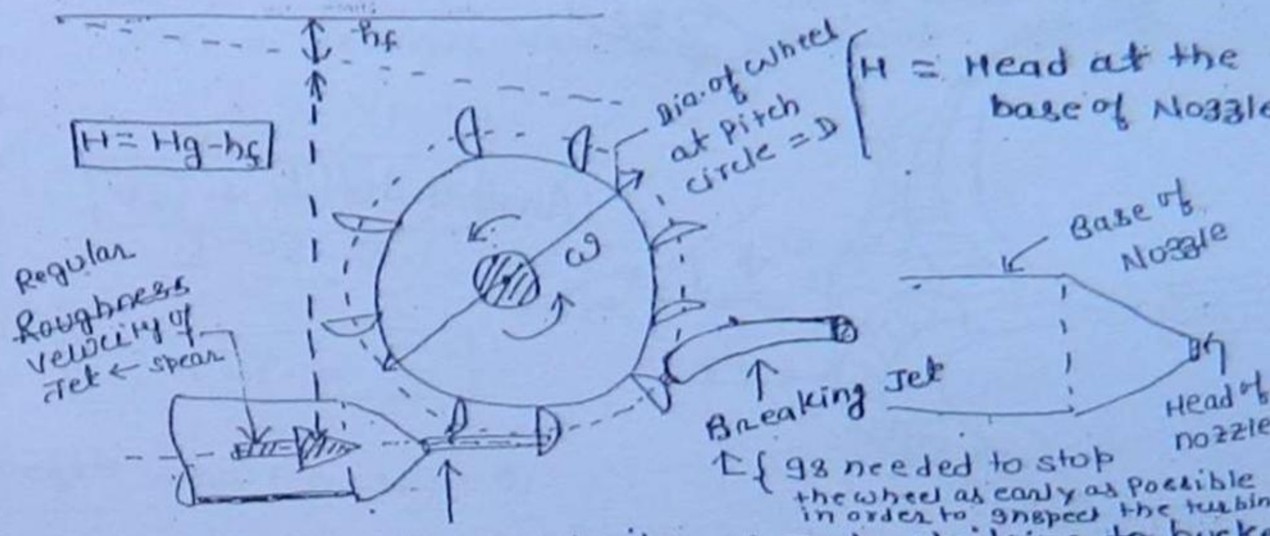
Vanes are made of two hemispherical bucket [illegible]



- Theoretically defl^n. angle should be 180° inorder to produce maxm. work-done but practically it causes retardation of coming vanes by hit[ting] the back of the vanes hence appropriate angle of de[flection] (160° to 165°) is desirable. In order to min[imise] friction Losses vanes are polished on insid[e].
- → Two hemispherical buckets a[re] provided because it will cancell the y-com[ponent] of force and alignment of bucket can be preserved.

2> PELTON WHEEL :-

Tangential flow Impluse Turbine



$$\therefore \boxed{V_1 = C_v \cdot \sqrt{2gH}}$$

$$\boxed{C_v \simeq 0.97 \text{ to } 0.98}$$

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→ When wheel is vertical and shaft is horizontal than It is called 'horizontal alignment', whereas 'vertical alignment' is that wheel is horizontal & shaft is vertical.

→ In the Pelton wheel hemispherical bucket are mounted on the pitch circle which may be 15 to 25 in number.

→ As far as possible less No. of vanes should be provided so as to minimize friction losses but specified minimum no. of vanes should be provided so as to prevent the loss of discharge without hitting the vanes. No. of vanes required depends upon Jet ratio which is defined as dia of pitch circle to dia. of Jet

$$m = \text{Jet Ratio} = \frac{\text{Dia of Pitchcircle}}{\text{Dia of Jet}} = D/d$$

$$\therefore \boxed{\text{No. of Vanes} = 15 + 0.5\, m}$$

where m is generally b/w 10 to 15 ≈ 12.

Q. A conical draft tube having inlet & outlet

heel 21

dia. 1m & 1.5m discharges water at outle with velocity of 2.5 m/sec. The total length the draft tube is 6m & 1.20 m Length low the draft tube is immersed in water. If th atmospheric pressure head is 10.3 m of wa and Loss of head due to friction in the draft tube is equal to 0.2 x velocity head at outlet of the tube. Find

(i) Pressure head at the inlet.

(ii) Efficiency of the draft tube.

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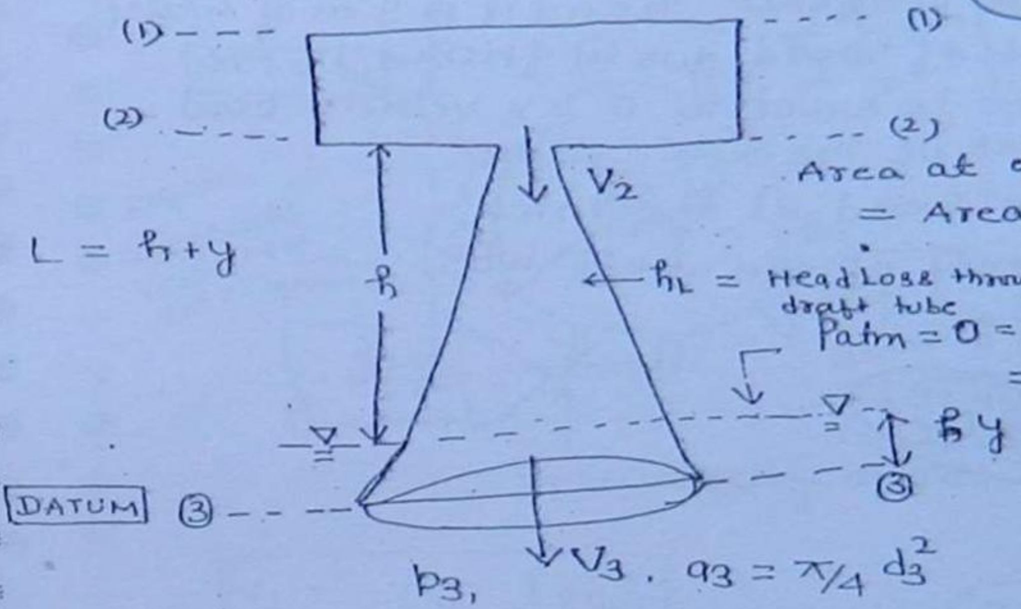
DRAFT TUBE :-



Area at exit of Runner = Area at inlet of draft tube $a_2 = \frac{\pi}{4} d$

$P_{atm} = 0$ = in gauge scale = 10.3 m head of water

Apply B. eqn b/w (2) & (3) -

$$(h+y) + \frac{V_2^2}{2g} + \frac{p_2}{\omega} = 0 + \frac{V_3^2}{2g} + \frac{p_3}{\omega} + h_L$$

$$= \frac{V_3^2}{2g} + \frac{p_{atm}}{\omega} + y + h_L$$

NOTE: Since p_2 is below atmosphere than it should be such that it should not fall below vapour pressure.

Efficiency of draft-tube :-

$$\eta = \frac{\text{Actual converging of K.H. into Pressure head}}{\text{original K.H.}}$$

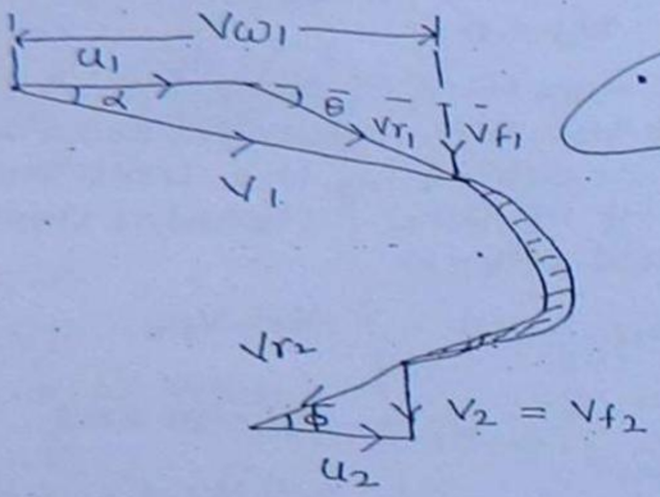
$$\eta = \frac{\frac{V_2^2}{2g} - \frac{V_3^2}{2g} - h_L}{V_2^2/2g}$$

$$u_1 = \frac{\pi D N}{60} = \frac{\pi \times 0.6 \times 750}{60} = 23.56 \text{ m/s}$$

$$\therefore \eta_h = \frac{V_{w_1} u_1}{gH} \Rightarrow V_{w_1} = \frac{0.94 \times 9.81 \times 68}{23.56}$$

$$= 26.61 \text{ m/sec.}$$

since $u_1 < V_{w_1} \Rightarrow \theta < 90^\circ$



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$$\therefore \tan\theta = \frac{V_{f_1}}{V_{w_1} - u_1} \Rightarrow \theta = 60.8^\circ$$

$$\tan\phi = \frac{V_{f_2}}{u_2} = \frac{V_{f_1}}{u_1/2} \Rightarrow \phi = 24.9^\circ$$

$$\tan\alpha = \frac{V_{f_1}}{V_{w_1}} \Rightarrow \boxed{\alpha = 11.64^\circ}$$

Sheet 1 Prob 17

1 Design a Francis turbine runner with the following data:

Net head 68 m

speed $N = 750$ r.p.m

output power = 330 kW (S.P.)

$\eta_h = 94\%$

η_o (overall efficiency) = 85% = η_o

ψ = Flow ratio = 0.15 $\Rightarrow \psi = \frac{V_{f_1}}{\sqrt{2gH}} = 0.15$

width ratio $n = b/d = 0.1$

Inner dia. of runner is ½ of outer dia. Also assume 6% of the circumferential area of runner to be occupied by the thickness of vanes. Velocity of flow remains constant & flow is radial at exit.

(237)

Given $K = 0.94$, $d_2 = d_1/2$, $b_1/d_1 = 0.1$, $V_{f_1} = V_{f_2}$

$$\boxed{\eta_o = \frac{S.P}{H.P.}} = \frac{330}{H.P} \Rightarrow HP = 388.235 \text{ kW}$$

$= \omega Q H$ [ω = 10 … = 9…]

$\Rightarrow Q = 0.58 \text{ m}^3/\text{sec}$

$\therefore \frac{V_{f_1}}{\sqrt{2gH}} \Rightarrow V_{f_1} = 5.48$ m/sec

$Q = K.(\pi d_1 b_1) \times V_{f_1} = 0.94 \times \pi \times d_1 b_1 \times 5.48$

$b_1 d_1 = 0.036 \text{ m}^2$ — (II)

$b_1/d_1 = 0.1$ — (I)

$b_1 = 0.1 d_1$

$\Rightarrow d_1 \times 0.1 d_1 = 0.036$

$\Rightarrow 0.1 d_1^2 = 0.036$

$\Rightarrow d_1 = 0.6$ M = 600 mm

$b_1 = 0.06$ M = 60 mm

$Q = 0.94 \pi d_1 b_1 V_{f_1} = 0.94 \pi d_2 b_2 V_{f_2}$

$b_2 = \frac{d_1 b_1}{d_2} \left(\frac{V_{f_1}}{V_{f_2}}\right)$

$\Rightarrow \boxed{b_2 = 120 \text{ mm}}$

5/2001 at an avg. head of 160 m with a discharge of 80 m^3/sec. The inlet and outlet dia. are 4 m & 2 m respectively. The runner blade angle is 120°. Radial discharging velocity at outlet is 15 m/sec. Assuming constant width of wheel and 90% hydraulic efficiency. Determine H.P. produced, in MW. & R.P.M. of machine.

Given

$H = 160\ m$

$Q = 80\ m^3/sec$

$d_1 = 4\ m$

$d_2 = 2\ m$

$\theta = 120°$

$V_{f_2} = V_2 = 15\ m/sec.$

$V_{w_2} = 0$

$b_1 = b_2 = const.$

$\eta_h = 0.9$

$H.P. = ?$

$N = ?$

(236)

$$u_1 = \frac{\pi d_1 N}{60}$$

$Q = \pi d_2 b_2 V_{f_2}$

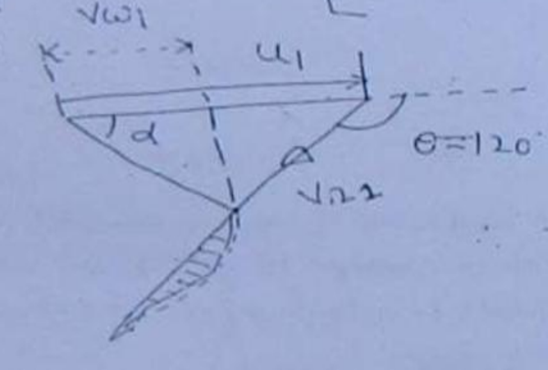
$80 = \pi \times 2 \times b_2 \times 15$

$\Rightarrow b_2 = 0.84\ m$

$b_1 = b_2 = 0.84\ m$

$Q = V_{f_1} \cdot \pi d_1 b_1$

$\Rightarrow V_{f_1} = 7.5\ m/sec.$



$$\therefore \tan(180-\theta) = \frac{V_{f_1}}{u_1 - V_{w_1}} \quad \text{-(}$$

$$\eta_h = \frac{V_{w_1} u_1}{g H}$$

$\Rightarrow V_{w_1} \cdot u_1 = 0.9 \times 9.81 \times 160$ —(ii)

By solving eqn (i) & (ii)

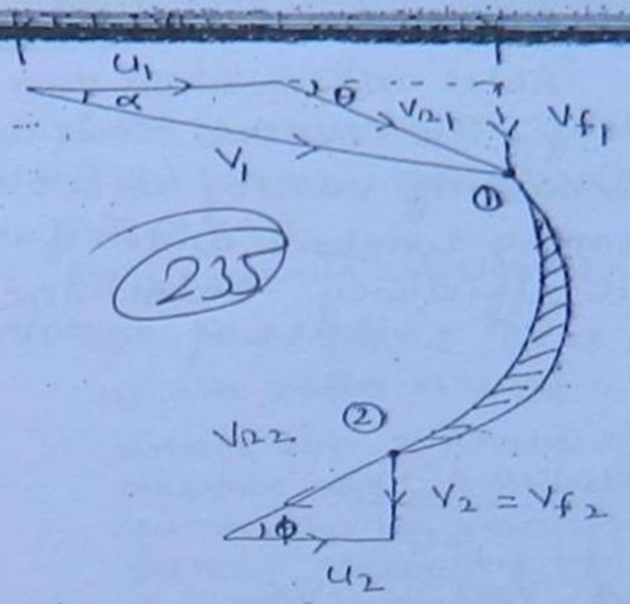
$u_1 = 39.81\ m/sec = \frac{\pi d_1 N}{60}$

$V_{w_1} = 35.96\ m/sec \quad \Rightarrow N = 190\ r.p.m.$

$\therefore$ Hydraulic Power $= \omega Q H$

$= 9.81 \times 80 \times 160\ kW$

$\therefore P = 125.5\ MW.$



$$\tan\alpha = \frac{V_{f1}}{V_{w1}}$$

$$\Rightarrow V_{f1} = V_{w1}\tan\alpha$$

$$V_2 = V_{f2} = V_{f1} = V_{w1}\tan\alpha$$

$$\tan\theta = \frac{V_{f1}}{V_{w1} - u_1}$$

$$\therefore \tan\theta = \frac{V_{w1}\tan\alpha}{V_{w1} - u_1}$$

$$\therefore V_{w1} - u_1 = V_{w1}\frac{\tan\alpha}{\tan\theta}$$

$$\therefore u_1 = V_{w1}\left[1 - \frac{\tan\alpha}{\tan\theta}\right]$$

$$\eta_h = \frac{V_{w1}u_1}{gH} \quad \text{---(iii)}$$

Apply B. Eqn b/w (1) & (2)

$$H = \frac{V_2^2}{2g} + \frac{V_{w1}u_1}{g}$$

$$= \frac{V_2^2}{2g} + \frac{V_{w1}\cdot u_1}{g}$$

$$\therefore \frac{V_{w1}u_1}{g\eta_h} = \frac{V_2^2}{2g} + \frac{V_{w1}\cdot u_1}{g}$$

$$\Rightarrow 1/\eta_h = \frac{V_2^2}{2u_1V_{w1}} + 1$$

$$\therefore \eta_h = \frac{1}{1 + \left(\frac{V_2^2}{2u_1V_{w1}}\right)}$$

$$= \frac{1}{1 + \frac{V_{w1}^2\tan^2\alpha/2}{V_{w1}\times V_{w1}\left[1 - \frac{\tan\alpha}{\tan\theta}\right]}}$$

$$\therefore \eta_h = \frac{1}{1 + \left[\frac{\tan^2\alpha/2}{1 - \frac{\tan\alpha}{\tan\theta}}\right]}$$

$Q = \pi d_1 b_1 \cdot V_{f_1}$

$= \pi \times 0.6 \times 0.15 \times 1.5$

$= 0.424 \ m^3/sec$

$= \pi d_2 . b_2 . V_{f_2}$

$\Rightarrow b_2 = 0.3m = 300mm$

$\sin\theta = \dfrac{V_{f_1}}{V_{r_1}} \Rightarrow V_{r_1} = V_{f_1} \text{cosec}\,\theta$
$= 2.89 \ m/sec.$

$R.P. = \dfrac{wQ}{g}\left[V_{w_1}u_1 - V_{w_2}u_2\right]$ ($V_{w_2} \to 0$)

$= 21.74 \ KW$

- Apply Master formula {Apply B.eqn b/w ① & ②}

$H = \dfrac{V_2^2}{2g} + \dfrac{V_{w_1}u_1}{g}$ [Assuming Minor Losses to be neglected

$= 5.34 \ M$

$\eta_h = \dfrac{V_{w_1}u_1}{gH}$

$= 95.1\%$

Prob.4 CS/2003

An inward flow reaction turbine discharges ra... the velocity of flow through the runner is con... so that hydraulic efficiency is given by

$\eta_h = \dfrac{1}{1 + \dfrac{\frac{1}{2}\tan^2\alpha}{1 - \left(\frac{\tan\alpha}{\tan\theta}\right)}}$, where α is the guide blade an... & θ is runner va... angle at inle...

Assume there is no friction on the blade...

Prob 9. An Inward reaction flow turbine runs at 192 r.p.m. the dia & width at inlet are 600 mm & 152 mm ... the outlet dia. is 300 mm. The velocity of flow through the runner is constant at 1.5 M/sec. If the guide blades are 10° to the wheel tangent. Draw the inlet & outlet velocity diagram, if velocity of whirl at outlet is zero. Determine

(i) Runner Blade Angle
(ii) Abs. Velocity of water leaving the guide bla...
(iii) Rel. velocity of water at inlet
(iv) width of the wheel at outlet
(v) Discharge through turbine
(vi) Head supplied
(vii) R.P. supplied (developed)
(ix) Hydraulic Efficiency.

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Given

$N = 192$ r.p.m.

$d_1 = 600$ mm

$b_1 = 152$ mm

$d_2 = 300$ mm

$V_{f_1} = V_{f_2} = 1.5$ M/sec

$\alpha = 10°$

$V_{w_2} = 0$

θ & $\phi = ?$

$u_1 = \frac{\pi d_1 N}{60} = 6.03$ M/se...

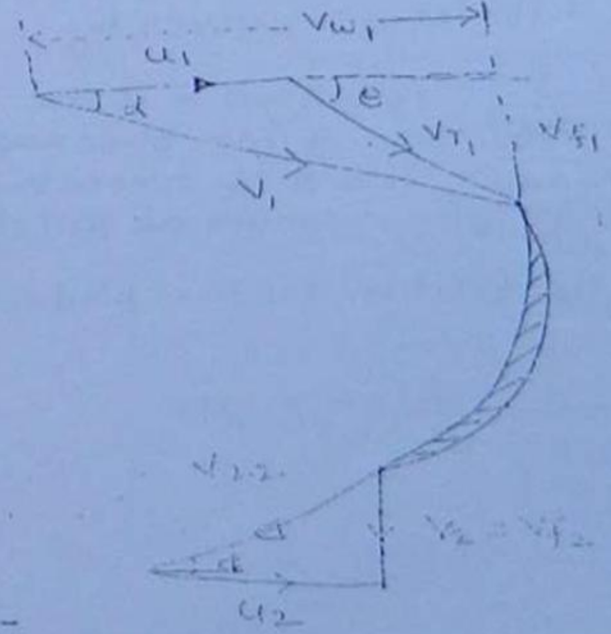
$\tan\alpha = \frac{V_{f_1}}{V_{w_1}}$

$\Rightarrow V_{w_1} = 8.507$ M/sec

$V_1 = \sqrt{V_{f_1}^2 + V_{w_1}^2}$

$= 8.63$ M/sec

since $u_1 < V_{w_1} \Rightarrow \theta < 90°$



$\tan\theta = \frac{V_{f_1}}{V_{w_1} - u_1}$

$\Rightarrow \theta = 31.19$

$\frac{u_1}{u_2} = d_1/d_2$

$\Rightarrow u_2 = u_1 \times d_2/d_1$

$= 3.015$ M/...

$\tan\phi = \frac{V_{f_2}}{u_2}$

$\Rightarrow \phi = 26.45°$

→ $N = 450$ R.P.M.

$H = 120$ M

$d_1 = 1.2$ M

$A_{f_1} = 0.4\ M^2$

$\alpha = 20^\circ$

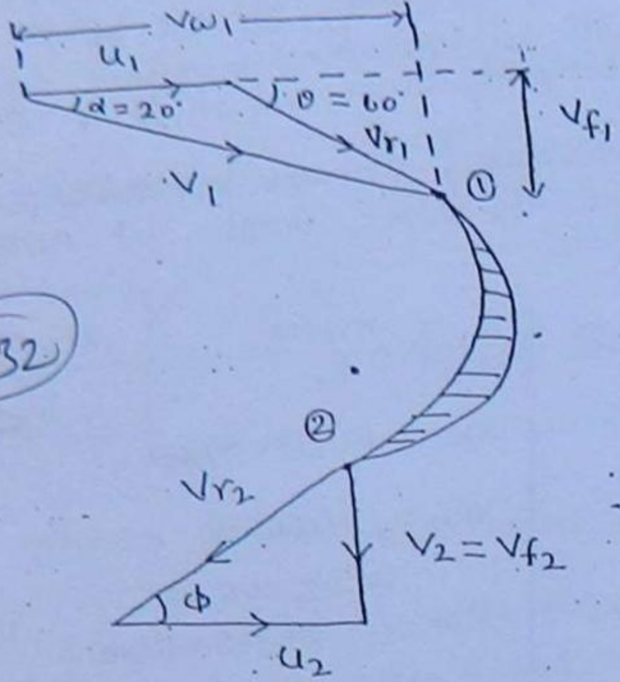
$\theta = 60^\circ$

$V_{w_2} = 0$

$Q = ?$

R.P = ?

$\eta_B = ?$



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$$u_1 = \frac{\pi d_1 N}{60} = 28.27 \text{ M/sec.}$$

$$\tan\theta = \frac{V_{f_1}}{V_{w_1} - u_1} \quad \text{——①}$$

$$\tan\alpha = \frac{V_{f_1}}{V_{w_1}} \quad \text{——②}$$

By eqn (1) & (2) $\quad V_{w_1} = 35.78$ M/sec

$\qquad V_{f_1} = 13.03$ M/sec.

$$Q = A_{f_1} \cdot V_{f_1}$$

$$= 0.4 \times 13.03$$

$$Q = 5.21 \ M^3/sec$$

$$\eta_B = \frac{V_{w_1} u_1 - V_{w_2} u_2}{gH} = 85.96\%.$$

($V_{w_2} \to 0$)

$$\text{Runner power} = \frac{wQ}{g}\left[V_{w_1} u_1 - V_{w_2} u_2\right]$$

($V_{w_2} \to 0$)

$$= 5270 \text{ KN}$$

An inward [illegible] reaction turbine [illegible] have an external diameter of 700mm & a width of 180mm. If the guide vanes are at 20° to the wheel tangent and the abs. velocity of water at inlet is 25 M/sec. Then find

a> Discharge through the turbine

b> Runner vane angle at inlet

$N = 500$ r.p.m.

$d_1 = 700$ mm $= 0.7$ m

$b_1 = 150$ mm $= 0.15$ M

$\alpha = 20^\circ$

$V_1 = 25$ M/sec.

$\theta = ?$

$Q = ?$

$u_1 = \frac{\pi d_1 N}{60}$

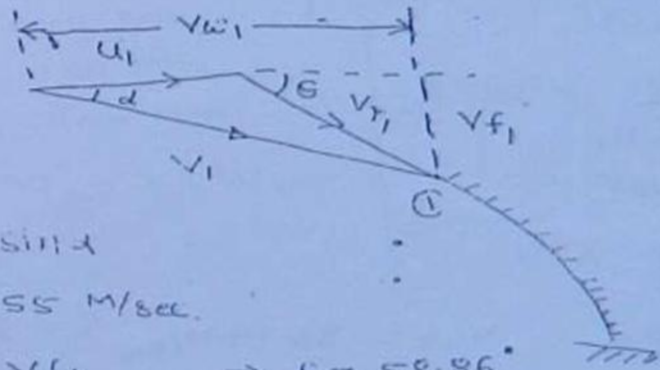
$u_1 = 18.326$ M/sec

$V_{w_1} = V_1 \cos\alpha$

$= 25 \cos 20^\circ$

$= 23.49$ M/sec

since $u_1 < V_{w_1} \Rightarrow \theta < 90^\circ$



$V_{f_1} = V_1 \sin\alpha$

$= 8.55$ M/sec.

$\tan\theta = \frac{V_{f_1}}{V_{w_1} - u_1} \Rightarrow \theta = 58.86^\circ$

$Q = A_{f_1} \cdot V_{f_1}$

$= (\pi d_1 b_1) V_{f_1}$

$= \pi \times 0.7 \times 0.15 \times 8.55$

$= 2.834$ M³/sec

Prob.2 A reaction turbine works at 450 r.p.m. under a head of 120 M. If the dia. at inlet is 1.2 M & flow area at inlet is 0.4 M². The angle made absolute and relative velocities at the inlet with the tangent at wheel is 20° & 20° respectively then determine

a> Flow rate

b> Runner power developed

c> Hydraulic efficiency

$$= \frac{\left(\frac{wQ}{g}\right)\left[V_{w_1}u_1 - V_{w_2}u_2\right]}{wQ} + \frac{V_2^2}{2g} + h_L$$

If $V_{w_2} = 0$ & Losses are Negligible [pressur... energy ... Negli...]
than

$$\boxed{H = \frac{V_2^2}{2g} + \frac{V_{w_1}u_1}{g}}$$ 230 ... Master For...

(d) If speed ratio is given than It Means

$$\phi = \frac{u_1}{\sqrt{2gH}}$$

[It is only signif... for Inlet poi... ϕ Lies between ...]

(e) If flow ratio is given than

$$\psi = \frac{V_{f1}}{\sqrt{2gH}}$$

[Also valid at Inl... ψ Lies b/w 0.15...]

(f) If width ratio is given than

$= b/d$ $\{b_1/d_1\}$

$$\eta_B = \frac{V_{w_1} u_1}{gH}$$

2> Mechanical efficiency

$$\eta_M = \frac{S.P.}{R.P.}$$

3> overall efficiency

$$\eta_0 = \frac{S.P.}{H.P.} = \frac{S.P.}{R.P.} \times \frac{R.P}{H.P} = \eta_B \times \eta_M$$

$$\therefore \eta_0 = \eta_B \times \eta_M$$

NOTE: If Leakage in the turbine chamber are also considered than Volumetric efficiency may be cosidered as

$$\eta_V = \frac{Q'}{Q}$$

$Q' \rightarrow$ Discharge at exi

$Q \rightarrow$ Discharge at inl

However this is More Imp. for centrifugal pu & Negligible for turbines.

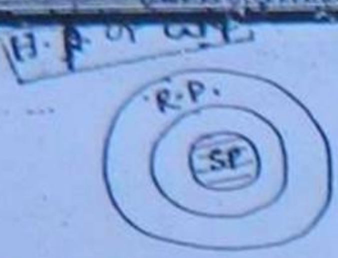
If It is also accounted than overall efficienc

$$\eta_0 = \eta_B \times \eta_M \times \eta_V$$

NOTE: (a) If It is given that velocity through the runn is constant than $V_{f_1} = V_{f_2}$ and Hence A_{f_1}=

(b) In case of some data is missing than Bernou eqn may be applied b/w Inlet & outlet of the runner by assuming No-Losses of head through the runner.

(c) Total Head at Inlet = work done/sec/unit wt. of water + Energy head at outlet + Losses



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a) Hydraulic Power (water Power): It is the power available at the inlet of turbine

$$H.P (W.P.) = \omega.QH \rightarrow KW \quad [\omega = 9.81\ KN/m3]$$

$$= \frac{\rho QH}{75} \rightarrow H.P. \{Horse Power\}$$

b) Runner Power = work-done by water on Runner

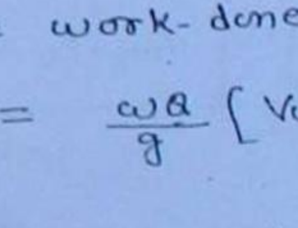
$$= \frac{\omega Q}{g}\left[V_{\omega 1} u_1 - V_{\omega 2} u_2\right]$$

c) Shaft-Power (Break Power): This is final power available at the shaft of turbine.

∴ S.P. = R.P. − Transmission Losses {Mechanical Losses}

7) Efficiency of Turbines: ↓

(a)



Hydraulic efficiency $= \eta_h = \frac{R.P.}{water\ Power}$

$$\therefore \eta_h = \frac{\left(\frac{\omega Q}{g}\right)\left[V_{\omega 1} u_1 - V_{\omega 2} u_2\right]}{\omega QH}$$

$$\therefore \boxed{\eta_h = \frac{V_{\omega 1} u_1 - V_{\omega 2} u_2}{gH}}$$

Ang. Momentum ...

$\therefore$ Ang. Moment/sec $= \left(\frac{Mass}{sec}\right) \cdot V/r$

$$\therefore T = (Mass/sec)\, V_{w_1} r_1 - \left(\frac{Mass}{sec}\right) V_{w_2} r_2$$

$$\therefore T = \rho Q \left[V_{w_1} r_1 - V_{w_2} r_2 \right] \quad (227)$$

$$\therefore \text{work-done/sec.} = T \times \omega$$

$$= \rho Q \left[V_{w_1} r_1 \omega - V_{w_2} r_2 \omega \right]$$

$$= \rho Q \left[V_{w_1} u_1 - V_{w_2} u_2 \right]$$

$$\therefore \boxed{\text{Work-done/sec.} = \left(\frac{\omega}{g}\right) Q \left[V_{w_1} u_1 - V_{w_2} u_2 \right]}$$

[$\omega \rightarrow$ unit a... of flu...

• For Francis Turbine

$$V_{w_2} = 0$$

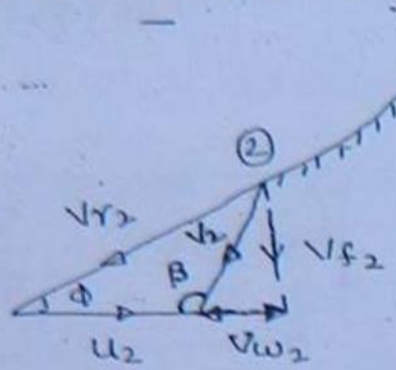
$$\therefore \text{Work done/sec.} = \text{R.P. (Runner Power)}$$

$$= \rho Q \left[V_{w_1} u_1 \right]$$

$$= \frac{\omega Q}{g} \left[V_{w_1} u_1 \right]$$

6) Powers of Turbine

— H = Net Head at inlet of turbine (Runner = Hg ...



$$\tan\phi = \frac{V_{f_2}}{|u_2| + |V_{w_2}|}$$

$$\therefore \; |V_{r_2}\cos\phi| = |u_2| + |V_{w_2}|$$

5) Work-done per sec by the water on Runner (Runner Power)

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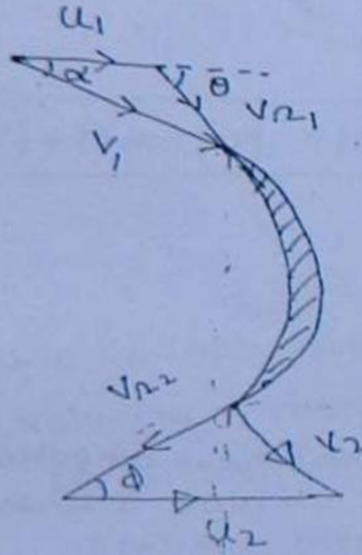


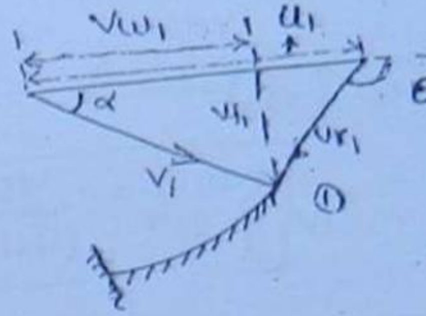
Rate of change of Angular Momentum = T

$$\text{Work-done/sec} = T \times \omega$$

T = Angular momentum/sec at inlet

Angular Momentum/sec at outlet

Case C) when θ > 90°

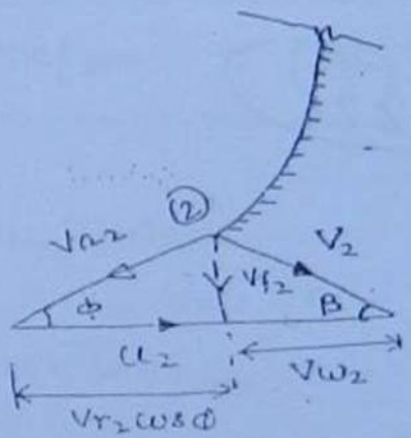


$$\tan(180-\theta) = \frac{V_{f_1}}{u_1 - V_{w_1}}$$

225

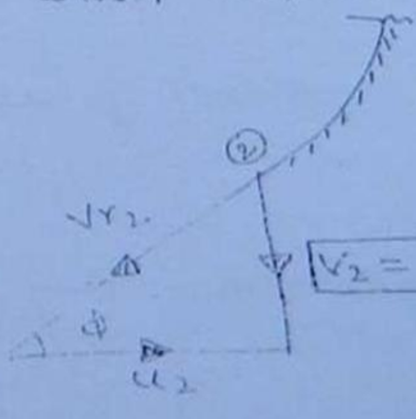
4) velocity triangle at exit

case A) when V_{w_2} is in direction of V_{w_1}



$$|u_2| = |V_{r_2}\cos\phi| + |V_{w_2}|$$

V.IMP Case B) when $V_{w_2} = 0$, whirl component at outlet is zero or turbine discharges radially outward.



$$V_2 = V_{f_2}$$

- $\beta = 90°$, $V_{w_2} = 0$
- $|u_2| = |V_{r_2}\cos\phi|$
- $\tan\phi = \frac{V_{f_2}}{u_2}$

- common case of Francis Turbine.

$$u_1 = \frac{\pi d_1 N}{60} = r_1 \omega$$

$$u_2 = \frac{\pi d_2 N}{60} = r_2 \omega$$

$$\therefore \boxed{u_1/u_2 = d_1/d_2}$$

(3) velocity triangle at inlet.

case A) when $\theta < 90^\circ$

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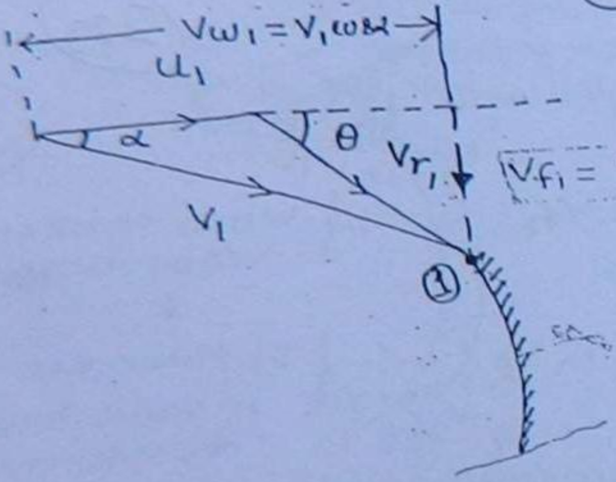


$$\boxed{\tan\theta = \frac{V_{f_1}}{V_{w_1} - u_1}}$$

NOTE: If θ is not given than in order to obtain velocity triangle compare magnitudes of u_1 & V_{w_1}. If

$u_1 < V_{w_1} \Rightarrow \theta < 90^\circ$

If $u_1 = V_{w_1} \Rightarrow \theta = 90^\circ$

If $u_1 > V_{w_1} \Rightarrow \theta > 90^\circ$

case B) when $\theta = 90^\circ$ means vanes are set Radially at inlet

$u_1 = V_{w_1}$

$V_2 \cos\beta$ = [illegible]

$V_2 \sin\beta = V_{f_2}$ = Radial (Flow) velocity at e[xit]

NOTE: If β is 90° than vanes are said to be radial [at] exit or if turbines discharges radially outwa[rd] than β = 90°

- In case of Francis Turbine in order to increase th[e] efficiency β is purposely made 90°.

- Following points may be noted w.r.t. Francis Tur[bine]

(i) Discharge through Runner (Turbine) : (223)

$$Q = A_{f_1} \times V_{f_1}$$

$$= (\pi d_1 b_1) \times V_{f_1} \quad \text{------ \{ When thickness [of] vane is neglig[ible] \}}$$

$$= [\pi d_1 - nt]\, b_1 V_{f_1} \quad \text{------ \{ If there are n vanes having t, thickness each \}}$$

$$= K.\ \pi d_1 b_1 V_{f_1} \quad \text{------ \{ K is coeff. which is account for reduced area occupied [by] vane thickness \}}$$

For eg: 5% area at circumference is occupied by vane thickness than K = 0.95

At exit

$$Q = V_{f_2} \times A_{f_2}$$

$$= (\pi d_2 b_2) \times V_{f_2}$$

$$= [\pi d_2 - nt] \times b_2 V_{f_2}$$

$$= K\, \pi d_2 \cdot b_2 \cdot V_{f_2}$$

$$\boxed{Q = \pi d_1 b_1 V_{f_1} = \pi d_2 b_2 V_{f_2}}$$

Blade Angle at Inlet of Runner

V_{r1} = Relative velocity at inlet (Rel. vel. of fluid with respect to Blade.

$\theta > 90°, = 90°, < 90°$

If $\theta = 90°$, Vanes are said to be radial at inlet

α = Guide blade angle or angle b/w u_1 & V_1

α = Angle of V_1 with the tangent of wheel / Runner at inlet [b/w 10 to 30°]

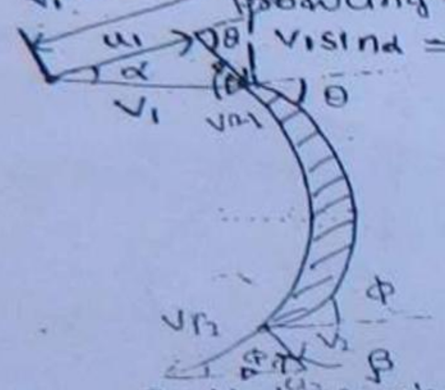
V_1 = Abs. velocity of fluid at inlet

$V_1 \cos\alpha$ = Tangential component of abs. velocity [whirl velocity at inlet V_{w1}].

$V_1 \cos\alpha = V_{w1}$ This component is responsible for producing torque

Exit point

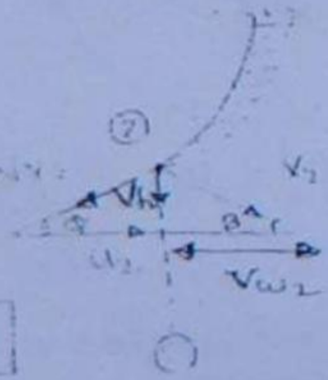
(222)



From vector diagram

$\overline{V_1} = \overline{u_1} + \overline{V_{r1}}$

$V_1 \sin\alpha$ = Radial component of V_1
(Radial velocity at inlet)
(Velocity of flow at inlet) [V_{f1}]



$\overline{V_{r2}} + \overline{u_2} = \overline{V_2}$

V_{r2} = Relative velocity at exit which is in the direction of vane. In turbine V_{r1} not necessarily to be equal

u_2 = Tangential velocity of the Runner at exit

V_2 = Abs. Velocity at

→ [β May be $> 90°, = 90°, < 90°$]

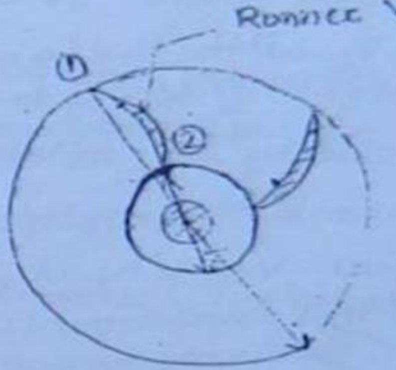
Rotating Runner transfers Energy to shaft & through
Shaft may be connected to generator.

29/10/...

1> FRANCIS TURBINE: ⤵

(24)

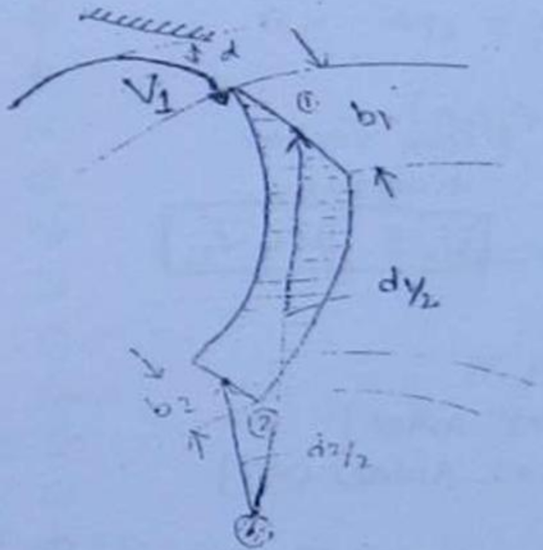
Runner ⤵

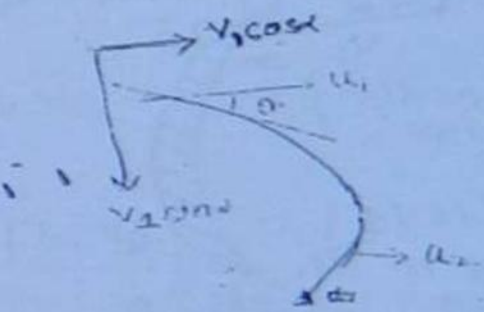


①→ Entry point
②→ Exit point

Inner dia. = Dia. at ...
= d_2

Outer diameter
= Dia. at Inlet
= d_1





Velocity triangle: ⤵ Guide Blade (Fixed in the casing)

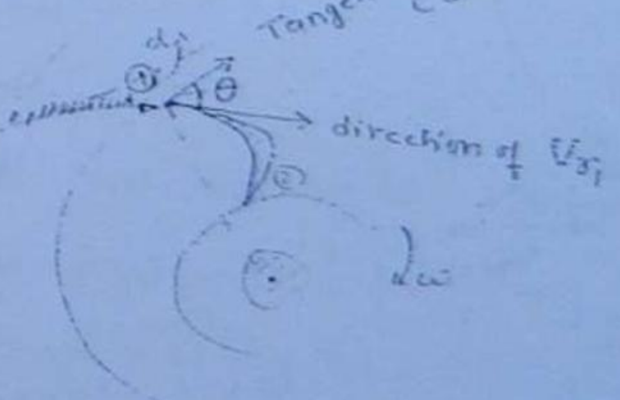
u = Tangential velocity / Peripheral velocity of Runner at Inlet

$= r_1 \omega$

$= d_1/2 \; \omega$

$= d_1/2 \left(\frac{2\pi N}{60}\right)$

$$\boxed{u_1 = \frac{\pi d_1 N}{60}} \text{ m/sec.}$$



energy is used to convert into work. Pressure at exit of turbine may fall below atmospheric therefore disposal of exit water directly into atmosphere is not safe hence a tube of gradually diverging section is used to carry exit water of turbine to tail rest & this is always submerged at some depth below tail rest level.

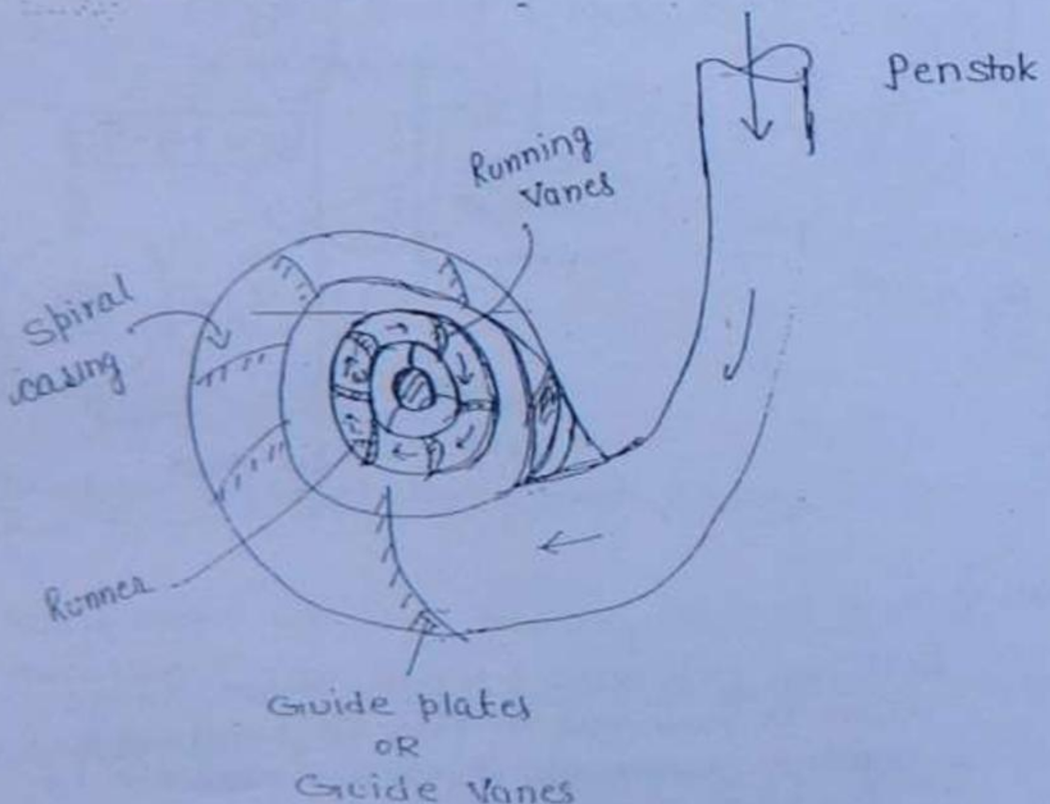
2. In case of impulse turbines, pressure remains const. hence draft tubes is not essential.

d) Turbine units:

(220)

1) Francis Turbine:

* Inward Radial Flow Reaction turbine



- Casing is a spiral chamber which is of gradually decreasing area in order to keep constant velocity at inlet of vanes. [Q decreases, so A is decreases] some water entered into runner
- Guide plates are parmanently attached to casing which

e> ~~Classification on the basis of which is the practical~~ is combination of Last two classification.

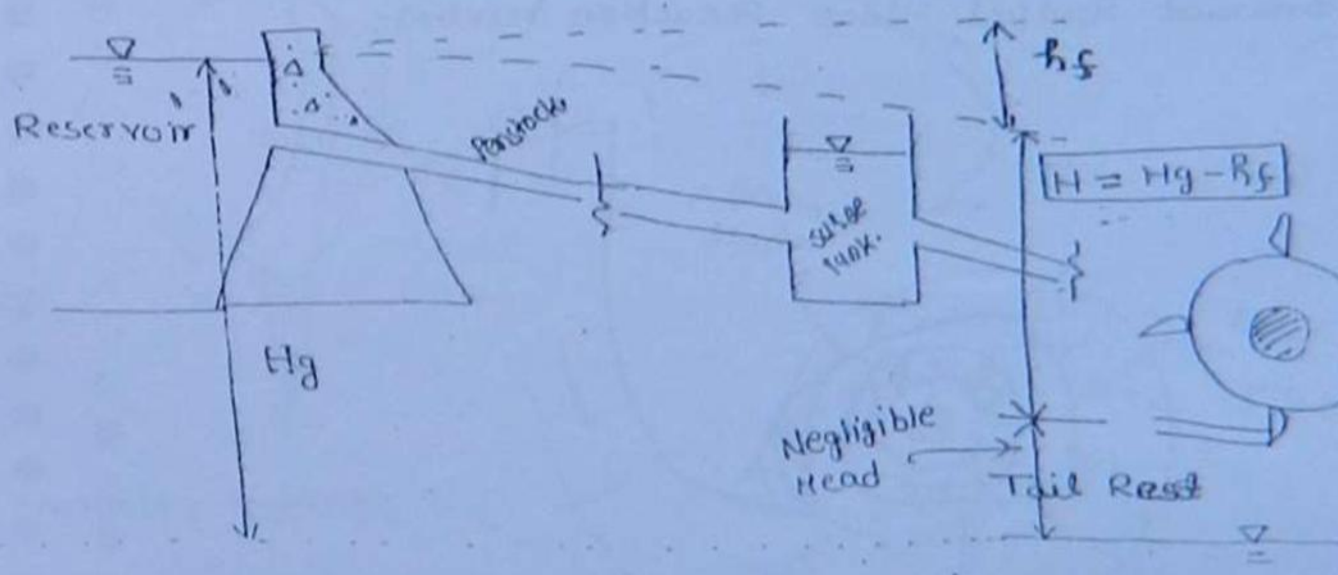
i> Francis Turbines → Inward Radial flow Reaction turbine.

ii> Pelton wheel / Turgo Impluse wheel → Tangential flow Impluse turbine.

iii> Kaplan / Propeller → Axial flow Reaction t

iv> Modern Francis → Mixed Flow Reaction turb

Important units of hydropower plant: ↓ (2/9)



a> Surge Tank: ↓

Betn the reservoir & turbine house surge tank is provided inorder to minimize water hammer pressure problem in penstock. Surge tank also helps in maintaining constant head at turbin

b> Penstock: ↓

It is the pipe through which water is brought from reservoir or from surge tank to the turbine chamber. The pipe always takes head loss at the turbine

→ High [V_1 = 300 to 1000]
ex: Kaplan & propeller

→ Medium sp. speed [V_2 = 60 to 300

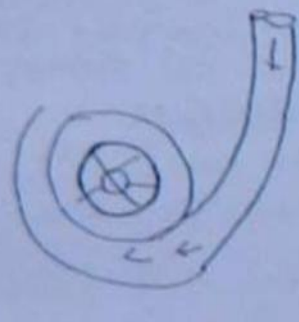
→ Low sp. speed [V_3 < 60 m/sec.
Ex: Pleton wheel

(218)

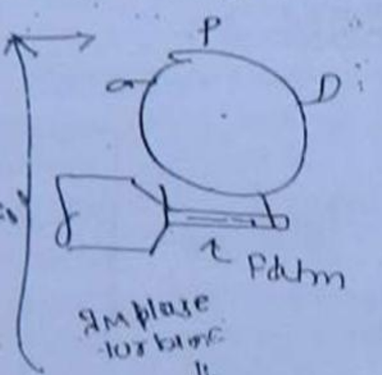
c> classification on the basis of available energy at the inlet of turbines

→ Reaction Turbine (Pressure Turbine) * at the inlet of turbine Energy available is pressure energy & K.E.

→ Impluse turbine (velocity turbine)
↳ only K.E. is available at the inlet & pressure is atmospheric



Ex:] Reaction turbine
- Propeller
- Francis T.
- Kaplan

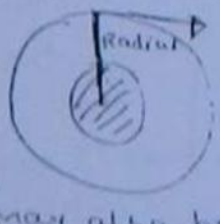


Impluse turbine
⇓
Ex: Pelton wheel
Turgo Impluse wheel

- Reaction turbnies have closed casing

d> classification on the basis of type of flow with in the turbine

→ Radial Flow
- Inward Radial flow → [Francis Turbines]
- outward Radial flow
↳ [centrifugal] pump, commonly but some turbines may also be design



→ Tangential Flow (Parallel Flow) → Ex: (a) [Pleton wheel] (b) Turgo Impluse wheel

→ Axial Flow → Ex: [Kaplan, propeller]

→ Mixed Flow
Ex: Modern Francis T. (water may enter in Radial dirn & may leave in axial direction)

Turbines

* used to convert hydraulic Energy into Mechanical Energy which is further converted into Electric Energy by Means of generators.
* It extracts Energy

Pumps / Fuel energy

* First electric Energy is converted into Mechanical Energy by Motor & Mech. Energy is converted into Pressure energy or Hydraulic Energy by pumps.
* It adds Energy.

Turbines:

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Energy
- → Thermal power plant ≃ 71 to 72%.
- → Hydral Power plant ≃ 23 to 24%.
- → Atomic " " ≃ 1.5 to 2%.
- → Minor
  - → Tidal Energy
  - → wind "
  - → Solar "
  - → Biogas "

Classification of Turbines:

a) classification on the basis of available head

- → High head Turbines { Suitable when H > 250 m }
  - Ex: Pelton wheel
  - Turgo Impluse wheel
- → Medium head Turbines { 60M ≤ H ≤ 250M }
  - Ex: Francies turbines.
- → Low head Turbines [H ≤ 60 M]
  - ex: Kaplan & prop Turbines.

$$\frac{x}{\cos\theta} \quad \ldots \quad \frac{L}{2}$$

$\hookrightarrow$ wt. of Plate

$$\therefore \left(\rho a v^2 \cos\theta\right)\left(\frac{x}{\cos\theta}\right) = W\left(\frac{L}{2}\sin\theta\right)$$

$$\therefore \boxed{\sin\theta = \frac{2\rho a v^2 . x}{WL}}$$

Special case:

When $x = L/2$ [Jet strikes on the C.G.

$$\therefore \boxed{\sin\theta = \frac{\rho a v^2}{W}}$$

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Prob. 1

A Jet of water of dia. 25 MM dia strikes to a 20cm square plates of uniform thickness with a vel. of 10 M/sec at the centre of the plate which is suspended vertically by a hinge on its top edge. The weight of the plate is 98.1 N/m. The Jet strikes normal to the plate. What Force must be applied at lower edge of plate so that plate is kept vertical. If the plate is allowed to deflect freely what will be the angle of defln with due to the force exerted by the Jet of water.

Ans: $\theta = 30°$. $F = 24.5$ N

Efficiency of Jet

$$\eta = \frac{\text{work-done/sec}}{\text{K.E./sec}}$$

$$\therefore \eta = \frac{\rho a V [V-u] \cdot u}{\frac{1}{2} \rho a V^3} = \frac{2 [Vu - u^2]}{V^2}$$

For Maxm. Efficiency of Jet, $\frac{d\eta}{du} = 0$ (215)

$$\therefore \frac{2}{V^2}[V-2u] = 0$$

$$\Rightarrow \boxed{u = V/2}$$ Imp

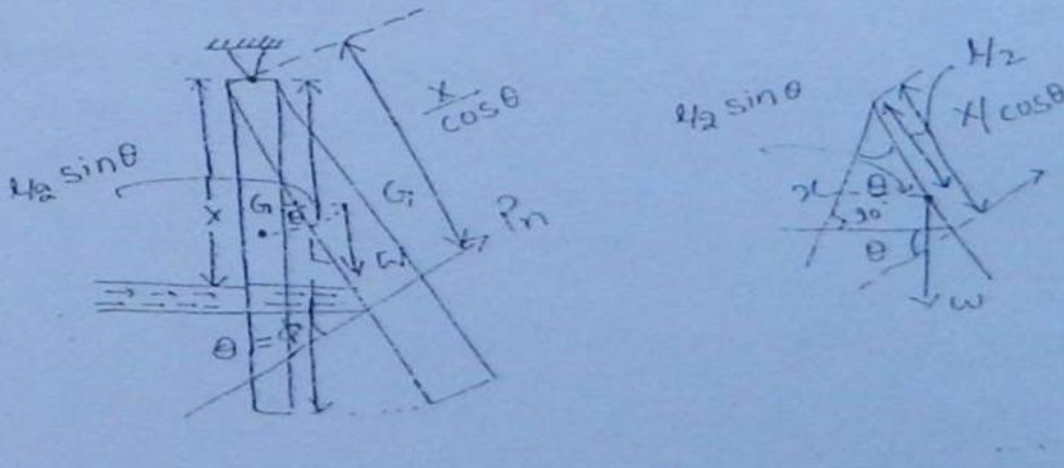
tangential vel. $= \frac{1}{2}$ J...

$$\therefore \eta_{Max} = \frac{2\left[V \times V/2 - (V/2)^2\right]}{V^2} = 0.5$$

$= 50\%$ Imp

NOTE: In above analysis vanes are flat & If va... are made curved than efficiency may b... further increased as in case of Platon...

Case VIII th. Jet of water strikes normal to a hang... vertical plate



$$P_n = \rho G [V\cos\theta - 0]$$

$$P_n = \rho a V^2 \cos\theta$$

$a \rightarrow$ area of Jet

$$= \rho Q$$

$$= \rho . a [V - u]$$

Force exerted by the jet on the plate

$$P_n = \rho . a (V-u) [V-u]$$

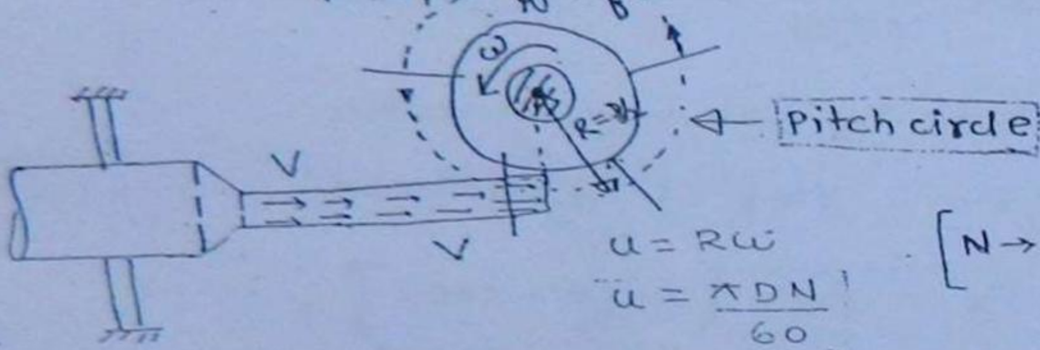
$$\boxed{P_n = \rho a (V-u)^2}$$

∴ Work-done per sec. by the Jet.

$$\boxed{W = \rho a (V-U)^2 \times u}$$

(2/4)

ase VIth: Jet strikes on a series of Vanes Mounted on a periphery of a wheel



$$u = R\omega$$

$$u = \frac{\pi D N}{60}$$

[N → R.P.M

Mass of water strikes the Vane / Per sec.

$$= \rho a V = \rho Q \qquad [Q = aV$$

Force exerted by Jet on Vane will be

$$= \rho a V [V - u]$$

$$= \rho a [V^2 - Vu]$$

Work-done by Jet Per sec. $= \rho a [V^2 - Vu] \times u$

$$= \rho a [V^2 u - u^2 V]$$

$$W = \rho Q [V - u] \times u$$

K.E / sec of Jet $= \frac{1}{2} \times$ Mass Flowing / sec $\times V^2$

$$= \frac{1}{2} \rho a V^3$$

Force exerted along the plate $= 0$

$$F = \rho Q V \cos\theta - \rho Q_1 V - (\rho Q_2(-V)) = 0$$

$$\Rightarrow \quad Q\cos\theta - Q_1 + Q_2 = 0 \quad \text{---(ii)}$$

By eqn (i) & (ii)

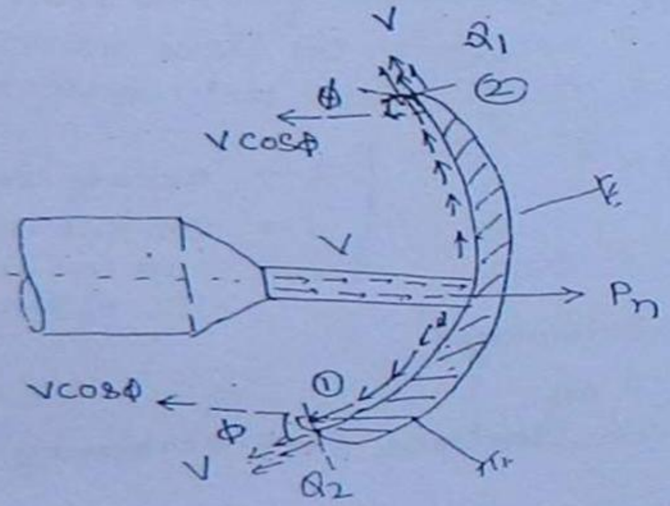
imp

$$Q_1 = Q/_2 [1+\cos\theta]$$
$$Q_2 = Q/_2 (1-\cos\theta)$$

(212)

$$\therefore \quad \frac{Q_1}{Q_2} = \frac{1+\cos\theta}{1-\cos\theta}$$ imp

case IIIrd: Force exerted by Jet on a stationary curve



Force exerted by Jet normal to the plate

$$P_n = \rho Q V - [\rho Q_1 (-V\cos\phi) + \rho Q_2 (-V\cos$$

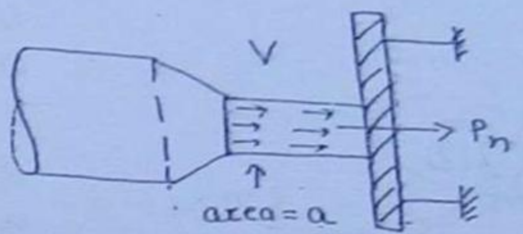
$$= \rho Q V + \rho Q \cdot V\cos\phi$$

$$\therefore \quad P_{n_1} = \rho Q V (1+\cos\phi)$$
$$P_n = \rho a V^2 (1+\cos\phi)$$

work done $= 0$

1.> Impact of JETS:

Case Ist: when Jet of water strikes normally to a stationa[ry] Flat plate



(211)

If Loss of energy due to impact is negligible & surfac[e] is smooth so that friction Loss is negligible, Force exer[ted] by the jet on the plate is

$$P_n = \rho Q \left[V - 0 \right]$$

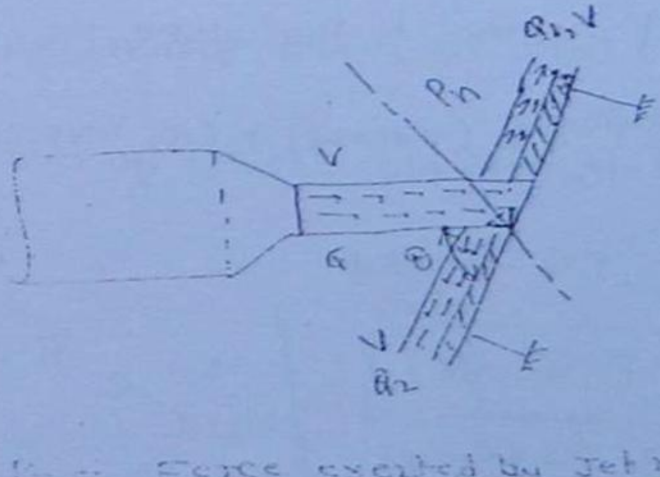
$$\boxed{P_n = \rho a V^2}$$

$\left[\begin{array}{l} a \rightarrow \text{area of Jet} \\ V \rightarrow \text{Initial velocit[y] in the directi[on] of flow} \end{array}\right.$

∴ work-done by the jet on plate = Zero.

[b'coz plate remains stationary]

Case IInd: Jet strikes on an Inclined Flat stationary pla[te]



P_n = Force exerted by Jet normal to plate

$= \rho Q \left[V \sin\theta - 0 \right]$

$\boxed{P_n = \rho a V^2 \sin\theta}$, [work-done = 0]

$y_{c2} = [q^2/g]^{1/3} = \left[\frac{(6)^2}{9.81}\right]^{1/3} = 1.542\ m$ **

$E_{c2} = 1.5\ y_{c2} = 1.5 \times 1.542 = 2.3136\ m$

$E_1' = E_{c2} = 2.3136$ with new u/s depth of y_1'

such that $q_1 = y_1' V_1' = 15/3.5$

$= 4.2857$ m...

$y_1' + \frac{V_1'^2}{2g} = 2.3136$

(210)

$y_1' + \frac{(4.2857)^2}{2 \times 9.81 \times y_1'^2} = 2.3136$

$\Rightarrow$ $\boxed{y_1' = 2.122\ m}$

NOTE: For the same discharge when $B_2 < B_{2m}$ (under choking conditions) the depth at critical section will be different from y_{cm} and depends upon value of B_2.

of 15.0 m³/sec. at a depth of 2.0m. It is proposed to reduce the width of the channel at a hydraulic structure. Assuming the transition to be horizontal and flow to be frictionless determine the water surface elevation U/s and D/s of the constriction when the constricted width is 2.50 m and 2.20m.

Step 1 Check for flow (subcritical or supercritical)

$\therefore F_1 = \frac{V_1}{\sqrt{g y_1}}$ $\left[V_1 = \frac{Q}{B_1 y_1} = \frac{15.0}{3.5 \times 2} = 2.143 \text{ m/sec} \right.$

$\therefore F_1 = \frac{2.143}{\sqrt{9.81 \times 2.0}} = 0.484 < 1$

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The U/s flow is subcritical and the transition will cause a drop in the water surface.

Step 2> $E_1 = y_1 + \frac{V_1^2}{2g} = 2.0 + \frac{(2.143)^2}{2 \times 9.81} = 2.234 \text{ m}$

Let B_{2m} = minimum width at section (2) which does not cause choking

than $E_{cm} = E_1 = 2.234 \text{ m}$

$\therefore y_{cm} = 2/3\, E_{cm} = 2/3 \times 2.234 = 1.489 \text{ m}$

But $y_{cm}^3 = \left[\frac{Q^2}{g B_{2m}^2} \right]$

$\Rightarrow B_{2m} = \left[\frac{Q^2}{g\, y_{cm}^3} \right]^{1/2} = 2.636 \text{ m}$

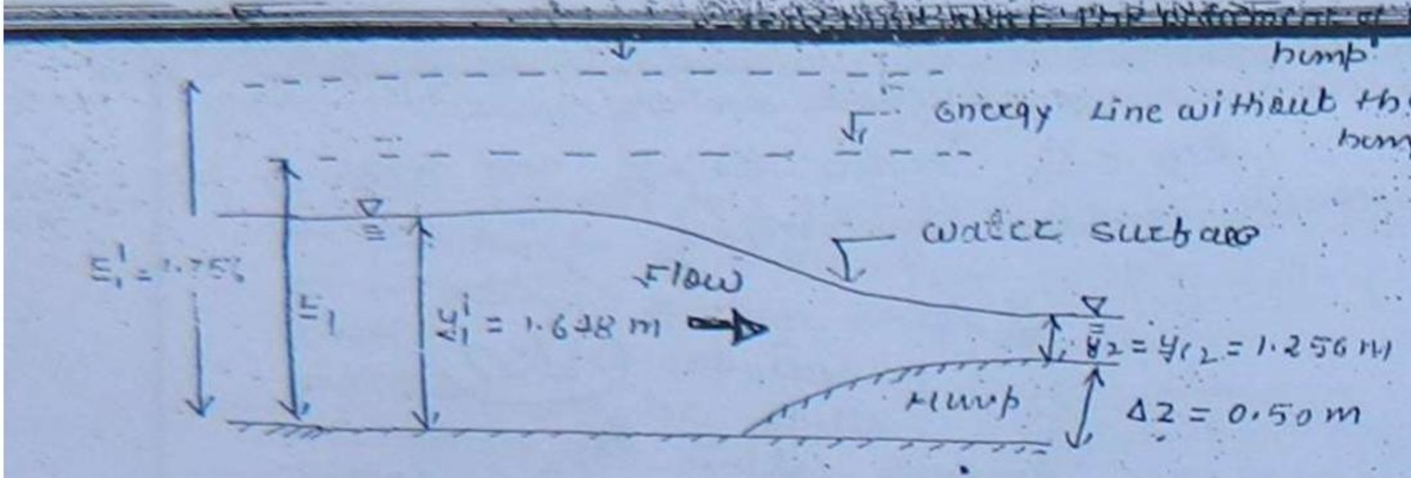
Step 3> Since $B_2 = 2.50 < B_{2m}$

Hence choking conditions would prevail

$\therefore$ The depth at section (2) = $y_{c2} = y_2$

$\therefore$ U/s depth y_1 will increase to y_1'

$q_2 = \frac{15.0}{B_2} = \frac{15.0}{2.5} = 6.0 \text{ m}^3\text{/sec/m}$



Prob2 A Rect. channel 2.5 m wide carries 6.0 m³/s of flow at a depth of 0.50 m. calculate the height of a flat topped hump required to be placed at a section to cause critical Flow. The energy Loss due to the obstruction by the hump can be taken as 0.1 times the U/s velocity head.

208

step 1>

$q = 6.0/2.5 = 2.4$ m³/sec/m

$V_1 = 2.4/0.5 = 4.8$ m/sec

$$Fr_1 = \frac{4.80}{\sqrt{9.81 \times 0.5}} = 2.167 > 1 \Rightarrow \text{U/s Flow is supercritical}$$

step2>

$$E_1 = 0.50 + \frac{(4.8)^2}{2 \times 9.81} = 1.674 \text{ m}$$

step3> since Flow at section (2) is critical

so $$y_c = (q^2/g)^{1/3} = \left[\frac{(2.4)^2}{9.81}\right]^{1/3} = 0.837 = y_2$$

Now $$\frac{V_c^2}{2g} = \frac{y_c}{2} = 0.419 = \frac{V_2^2}{2g}$$

∴ Applying Energy Equation b/w section (1) and (2)

$$E_1 - E_L = y_2 + \left(\frac{V_2^2}{2g}\right) + \Delta Z$$

↳ height of hump

$$E_L = 0.1 \frac{V_1^2}{2g} = 0.117 \text{ m}$$

$\Rightarrow 1.674 - 0.117 = 0.837 + 0.419 + \Delta Z$

$\Rightarrow$ $\boxed{\Delta Z = 0.301 \text{ m}}$

~~Since Min. sp. energy at section (2) ... then the~~ available Energy at that section

i.e. $E_{c2} < E_2$ hence $y_2 > y_c$ and depth y_1 will be remain unchanged.

step 4> calculation of depth y_2 **207**

$: E_2 = y_2 + \frac{v_2^2}{2g}$ $\left[v_2 = q/y_2\right.$

$\therefore E_2 = y_2 + \frac{q^2}{2g y_2^2}$ By trial & error me...

$1.615 = y_2 + \frac{(2.4)^2}{2 \times 9.81 \times y_2^2} \Rightarrow \boxed{y_2 = 1.481 m}$

(b) If the height of the hump is 0.5m. Estimate the water surface elevation on the hump and at a se... of the hump.

$V_1 = 1.50$ m/sec
$F_1 = 0.378 < 1$
$E_1 = 1.715$ m
$y_2 = y_{c2} = 0.837m$

Available sp. energy at section
$\Rightarrow E_2 = E_1 - \Delta Z$
$E_2 = 1.715 - 0.5 = 1.215 m$
$E_{c2} = 1.5 y_{c2} = 1.256m$

→ Since sp. energy at section (2) is greater than E_2 the available sp. Energy at that section.
Hence the depth at section (2) will be at the critical depth.
Hence $y_2 = y_{c2} = 1.256 m$
The U/s depth y_1 will increase to a depth y_1' so that new sp. energy at the U/s section 1 is

$E_1' = E_{c2} + \Delta Z$

$E_1' = y_1' + \frac{v_1'^2}{2g} = E_{c2} + \Delta Z$

$\Rightarrow y_1' + \frac{q^2}{2g y_1'^2} = 1.256 + 0.5 = 1.756$

$\Rightarrow y_1' + \frac{(2.4)^2}{2 \times 9.81 \times y_1'^2} = 1.756$

$\Rightarrow \boxed{y_1' = 1.648} \Rightarrow \boxed{y_1' > y_2}$

i) channel with hump: I

Probl (a) A Rect. channel has a width of 2.0 m and carr[ies] a discharge of 4.80 m³/sec with a depth of [1.6 m]. At a certain section a small, smooth hum[p] with a Flat top and of height 0.10m is proposed to be built. Calculate the Like[ly] change in the water surface. Neglect the Energy Loss.

Step (1) Determine the U/s Flow conditions i.e. wheth[er] Flow is subcritical or super critical.

$$q = \frac{4.80}{B} = \frac{4.80}{2.0} = 2.40 \; m^3/sec/m$$

$$V_1 = \frac{2.40}{1.6 = y_1} = 1.50 \; m/sec$$

$$F_1 = \frac{V_1}{\sqrt{g y_1}} = \frac{1.5}{\sqrt{9.81 \times 1.6}} = 0.378 < 1$$

[D = y_1 since channel is rectangular

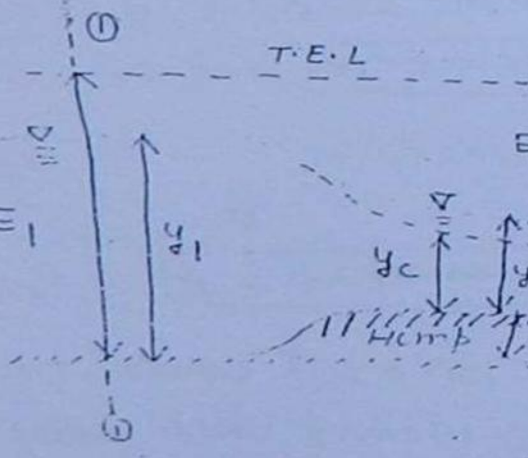
U/s Flow is subcritical so the hump will cause a drop in the water surface elevation.

step2)

$$E_1 = y_1 + \frac{V_1^2}{2g}$$

$$= 1.6 + \frac{(1.5)^2}{2 \times 9.81}$$

$$= 1.715 \; m$$



similarly at section (2)

$$E_2 = E_1 - \Delta Z$$

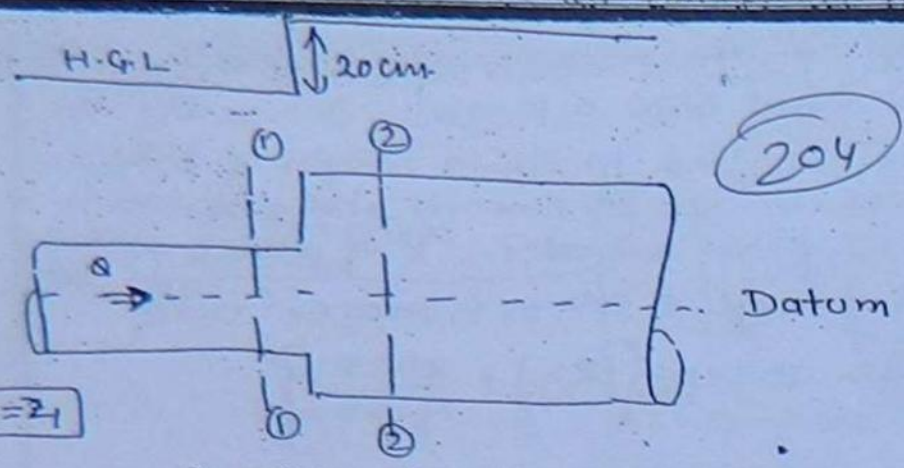
$$= 1.715 - 0.10$$

$$= 1.615 \; m$$

step3) check of the flow condition at section (2) is critical.

$$y_c = \left[\frac{q^2}{g}\right]^{1/3} = \left[\frac{(2.4)^2}{9.81}\right]^{1/3} = 0.837 \; m$$

$$E_c = 1.5 \, y_c = \ldots$$



(204)

$Z_2 = Z_1$

$D_1 = 0.5\,M \quad D_2 = 1.0\,m$

$$H.G.L \Rightarrow \left(\frac{p_2}{w} + Z_2\right) - \left(\frac{p_1}{w} + Z_1\right) = 0.2$$

$$\therefore \frac{p_2}{w} - \frac{p_1}{w} = 0.2\,M \quad \text{—— (1)}$$

Apply B. eqn b/w (1)-(1) & (2)-(2)

Head loss due to sodden expan…

$$Z_1 + p_1/w + \frac{V_1^2}{2g} = Z_2 + \frac{p_2}{w} + \frac{V_2^2}{2g} + \frac{(V_1 - V_2)^2}{2g}$$

$$\therefore \frac{p_2}{w} - \frac{p_1}{w} = \frac{V_1^2}{2g} - \frac{(V_1 - V_2)^2}{2g} - \frac{V_2^2}{2g}$$

$$0.2 = \frac{V_1^2}{2g} - \frac{V_1^2}{2g} - \frac{V_2^2}{2g} + \frac{2V_1V_2}{2g} - \frac{V_2^2}{2g}$$

$$\Rightarrow 0.2 = \frac{2V_1V_2 - 2V_2^2}{2g} \Rightarrow 2V_1V_2 - 2V_2^2 = 0.4 \times 9\ldots$$

$$\Rightarrow \boxed{V_1V_2 - V_2^2 = 0.2 \times 9\ldots}$$

$$V_1 = Q/A_1 = \frac{Q}{\frac{\pi}{4} D_1^2}$$

$$V_2 = Q/A_2 = \frac{Q}{\frac{\pi}{4} D_2^2}$$

⇓

$$\boxed{Q = 0.635\ M^3/sec}$$

→ To know direction of flow, know TE_1 & TE_2

If $TE_1 > TE_2$ than flow from (1)-(1) to…

S/1993

Water flows in a 80 mm pipe at Reynolds No. 80,0[illegible] The pipe is estimated to have a equivalent sand grain roughness of size 0.16 mm. Determine th[illegible] head loss expected in 500 m length of pipe. If pipe wear to act as smooth pipe, how mu[illegible] head loss may be expected. ν of water $= 10^{-6}$[illegible]

The following explicit eqn of f may be used

$$\frac{1}{\sqrt{f}} = 1.14 - 2\log_{10}\left[\left(K/d\right) + \frac{21.25}{Re^{0.9}}\right]$$

where K = Equivalent sand grain roughness =[illegible]

d = dia. of pipe = 80 mm

Re = Reynolds No. = 80,000

L = 500 m

203

$$Re = \frac{Vd}{\nu} \Rightarrow V = \frac{80{,}000 \times 10^{-6}}{0.08} = 1\ \text{m/sec.}$$

For Rough pipe ↓

$$\frac{1}{\sqrt{f}} = 1.14 - 2\log_{10}\left[\left(\frac{0.16}{80}\right) + \frac{21.25}{(80{,}000)^{0.9}}\right]$$

$\Rightarrow f = 0.0257$

$\therefore$ Head Loss $= \frac{fLV^2}{2gD} = 8.15$ m

For smooth pipe ↓ $\boxed{K=0}$

$$\frac{1}{\sqrt{f}} = 1.14 - 2\log_{10}\left[\frac{21.25}{(80{,}000)^{0.9}}\right]$$

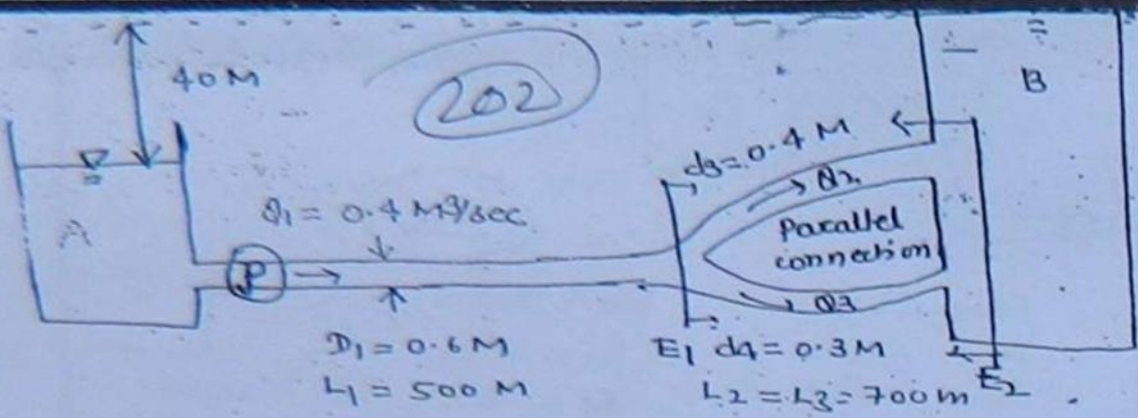
$\therefore f = 0.0187$

$\therefore$ Head Loss $= \frac{8.15}{0.0257} \times 0.0187 = 5.96$ m.

[illegible]

A horizontal pipe having diameter of 0.5 m expends at a junction to one meter pipe ha[illegible] straight length. If hydraulic gradeline at junct[illegible] rises by 20 cm. Find the flowrate in the pipe.

(202)



$\boxed{h_{f_2} = h_{f_3}}$

$$\therefore \frac{f L Q_2^2}{12.1\, D_2^5} = \frac{f L Q_3^2}{12.1\, D_3^5} \Rightarrow \frac{Q_2^2}{Q_3^2} = \left(\frac{D_2}{D_3}\right)^5 = (4/3)^5$$

$$\therefore Q_2/Q_3 = \sqrt{4.21} \quad \text{— i)}$$

$$Q_2 + Q_3 = 0.4 \quad \text{— ii)}$$

$$\Leftarrow \left.\begin{aligned} Q_2 &= 0.268 \\ Q_3 &= 0.13 \end{aligned}\right\}$$

Total head added by the pump $\left[P = 309\ \text{K}\right.$

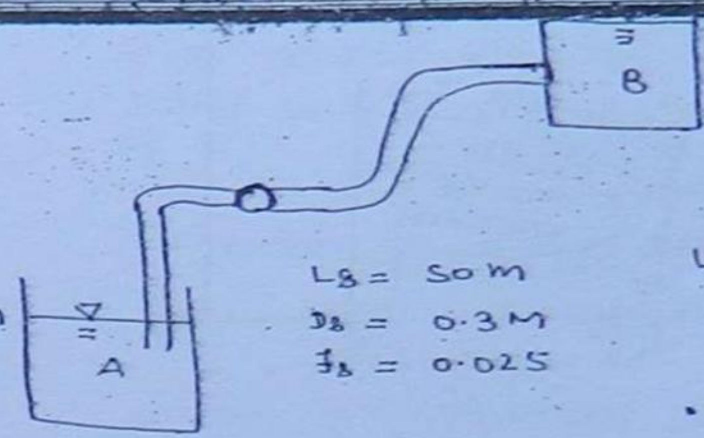
$= 40 + h_L$

NOTE: Head added by the pump is $h_s + h_{f_1} + (h_{f_2} \neq h_{f_3})$
(40) (9.87)
However $h_{f_2} = h_{f_3}$

~~Prob 6~~ (E.S 2004) A town of 2 Lakh population is to be suppl[ied] water from a source, 2500 M away. Th[e] Lowest water Level in the source is 15 M b[elow] the water works of the town. The deman[d of] the water is estimated as 150 Lit/capital/da[y]. A pump of 300 H.P. is oprated for 15 H[ours] & if the Max^m demand is 150% of avg. d[emand] and velocity of flow through pipe is 1.[…] and Efficiency of the pump is 70%. Det[ermine] the H.G. and friction factor. [Determi[ne] $(P/\omega + Z)$ the total water required]

$$\boxed{P = \frac{\omega Q H_{added\ by\ the\ pump}}{\eta}} \quad \eta \rightarrow \text{Efficiency of pump}$$

EL = 150m



EL = 100M

(201)

$L_s = 50\,m$ $\quad$ $L_d = 900\,M$

$D_s = 0.3\,M$ $\quad$ $D_d = 0.2\,M$

$f_s = 0.025$ $\quad$ $f_d = 0.02$

Head added by the pump.

$$H_p = \text{static head} + h_{fs} + h_{fd}$$

$$= (150-100) + \frac{f_s \cdot L_s Q^2}{12.1 D_s^5} + \frac{f_d \ldots}{12 \ldots}$$

$$\therefore h_{fs} = \frac{0.025 \times 50 \times Q^2}{12.1 \times (0.3)^5} = 42.5\,Q^2$$

$$h_{fd} = \frac{0.02 \times 900 \times Q^2}{12.1 \times (0.2)^5} = 4648.76\,Q^2$$

$$\therefore H_p = 50 + 42.5\,Q^2 + 4648.76\,Q^2$$

$$= 50 + 4691.26\,Q^2 = 80 - 7000\,Q^2$$

$$\therefore Q = 0.05\ M^3/sec$$

$$\therefore H_p = 80 - 7000 \times (0.05)^2$$

$$= 62.5\ m$$

$\therefore$ Power $= wQH_p$

Prob: Two reservoirs A & B are connected through a system, consisting of one 60 cm pipe having 500M L… which branches thereafter into two pipes of 40cm dia. & 30 cm dia. each 700 M Long… pump situated near reservoir A discharg… 0.4 M3/sec through the pipe system. The difference in the reservoir level is such that reservoir level B is 48 M above than Level A. Assuming $f = .02$ determine… power required for the pump. Assumi… efficien…

15. University Question papers of previous year

USN www.vtu.us **10CV45**

Fourth Semester B.E. Degree Examination, Dec.2014/Jan.2015

Hydraulics and Hydraulic Machines

Time: 3 hrs. Max. Marks:100

Note: *1. Answer any FIVE full questions, selecting atleast TWO questions from each part.*
2. Missing data may suitably assumed.

PART – A

1 a. The efficiency η of a fan depends on density ρ, dynamic viscosity μ of the fluid, angular velocity ω, diameter D of the rotor and discharge Q. Express η as
$\eta = f\left[\frac{Q}{\omega D^3}, \frac{\mu}{\rho\omega D^2}\right]$. **(08 Marks)**

b. Derive different scale ratio's as per Reynold's model law. **(06 Marks)**

c. A flow meter tested in the laboratory, gave a pressure drop of 200kN/m^2 for a discharge of 0.2m^3/s in 200mm diameter pipe. If a geometrically similar model is tested in 1000mm diameter pipe at identical conditions of fluid, determine the corresponding discharge and pressure drop in the model. **(06 Marks)**

2 a. Distinguish between: Pipe flow and open channel flow. **(06 Marks)**

b. Derive the Chezy's equation for uniform flow in open channel with usual notations. **(07 Marks)**

c. A canal is to have a trapezoidal section with one side vertical and the other sloping at 60° to the horizontal. It has to carry water at 30m^3/s with mean velocity 2 m/s. Compute the dimensions of the section which will require minimum lining. **(07 Marks)**

3 a. Define specific energy. Explain specific energy curve (sketch). **(06 Marks)**

b. A horizontal rectangular channel 4m wide carries a discharge of 16m^3/s. If the initial depth of flow is 0.5m, determine is there a possibility of formation of hydraulic jump? If the jump forms, determine the sequent depth, Froude number after jump and energy loss. **(06 Marks)**

c. Give the classification of surface profiles in case of GVF. **(08 Marks)**

4 a. Show that the efficiency of a jet striking a series of flat vanes mounted on the periphery of a circular wheel is maximum when the jet velocity is double of vane velocity and maximum efficiency is 50%. **(10 Marks)**

b. A jet of 30mm radius strikes normally on a fixed plate, with a velocity of 35m/s. Calculate the force exerted by the jet on the plate. If the plate is moving with 15 m/s in the direction of the plate, find the efficiency of the jet. **(10 Marks)**

1 of 2

PART – B

5 a. Derive an equation of force exerted by a jet on an unsymmetrical curved vane tangentially, when vane K moving in the x-direction. Draw the velocity triangles and explain. Also find the workdone and efficiency. **(10 Marks)**

b. A jet of water with velocity 40m/s strikes a curved vane, which is moving with velocity 20m/s. The jet makes an angle of 30° with the direction of motion of vane at inlet and leaves at an angle of 90° to the direction of motion of vane at outlet. Draw the velocity triangles at inlet and outlet and determine the vane angles at inlet and outlet so that the water enters and leaves the vane without shock. **(10 Marks)**

6 a. Give the classification of turbine with examples. **(10 Marks)**

b. Design a Pelton wheel turbine required to develop 1471.5 kW power under a head of 160m at 420 rpm. The overall efficiency may be taken as 85%. Assume C_v = 0.98, c_u = 0.46, jet ratio = 12. **(10 Marks)**

7 a. Define draft tube. What are its functions? **(06 Marks)**

b. What is cavitation? How to eliminate it? **(06 Marks)**

c. A Kaplan turbine runner is to be designed to develop brake power of 7350kW, under a head of 5.5m. Diameter of bass is 1/3rd of diameter of runner. Assuming speed ratio = 2.09, flow ratio = 0.68, calculate: i) diameter of runner and boss; ii) speed of runner. Take η_0 = 85%. **(08 Marks)**

8 a. Define:

i) Manometric efficiency

ii) Mechanical efficiency

iii) Overall efficiency. **(06 Marks)**

b. Derive an expression for minimum starting speed of a centrifugal pump. **(06 Marks)**

c. The internal and external diameters of the impeller of a centrifugal pump are respectively 200mm and 40mm. The pump is running at 1200rpm. The vane angles of the impeller at inlet and outlet are 20° and 30°. Water enters radially and velocity of flow is constant. Determine the workdone by the impeller per unit weight of water. **(08 Marks)**

* * * * *

16. Question Bank

Unit-1

1. What is open channel flow?.

2. Differentiate between open channel and pipe flow.

3. Derive various economic sections.

4. Dynamic equation for G.V.F, mild, critical, steep slope.

5.Derive critical depth for various sections?

Unit-2

1. Derive rayleighs, buckinghams pi theorem methods?

2. Derive dimensionless numbers for various formulaes.

3. Model and prototype relations

Unit-3

1. Derive the formulaes for impact on jets for inclined, straight etc.

2. Forces on inclined moving plate, flat stationary plate.

3. Draw the velocity diagrams for jet striking centrally curved symmetrical plate.

4. Work done and Efficiency of flow over radial plate.

5. What is a surge tank? What is the purpose of it? Describe various types of surge tanks

6. Define i) Firm power and secondary power ii) Load factor, Utilization factor and Capacity factor.

7. Describe how hydro power plants are classified into different types based on various criteria.

8. What is intake? Explain different types of intakes with neat sketches

9. Enumerate different elements of hydro electric power station and draw its layout.

Unit-4

1. Describe briefly about the classification of water turbines.

2. Explain the terms unit speed, unit discharge and unit power of a turbine and explain their importance.

3 .A pelton wheel operates with a free jet of 150mm diameter under the head of 500m. Its mean runner diameter is 2.25m and it rotates with a speed of 375 rpm. The angle of bucket tip at outlet is 15^0 coefficient of velocity is 0.98, mechanical losses equal to 3% of power supplied and the reduction in relative velocity of water while passing through bucket is 15%. Find

i) The force of jet on the bucket ii) the power developed iii) bucket efficiency and iv) the overall efficiency.

4. Draw a neat sketch of Pelton wheel installation and briefly explain the functions of each component.

5. Describe the points of distinction between impulse turbine and reaction turbines.

Unit-5

1. Obtain the expression for the specific speed of a turbine

2 .What do you mean by characteristic curves of a turbine? Discuss about different operating characteristics of a turbine with neat sketches.

3. What is cavitations'? How to detect the cavitation? Explain how to avoid the cavitation.

4. A Kaplan turbine operates under a head of 15.2m, has a speed of 75rpm and develops 50MW of power. The overall efficiency of the turbine is 82%. Calculate the specific speed, unit speed, unit discharge and unit power.

5 .Explain the governing of turbines with a neat sketch.

6. The impeller of a centrifugal pump having external diameter and internal diameter 500mm and 250mm respectively, width at outlet 50mm and running at 1200 rpm works against a head of 48m. The velocity of flow through the impeller is constant and is equal to 3m/s. The vanes are back at an angle of 400 at outlet. Determine inlet vane angle, work done by the impeller on water per second and manometric efficiency.

7. Derive an expression for minimum outside diameter of an impeller to enable the pump to start at its normal speed.

8. Explain what are the different efficiencies of a centrifugal pump.

9. Describe multistage pump with (i) impellers in series and (ii) impellers in parallel with the aid of neat sketches.

10. Explain with neat sketches the volute and the diffuser pumps. What is the role of volute chamber of a centrifugal pump

17. Assignment topics

Unit-1: Problems on chezy's Mannings and bazin formulae. Most economical sections. Concept of critical depth, sub critical and super critical

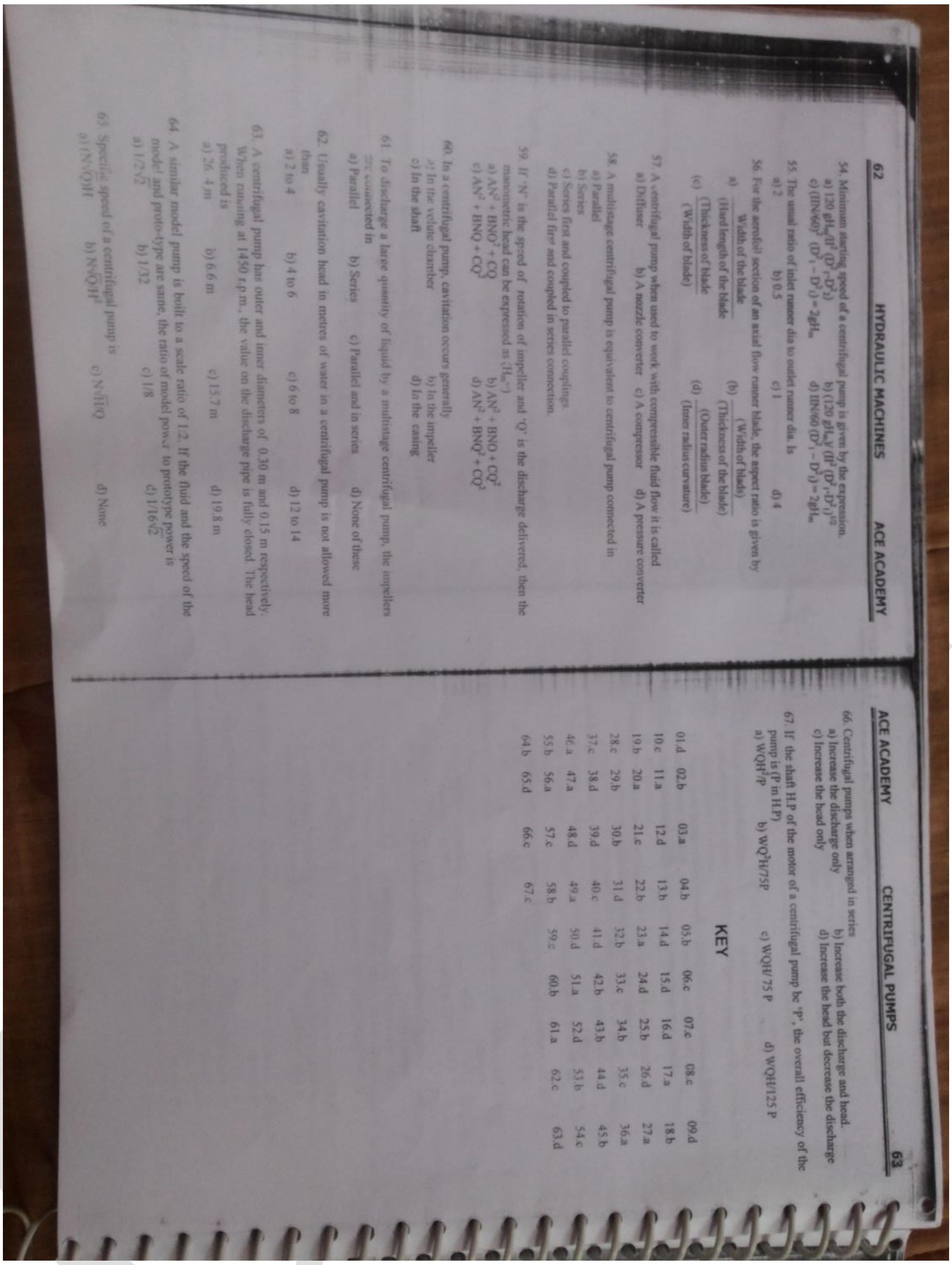
Unit-2: Derivation of Rayleighs , buckinghams pi theorm, problems on dimensional similitude.

Unit-3: Derivation of Impact on jets and its problems. Layout of Hydro Power plant.

Unit-4: Classification of turbines, differentiate between francis, pelton, Kaplan turbine, specific speed concept, cavitation and use of surge tank.

Unit-5: classification of pumps, efficiencies, specific speed of pump, NPSH cavitaion, load factor, capacity factor

18. Unit wise Quiz Questions



62 HYDRAULIC MACHINES ACE ACADEMY

54. Minimum starting speed of a centrifugal pump is given by the expression.
   a) $120\ gH_m/\Pi^2 (D^2_1 - D^2_2)$ b) $(120\ gH_m)/(\Pi^2 (D^2_1 - D^2_1))^{1/2}$
   c) $(\Pi N/60)^2 (D^2_1 - D^2_1) = 2gH_m$ d) $\Pi N/60 (D^2_1 - D^2_1) = 2gH_m$

55. The usual ratio of inlet runner dia to outlet runner dia. Is
   a) 2 b) 0.5 c) 1 d) 4

56. For the aerofoil section of an axial flow runner blade, the aspect ratio is given by
   a) $\frac{\text{Width of the blade}}{\text{(Hard length of the blade}}$ (b) $\frac{\text{(Width of blads)}}{\text{(Thickness of the blade)}}$
   (c) $\frac{\text{(Thickness of blade}}{\text{(Width of blade)}}$ (d) $\frac{\text{(Outer radius blade)}}{\text{(Inner radius curvature)}}$

57. A centrifugal pump when used to work with compressible fluid flow it is called
   a) Diffuser b) A nozzle converter c) A compressor d) A pressure converter

58. A multistage centrifugal pump is equivalent to centrifugal pump connected in
   a) Parallel
   b) Series
   c) Series first and coupled to parallel couplings.
   d) Parallel first and coupled in series connection.

59. If 'N' is the speed of rotation of impeller and 'Q' is the discharge delivered, then the manometric head can be expressed as $(H_m=)$
   a) $AN^2 + BNO^2 + CQ$ b) $AN^2 + BNO + CQ^2$
   c) $AN^2 + BNQ + CQ^2$ d) $AN^2 + BNQ^2 + CQ^2$

60. In a centrifugal pump, cavitation occurs generally
   a) In the volute chamber b) In the impeller
   c) In the shaft d) In the casing

61. To discharge a large quantity of liquid by a multistage centrifugal pump, the impellers are connected in
   a) Parallel b) Series c) Parallel and in series d) None of these

62. Usually cavitation head in metres of water in a centrifugal pump is not allowed more than
   a) 2 to 4 b) 4 to 6 c) 6 to 8 d) 12 to 14

63. A centrifugal pump has outer and inner diameters of 0.30 m and 0.15 m respectively. When running at 1450 r.p.m., the value on the discharge pipe is fully closed. The head produced is
   a) 26. 4 m b) 6.6 m c) 15.7 m d) 19.8 m

64. A similar model pump is built to a scale ratio of 1:2. If the fluid and the speed of the model and proto-type are same, the ratio of model power to prototype power is
   a) $1/2\sqrt{2}$ b) 1/32 c) 1/8 d) $1/16\sqrt{2}$

65. Specific speed of a centrifugal pump is
   a) $(N\sqrt{Q})H$ b) $N\sqrt{Q}/H^2$ c) $N\sqrt{H}/Q$ d) None

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66. Centrifugal pumps when arranged in series
   a) Increase the discharge only b) Increase both the discharge and head.
   c) Increase the head only d) Increase the head but decrease the discharge

67. If the shaft H.P of the motor of a centrifugal pump be 'P', the overall efficiency of the pump is (P in H.P)
   a) WQH^2/P b) $WQ^2H/75P$ c) $WQH/75\ P$ d) $WQH/125\ P$

KEY

01.d	02.b	03.a	04.b	05.b	06.c	07.c	08.c	09.d
10.c	11.a	12.d	13.b	14.d	15.d	16.d	17.a	18.b
19.b	20.a	21.c	22.b	23.a	24.d	25.b	26.d	27.a
28.c	29.b	30.b	31.d	32.b	33.c	34.b	35.c	36.a
37.c	38.d	39.d	40.c	41.d	42.b	43.b	44.d	45.b
46.a	47.a	48.d	49.a	50.d	51.a	52.d	53.b	54.c
55.b	56.a	57.c	58.b	59.c	60.b	61.a	62.c	63.d
64.b	65.d	66.c	67.c					

32. In a centrifugal pump the inlet angle will be designed to have
   a) Relative velocity vector in the radial direction
   b) Absolute velocity vector in the radial direction
   c) Velocity of flow to be zero.
   d) Peripheral velocity to be zero.

33. A fast centrifugal impeller will have
   a) Forward facing blades b) Radial blades
   c) Backward facing blades d) Propeller type blades

34. In a centrifugal pump the work done by the impeller is
   a) The manometric head b) Greater than manometric head
   c) Less than manometric head d) the manometric head loss or losses.

35. Which of the following defines the manometric head of a centrifugal pump
   a) Total height to which the liquid is lifted.
   b) Static head min V_s losses in the pump
   c) Difference of energy heads between the outlet of pump casing and the inlet of pump casing.
   d) None of the above.

36. The number of blades in a centrifugal pump impeller are usually
   a) 8 to 16 b) 16 to 24 c) 4 d) 6

37. Which of the following velocity components is zero at the inlet of a centrifugal pump impeller
   a) Velocity of flow b) Absolute velocity
   c) Whirl velocity d) Relative velocity

38. The Hydraulic machines subjected to cavitation are
   a) Impulse turbines
   b) Reaction turbines and impulse turbines
   c) Centrifugal pumps and impulse turbines
   d) Centrifugal pumps and reaction turbines.

39. Cavitation is caused by
   a) Low barometric pressure b) High pressure
   c) Low velocity d) Low pressure.

40. In centrifugal pumps, for the vapour pressure consideration, select the incorrect statement.
   a) The diameter of suction side is kept usually more than the discharge side
   b) The suction head is limited to 6 to 8 metres.
   c) The minimum pressure generally occurs along the concave side of vanes near the low pressure side of the impeller
   d) On set of cavitation is due to higher rotational speeds, restricted suctions and higher temperature of liquid.

41. A centrifugal pump w hen used to work with compressible fluid is called
   a) A fan b) A blower c) A compressor d) All of the above.

42. The partial vacuum created near the impeller centre of a centrifugal pump is called
   a) Diffusion zone b) Eye of the impeller
   c) Vortex chamber d) Whirl pool chamber

43. In a cenrifugal pump impeller, straight radial blades are used to handle
   a) Non-Viscous liquids b) Dustly liquids c) Oils d) Water

44. Manometric head of a centrifugal pump is given by
   a) $h_s + h_{fs} + h_d + h_{fd} + V^2_d/2g$ b) Work done per kg of water losses with in the impeller.
   c) $V_{w2}\,U_2/g$ for no. losses d) All of the above.

45. Manometric efficiency of a centrifugal pump is given by
   a) $2gH_m/V_{w2}\,U_2$ b) $gH_m/V_{w2}U_2$ c) $V_{w2}U_2/gH_m$ d) $V_{w2}U_2/2gH_m$

46. Mechanical efficiency of a centrifugal pump is given by
   a) $(V_{w2}U_2/g)/$S.H.P. b) S.H.P/ $(V_{w2}U_2/g)$ c) S.H.P/H_m d) H_m/S.H.P.

47. Horse power required to drive a centrifugal pump shaft is given
   a) $(W.Q.H_m/75)\,\eta_o$ b) $75\,\eta_o/W.Q\,H_m$
   c) η_o/WQH_m d) $\dfrac{\eta_{mech}}{V_{w2}\,U_2/g}$

48. Euler's head for a centrifugal pump is
   a) $V_{w2}U_2/g$ b) The head imparted to the liquid by the impeller
   c) The workdone per second per kg of liquid. d) All of the above.

49. If H_i is the head imparted to the liquid by the pump impeller with finite number of blades and H_e be the Euler's head then vane efficiency is given by
   a) H_i/H_e b) H_e/H_i c) H_e+H_i d) $H_e.\,H_i$

50. For maximum efficiency the lease practicable value for outlet vane angle of a centrifugal pump vane is
   a) 60° b) 90° c) 45° d) 20_o

51. For 100% vane efficiency, manometric efficiency of a centrifugal pump is
   a) Equal to the hydraulic efficiency b) Less than the hydraulic efficiency
   c) Greater than the hydraulic efficiency d) None of the above.

52. Loss of head due to shock (varied discharge) at entrance of the impeller of a centrifugal pump
   a) $(U + V\cot\theta)^2/g$ b) $(U + V\cot\theta)/g$
   c) $U - (V\cot\theta)^2/g$ d) $(U - V\cot\theta)^2/2g$

53. The angle of divergence for the enlarging section of a volute casing
   a) Shall not be $> 20^\circ$ b) Shall not be $> 10^\circ$ c) Shall be 0° d) Shall be 45°

10. The pressure in the suction pipe is
a) above atmospheric b) atmospheric
c) Below atmospheric d) none of the above.

11. The impeller that are more efficient and suitable for pumping relatively pure liquids are
a) Shrouded impellers b) Semi open impellers
c) Open impellers d) None of the above.

12. The foot valve of a centrifugal pump
a) Is a non return valve b) Is a lower end of suction pipe
c) Is lower end of delivery pipe d) Both a and b are correct.

13. The first operation of a centrifugal pump is
a) Governing b) Priming c) Fuelling d) None of the above.

14. Pickup the correct statement. The centrifugal pump should be installed above the water level in the sump such that
a) Its height is not allowed to exceed 6.7 m
b) The negative pressure do not reach as low a value as the vapour pressure
c) Its height is not more than 10.3 m at ordinary temperature of liquid.
d) Both a and b are correct.

15. Pickup the correct statement Pertaining to centrifugal pump installation.
a) The suction pipe has larger dia as compared to the discharge pipe.
b) The suction pipe is provided with a foot valve and a strainer.
c) The discharge control valve is fitted in the delivery pipe.
d) All are correct.

16. The purpose of priming is to
a) Drive out water from sump
b) Fill the suction pipe with water
c) Fill the delivery pipe with water
d) Drive out air or gas or vapour from suction pipe, casing and part of delivery valve.

17. The pressure at the 'eye' of the impeller is
a) Partial vacuum b) Atmospheric
c) Above atmospheric d) none of the above.

18. In a centrifugal pump water enters the impeller
a) Axially b) Radially c) Taugentially d) None

19. When guide vanes are installed in a centrifugal pump, it is called
a) Volute casing pump b) Turbine pump
c) Multi stage pump d) Double inlet pump

20. A "turbine pump" is
a) A diffuser vane pump b) A single volute pump
c) A double volute pump d) A variable speed pump

21. "Spiral shaped casing" is provided for
a) Turbine pump b) Diffuser pump c) Volute pump d) none

22. A multi stage pump consists of
a) Two or more pumps b) Two or more impellers
c) Two or more suction pipes d) Two or more delivery pipes.

23. A centrifugal pump is basically a
a) Radial flow pump b) Axial flow pump
c) Mixed flow pump d) Tangential flow pump

24. Pickup the correct statements:
a) Mixed flow pumps are generally used where a large quantity of liquid is to be discharged to low heights.
b) Axial flow pumps are usually designed to deliver very large quantities of liquid at relatively low heads.
c) A double suction pump neutralize the axial thrust on the impeller.
d) All are correct.

25. For deep wells and mines, it is better to provide the shaft
a) Horizontally b) Vertically c) Inclined d) Curvilinearly

26. Pickup the correct pair of the following:

Type of pump		Total Head
a) Low head	:	0 to 15 m
b) Medium head	:	15 to 40 m
c) High head	:	40 m

d) All are correct

27. 'Static head is' is
a) $h_0 + h_d$ b) $h_s + h_d + h_{fs}$ c) $h_s + h_d + h_{fs} + h_{fd}$ d) $h_s - h_d$

28. The 'Mano metric head is the
a) Difference in elevation between the water surface in the high level reservoir and the water level in the pump
b) The height to which water is lifted the pump
c) The difference in piezometric heads between the points on the delivery and suction pipes as close to the pump as possible.
d) Head developed by the pump.

29. The work done by the impeller of a centrifugal pump on water per second per unit weight of water is given by ('2' represents outlet '1' represents inlet).
(a) $\frac{V_{w1}U_1}{g}$ (b) $\frac{V_{w2}U_2}{g}$ (c) $\frac{V_{w2}U_2 - V_{w1}U_1}{g}$ (d) None

30. The inlet velocity triangle for a centrifugal pump is generally
a) An acute angled triangle b) Right angle triangle
c) Obtuse angled triangle d) Straight line

31. The work done by the impeller of a centrifugal pump is
a) Independent of inlet radius b) Dependent on inlet radius
c) Dependent on outlet radius d) both a and C are correct.

$\therefore NPSH = P_a/W - V_s^2/2g - h_s - h_{fs} - P_v/W + V_s^2/2g$

$$NPSH = \frac{P_a - P_v}{W} - h_s - h_{fs}$$

But R.H.S is the total suction head

$$H_{sv} = \frac{P_a - P_v}{W} - h_s - h_{fs}$$

$\therefore NPSH = H_{sv}$ i.e. Total suction head

$\therefore$NPSH is the head required to make the liquid flow through the suction pipe into the impeller.

20. **Cavitation in Centrifugal Pumps:**

If the pressure at the suction side of the pump drops below the vapour pressure of the liquid then cavitation may occur.

Cavitation in a centrifugal pump results in sudden drop of head and efficiency.

$$\text{Thomas's cavitation factor} = \frac{(H_{atm} - H_v) - (h_s + h_{fs})}{H_m}$$

$$= \frac{NPSH}{H_m} = \frac{H_{sv}}{H_m}$$

H_{atm} = atm. pr. head,
H_v = vapour pr. head,
h_s = suction head,
h_{fs} = head loss in suction,
H_m = manometric head,
H_{sv} = total suction head,
N_s = sp. speed.

Critical τ = $0.103\,(N_s/1000)^{4/3}$

"When hot liquids are to be pumped the pumps have to be installed at liquid surface or even below the liquid surface"

In first case $h_s = 0$, in second case $h_s \le 0$ indicating that there is +ve pr. at pump inlet.

Suction specific speed:

$S = N\sqrt{Q} \quad = (N_s/g)^{4/3}$

$H_{sv}3/4$

Range of 'S' for cavitation free operation of C.P. and propeller pumps.

S = 4700 to 6700

$$S = \frac{r.p.m\,(l.p.s)^{1/2}}{m^{3/4}}$$

Cavitation due to min. pr. occurs along the convex side of vanes near the impeller.

CENTRIFUGAL PUMPS
OBJECTIVES

1. A centrifugal pump is a
   a) Turbo machine b) Rotodynamic machine
   c) Positive displacement pump d) both a and b

2. In case of centrifugal pumps the energy imparted to the liquid (increases of pressure) is due to
   a) Centrifugal action alone b) Change of angular momentum also
   c) Positive displacement d) None of the above.

3. The action of centrifugal pump is
   a) Reverse of radially in ward flow reaction turbine
   b) Reverse of propeller turbine
   c) Reverse of mixed flow turbine
   d) None

4. A centrifugal pump is a hydraulic machine which converts.
   a) Hydraulic energy to mechanical b) Mechanical energy to pressure energy
   c) Mechanical energy to electrical energy d) none

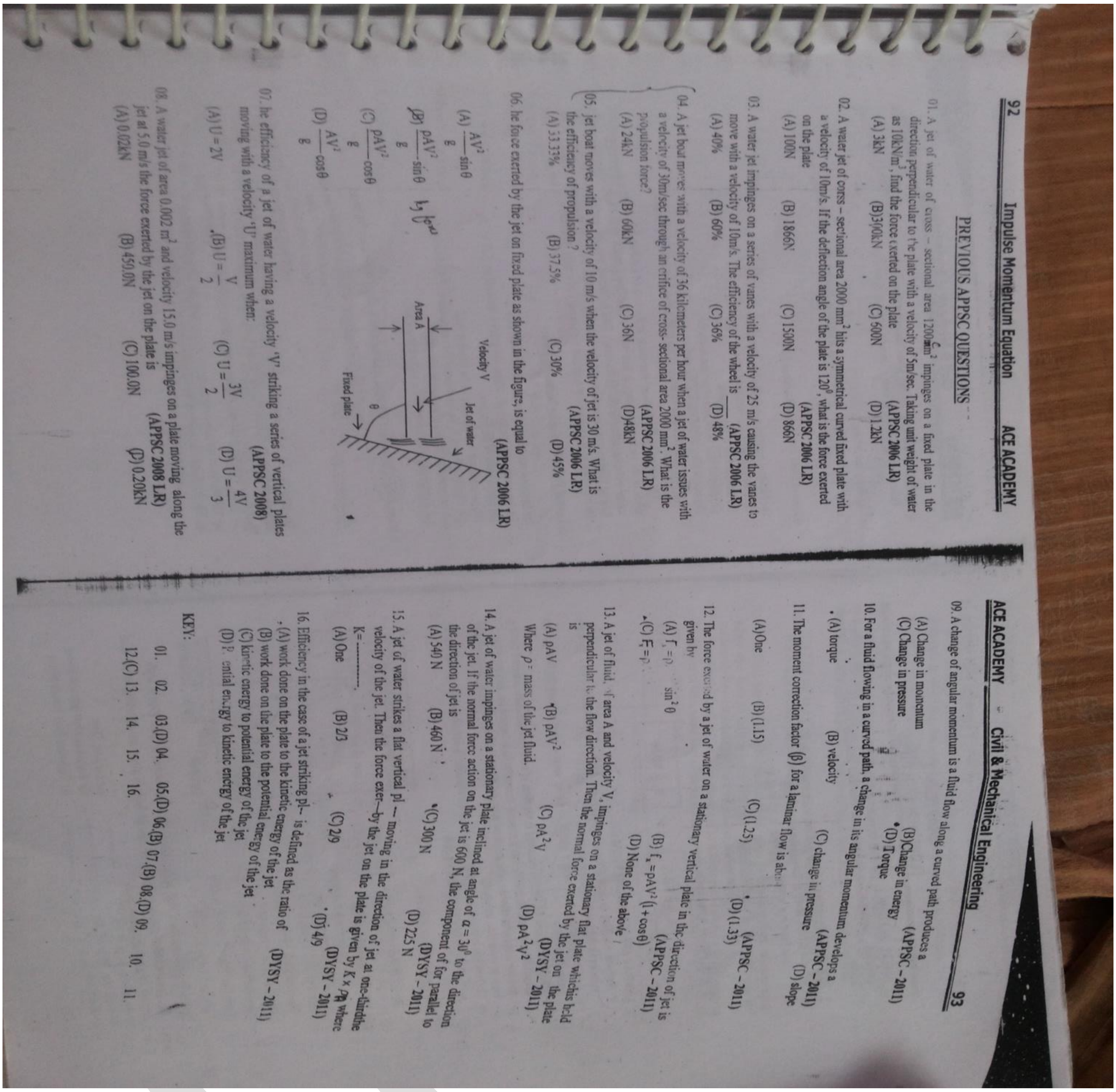
5. A centrifugal pump converts
   a) Electrical energy to mechanical energy
   b) Kinetic energy to pressure energy
   c) Pressure energy to kinetic energy
   d) mechanical energy to electrical energy.

6. The motion that helps in the working of a centrifugal pump is
   a) Radial flow b) Free vortex flow
   c) Forced vortex flow d) Axial flow

7. The pipe which connects the sump and the inlet of the pump is called
   a) Delivery pipe b) Foot value
   c) Suction pipe d) none of the above.

8. Pickup the correct statement of the following:
   The hydraulic function of
   a) An impeller is to convert mechanical energy into hydraulic energy.
   b) A casing is to transform most of the kinetic energy to into pressure energy
   c) Both a and b are correct
   d) None

9. Pickup the incorrect statement
   a) The discharging capacity of a centrifugal pump is much greater than that of a reciprocating pump.
   b) Centrifugal pump can be used for lifting highly viscous liquids.
   c) Centrifugal pump can be operated at high speeds without any danger of separation and cavitation.
   d) Maintenance cost of centrifugal pump is very high.



20. Known gaps ,if any

--NONE--

21. References, Journals, websites and E-links

Text Books

1. Fluid mechanics and Hydraulic machines by Modi & Seth

2. Fluid mechanics and Hydraulic machines by Raj put

Reference Text Books

1. Fluid mechanics and fluid power engineering by D.S. Kumar

2. Fluid mechanics and machinery by D.Rama durgaiah.

3. Hydraulic machines by Banga & Sharma

4. Instrumentation for engineering Measurements by James W. Dally, William E. Riley,

Journals

1. International Journal of fluid mechanics
2. International Journal of numerical methods in fluids.
3. Annual Review of Fluid Mechanics
4. Journal of Fluid Mechanics
5. Physics of Fluids
6. European Journal of Mechanics B/Fluids
7. Journal of Turbulence

Websites

1. www.**ieee**fmhm.org/

http://www.efluids.com/

http://www.yahoo.com/Science/Engineering/Mechanical_Engineering/Fluid_Dynamics/

http://www.cfd-online.com/

22. Quality Control Sheets

EVALUATION SCHEME:

PARTICULAR	WEIGHTAGE	MARKS
End Examinations	75%	75
Two Sessionals	20%	20
Assignment	5%	5
TEACHER'S ASSESSMENT(TA)*	WEIGHTAGE	MARKS

*TA will be based on the Assignments given, Unit test Performances and Attendance in the class for a particular student.

23. Student List

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2	14R11A0103	BODAPATI ARVIND RAJ
3	14R11A0104	BODHASU MADHU
4	14R11A0105	BOLAGANTI YASHWANTH TEJA
5	14R11A0106	CHADA SHIVASAI REDDY
6	14R11A0107	D SATISH KUMAR
7	14R11A0108	E TEJASRI
8	14R11A0109	G DARSHAN
9	14R11A0110	GALIPELLI SRIKANTH
10	14R11A0111	GATTU MANASA
11	14R11A0112	GEEDI SRINIVAS
12	14R11A0113	GUNTUPALLY MANOJ KUMAR
13	14R11A0114	K ANJALI
14	14R11A0115	KASULA HIMA BINDU
15	14R11A0116	KASTHURI VINAY KUMAR
16	14R11A0117	KOPPULA KEERTHIKA
17	14R11A0118	KRISHNA VAMSHI TIPPARAJU
18	14R11A0119	MADDULA MANORAMA REDDY
19	14R11A0120	MALINENI VENKATA DILIP
20	14R11A0121	MANDA KUMIDINI
21	14R11A0122	MINNIKANTI NAGASAI GANESH BABU
22	14R11A0123	MOHD ABDUL WALI KHAN
23	14R11A0124	MOTUPALLI VENTAKA KIRAN
24	14R11A0125	MUDDETI HARI

25	14R11A0126	MUSHKE VAMSHIDAR REDDY
26	14R11A0127	NAGUNOORI PRANAY KUMAR
27	14R11A0128	NALLA UDHAY KUMAR REDDY
28	14R11A0129	P GAYATHRI
29	14R11A0130	PADALA SRIKANTH
30	14R11A0131	PASUPULATI SWETHA
31	14R11A0132	POLISETTY VINEEL BHARGAV
32	14R11A0133	PUNYAPU VENKATA SHRAVANI
33	14R11A0134	R DIVYA
34	14R11A0136	RAVULA VAMSHI
35	14R11A0138	S BARATH KUMAR
36	14R11A0139	S PRASHANTH REDDY
37	14R11A0140	S SAI RAGHAV
38	14R11A0141	SHAIK SHAMEERA
39	14R11A0142	SREEGAADHI SAICHARAN
40	14R11A0143	SRIRAM SURYA
41	14R11A0144	SUNKARI SHIVA
42	14R11A0145	VANAMALA SURENDER NIKITHA
43	14R11A0146	YADAVALLI PAVAN KUMAR

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3	14R11A0151	B. VIJAY
4	14R11A0152	B. KIRAN KUMAR
5	14R11A0153	B. SUNIL NAIK
6	14R11A0154	D. VENU CHARY
7	14R11A0155	D. VASANTHA KUMAR

8	14R11A0157	G. NIKHIL
9	14R11A0158	G. SANDEEP KUMAR
10	14R11A0159	G. CHARAN KUMAR
11	14R11A0160	J. HARISH KUMAR
12	14R11A0161	K.J. NANDEESHWAR
13	14R11A0162	K. SANTHOSH KUMAR
14	14R11A0163	K BHARATH KUMAR
15	14R11A0164	K ABHILASH
16	14R11A0165	K SAI KRISHNA
17	14R11A0168	MOHD. ABBAS
18	14R11A0169	M SRINIVAS
19	14R11A0170	N SANTHOSH
20	14R11A0172	OSA NITHISH
21	14R11A0173	P INDRA TEJA
22	14R11A0174	P NAVEEN KUMAR
23	14R11A0175	P BHARATH NARSIMHA REDDY
24	14R11A0176	P SURENDER
25	14R11A0177	R VIHARI PRAKASH
26	14R11A0178	S BHANU KISHORE
27	14R11A0179	SHAILESH KUMAR SINGH
28	14R11A0180	SYED OMER ASHRAF
29	14R11A0181	V SAI SHARATH
30	14R11A0182	Y VENKATA MOHAN REDDY

24. Group-Wise students list for discussion topics

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3	1	14R11A0104	BODHASU MADHU
4	1	14R11A0105	BOLAGANTI YASHWANTH TEJA
5	1	14R11A0106	CHADA SHIVASAI REDDY
6	1	14R11A0107	D SATISH KUMAR
7	2	14R11A0108	E TEJASRI
8	2	14R11A0109	G DARSHAN
9	2	14R11A0110	GALIPELLI SRIKANTH
10	2	14R11A0111	GATTU MANASA
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35	6	14R11A0138	S BARATH KUMAR
36	7	14R11A0139	S PRASHANTH REDDY
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38	7	14R11A0141	SHAIK SHAMEERA
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40	7	14R11A0143	SRIRAM SURYA
41	8	14R11A0144	SUNKARI SHIVA
42	8	14R11A0145	VANAMALA SURENDER NIKITHA
43	8	14R11A0146	YADAVALLI PAVAN KUMAR

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5	1	14R11A0153	B. SUNIL NAIK
6	1	14R11A0154	D. VENU CHARY
7	2	14R11A0155	D. VASANTHA KUMAR
8	2	14R11A0157	G. NIKHIL
9	2	14R11A0158	G. SANDEEP KUMAR
10	2	14R11A0159	G. CHARAN KUMAR
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27	5	14R11A0179	SHAILESH KUMAR SINGH
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