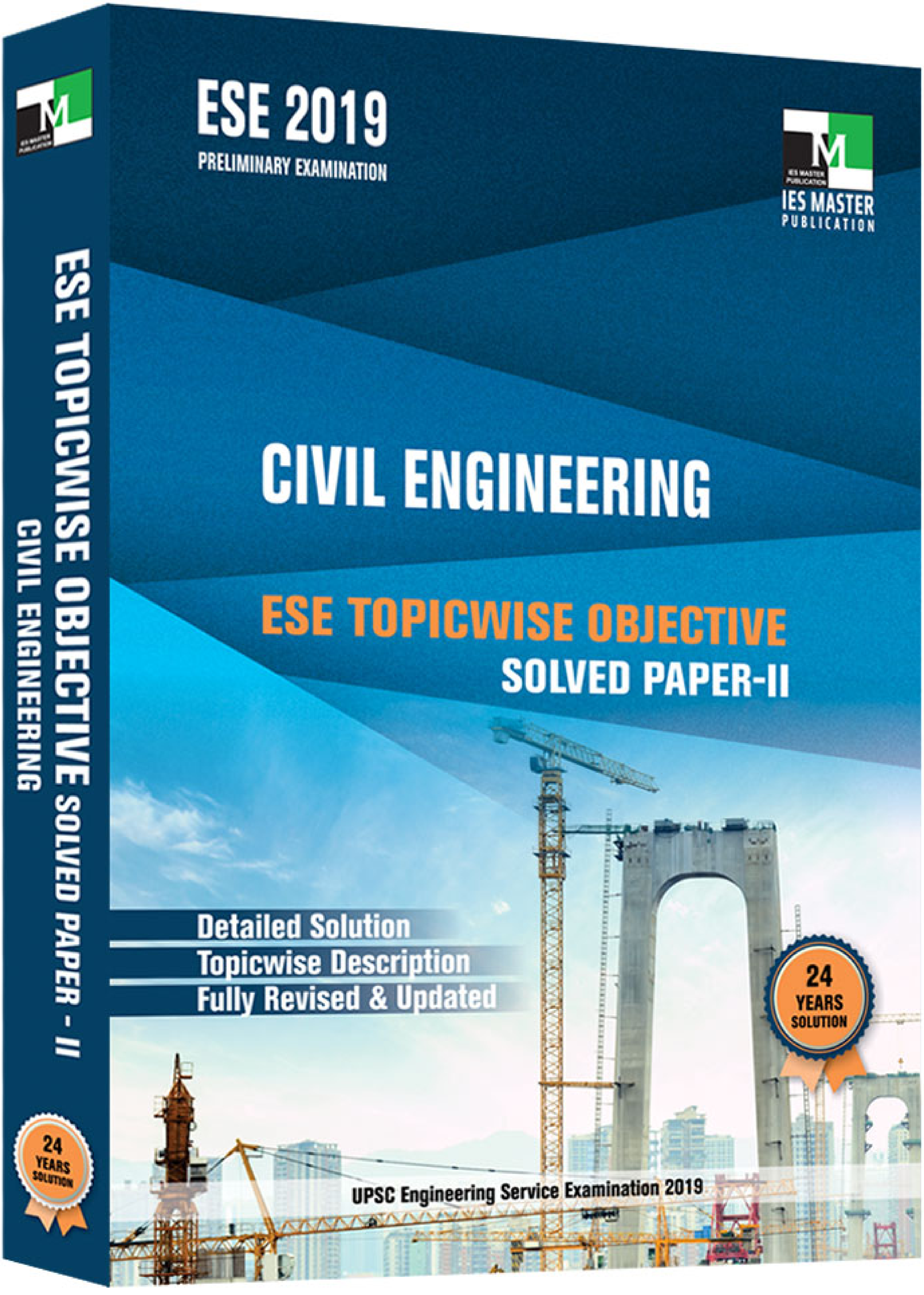
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Preface

It is an immense pleasure to present topic wise previous years solved paper of Engineering Services Exam. This booklet has come out after long observation and detailed interaction with the students preparing for Engineering Services Exam and includes detailed explanation to all questions. The approach has been to provide explanation in such a way that just by going through the solutions, students will be able to understand the basic concepts and will apply these concepts in solving other questions that might be asked in future exams.

Engineering Services Exam is a gateway to a immensly satisfying and high exposure job in engineering sector. The exposure to challenges and opportunities of leading the diverse field of engineering has been the main reason for students opting for this service as compared to others. To facilitate selection into these services, availability of arithmetic solution to previous year paper is the need of the day. Towards this end this book becomes indispensable.

Mr. Kanchan Kumar Thakur
Director–IES Master

CONTENTS

Fluid Mechanics

Unit 1

Syllabus

(A) FLUID MECHANICS, OPEN CHANNEL FLOW, PIPE FLOW

Fluid Properties, Pressure, Thrust, Buoyancy: Flow Kinematics; Integration of flow equations, Flow measurement: Relative motion; Moment of momentum, Viscosity, Boundary layer and Control. Drag, Lift; dimensional Analysis. Modelling, Cavitation; Flow oscillations- Momentum and Energy principles in Open channel flow, Flow controls, Hydraulic jump. Flow sections and properties, Normal flow. Gradually varied flow; Surges, flow development and losses in pipe flows. Measurements; Siphons, Surges and Water hammer; Delivery of Power Pipe networks.

(B) HYDRAULIC MACHINES AND HYDROPOWER

Centrifugal pumps, types, performance parameters, scaling, pumps in parallel; Reciprocating pumps, air vessels, performance parameters; Hydraulic ram; Hydraulic turbines, types, performance parameters, controls, choice; Power house, classification and layout, storage, poundage, control of supply.

Contents

Fluid Properties

IES-1997

1. Which one of the following pressure units represents the LEAST pressure?

(a) millibar (b) mm of mercury
(c) N/mm^2 (d) kgf/cm^2

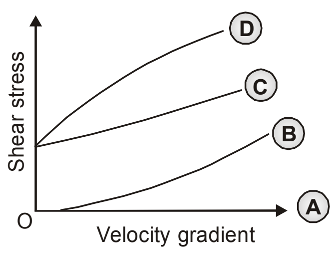
IES-1998

2. The surface tension of water at 20°C is 75 × 10^{-3} N/m. The difference in the water surface within and outside an open-ended capillary tube of 1mm internal bore, inserted at the water surface would nearly be

(a) 5 mm (b) 10 mm
(c) 15 mm (d) 20 mm

IES-1999

3. Match **List-I (curves labelled A, B, C and D in figure)** with **List-II (types of fluid)** and select the correct answer:

List-I	List-II
	**1.** Ideal plastic **2.** Ideal **3.** Non-Newtonian **4.** Pseudoplastic **5.** Thixotropic

Code:

	A	B	C	D
(a)	2	3	1	5
(b)	3	2	1	5
(c)	4	2	5	1
(d)	2	3	5	1

IES-2001

4. Match **List-I** with **List-II** and select the correct answer:

List-I	List-II
A. Concentrated sugar solution	**1.** Dilatant fluid
B. Sewage sludge	**2.** Bingham plastic fluid
C. Blood	**3.** Pseudoplastic fluid
D. Air	**4.** Newtonian fluid

Code:

	A	B	C	D
(a)	1	2	3	4
(b)	1	2	4	3
(c)	2	1	3	4
(d)	2	1	4	3

IES-2002

5. Match **List-I (Definitions)** with **List-II (Properties)** and select the correct answer

List-I	List-II
A. Newtonian fluid	**1.** Frictionless and incompressible
B. Ideal fluid	**2.** Viscosity invariant with shear stress
C. Thixotropic fluid	**3.** Viscosity decreases at higher shear stress
D. Rheological fluid	**4.** Viscosity increases at higher shear stress

Code:

	A	B	C	D
(a)	2	4	1	3
(b)	3	1	4	2
(c)	2	1	4	3
(d)	3	4	1	2

IES-2003

6. Which one of the following statements is correct?

(a) Dynamic viscosity of water is nearly 50 times that of air

(b) Kinematic viscosity of water is 30 times that of air

(c) Water in soil is able to rise a considerable distance above the groundwater table due to viscosity

(d) Vapour pressure of a liquid is inversely proportional to the temperature

7. Which of the following fluids can be classified as non-Newtonian?

1. Kerosene oil
2. Diesel oil
3. Human Blood
4. Toothpaste
5. Water

Select the correct answer using the codes given below :

(a) 1 and 2 (b) 3 and 4
(c) 2 and 5 (d) 1 and 5

IES-2004

8. **Assertion (A) :** At the standard temperature, the kinematic viscosity of air is greater than that of water at same temperature

Reason (R) : The dynamic viscosity of air at standard temperature is lower than that of water at the same temperature.

IES-2006

9. A flat plate of 0.15 m^2 is pulled at 20 cm/s relative to another plate, fixed at a distance of 0.02 cm from it with a fluid having $\mu = 0.0014\ Ns/m^2$ separating them. What is the power required to maintain the motion?

(a) 0.014 W (b) 0.021 W
(c) 0.035 W (d) 0.042 W

IES-2007

10. Which one of the following expresses the height of rise or fall of a liquid in a' capillary tube?

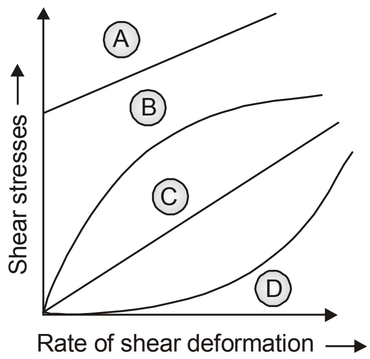
(a) $\dfrac{4wd}{\sigma \cos \alpha}$ (b) $\dfrac{\sigma \cos\alpha}{4\ w\alpha}$

(c) $\dfrac{4\sigma \cos\alpha}{wd}$ (d) $\dfrac{wd}{4\sigma \cos\alpha}$

w = Specific weight of the liquid
a = Angle of contact of the liquid surface
s = Surface tension

IES-2010

11. Match **List-I (Curve identification in figure)** with **List-II (Nature of fluid)** and select the correct answer using the codes given below the lists:'



List-I	List-II
A. Curve A	**1.** Newtonian
B. Curve B	**2.** Dilatant
C. Curve C	**3.** Ideal bingham plastic
D. Curve D	**4.** Pseudo-plastic

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	2	4	1	3
(c)	3	1	4	2
(d)	2	1	4	3

12. **Assertion (A) :** The movement of two blocks of wood welted with hot glue requires greater and greater effort as the glue is drying up.

Reason (R) : Viscosity of liquids varies inversely with temperature.

IES-2011

13. Which one of the following statements is correct?

(a) Local atmospheric pressure is always lesser than standard atmospheric pressure

(b) Local atmospheric pressure depends upon the elevation of the locality only

(c) Standard atmospheric pressure is at sea level

(d) A barometer reads the difference between local and standard atmospheric pressure

14. Poise has the unit of

(a) Dyne-cm/s^2 (b) Dyne-cm/s

(c) Dyne-s/cm (d) Dyne-s/cm^2

15. Which of the following statements is correct?

(a) Dynamic viscosity is the property of a fluid which is not in motion

(b) Surface energy is a fluid property giving rise to the phenomenon of capillarity in water

(c) Cavitation results from the action of very high pressure

(d) Real fluids have lower viscosity than ideal fluids

IES-2013

16. **Statement (I) :** As temperature increases, viscosity of air decreases.

Statement (II) : As temperature increases, activity of the air molecules increases.

17. **Statement (I):** Fluid pressure is a scalar quantity.

Statement (II): Fluid thrust always acts downwards.

IES-2015

18. The surface tension in a soap bubble of 50 mm diameter with its inside pressure being 2.5 N/m^2 above the atmospheric pressure is

(a) 0.0125 N/m (b) 0.0156 N/m

(c) 0.2 N/m (d) 0.0312 N/m

IES-2016

19. The surface tension of water at 20°C is 75 × 10^{-3} N/m. The difference in water surface within and outside an open-ended capillary tube of 1mm internal bore, inserted at the water surface, would nearly, be

(a) 7 mm (b) 11 mm

(c) 15 mm (d) 19 mm

20. Cavitation is likely to occur if

1. Pressure becomes very high
2. Temperature becomes low
3. Pressure at the specific points falls below vapour pressure
4. Energy is released with the onset of a high intensity wave due to noise and vibration of the machine.

Which of the above statements are correct?

(a) 1 and 3 (b) 2 and 3

(c) 3 and 4 (d) 2 and 4

21. **Statement (I):** The shear strain graph for a Newtonian fluid is linear.

Statement (II): The coefficient of viscosity μ of the fluid is not a constant.

IES-2017

22. Which of the following statements are correct?

1. Depression of mercury in a capillary tube is dependent on density and surface tension.
2. Modelling of flow-induced drag on a ship is done invoking both of Froude number 30. and Reynolds number.
3. Flow of a fluid in a narrow pipe is relatable to both Reynolds number and Cauchy number.
4. Formation and collapse of a soap bubble is analyzed through employing surface tension and external pressure.
5. Flow over the downstream slope of an ogee spillway can be affected by surface tension.

Select the correct answer using the codes given below:

(a) 1, 2 and 4 only (b) 1, 3 and 5 only

(c) 2, 3 and 4 only (d) 3, 4 and 5 only

IES-2018

23. **Statement (I) :** In areas where extreme cold conditions are a regular feature, and more so particularly in winter, it is necessary to use lighter oil for automobiles than in summer.

Statement (II) : 'Lighter' in Statement (I) refers to the oil density, which may be adjusted by admixtures.

24. The surface tension in a soap bubble of 20 mm diameter, when the inside pressure is 2.0 N/m^2 above atmospheric pressure, is

(a) 0.025 N/m (b) 0.0125 N/m

(c) 5×10^{-3} N/m (d) 4.25×10^{-3} N/m

25. A jet of water has a diameter of 0.3 cm. The absolute surface tension of water is 0.072 N/m and atmospheric pressure is 101.2 kN/m^2 The absolute pressure within the jet of water will be

(a) 101.104 kN/m^2 (b) 101.152 kN/m^2

(c) 101.248 kN/m^2 (d) 101.296 kN/m^2

26. A glass tube of 2.5 mm internal diameter is immersed in oil of mass density 940 kg/m^3 to a depth of 9 mm. If a pressure of 148 N/m^2 is needed to from a bubble which is just released. What is the surface tension of the oil?

(a) 0.041 N/m (b) 0.043 N/m

(c) 0.046 N/m (d) 0.050 N/m

ANSWERS

1.	(a)	**6.**	(a)	**11.**	(a)	**16.**	(d)	**21.**	(c)	**26.**	(a)
2.	(c)	**7.**	(b)	**12.**	(a)	**17.**	(c)	**22.**	(a)		
3.	(a)	**8.**	(b)	**13.**	(c)	**18.**	(b)	**23.**	(c)		
4.	(a)	**9.**	(d)	**14.**	(d)	**19.**	(c)	**24.**	(c)		
5.	(c)	**10.**	(c)	**15.**	(b)	**20.**	(c)	**25.**	(c)		

SOLUTION...

1. (a) 1 millibar $= 10^{-3} \times 10^5$ N/m^2 = 100 N/m^2

1 mm of Hg $= 10^{-3}$ m of Hg

$= 10^{-3} \times 13.6$ m of water

$= 10^{-3} \times 13.6 \times 9810$

$= 133.41$ N/m^2

1 N/mm^2 $= 10^6$ N/m^2

$$1\text{Kgf/cm}^2 = \frac{9.81\text{N}}{10^{-4}\text{m}^2} = 98.1 \times 10^3 \text{ N/m}^2$$

2. (c) For equilibrium

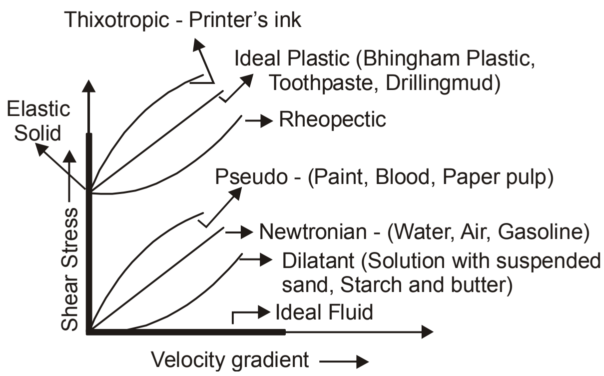
$$2\pi r\sigma = \pi r^2 h\rho g$$

$$\Rightarrow \quad h = \left(\frac{2\sigma}{r\rho g}\right) = \frac{2\times 75\times 10^{-3}}{(10^{-3}\times 10^3\times 10)} = 15\times 10^{-3} \text{ m}$$

$h = 15$ mm

3. (a) Curve between shear stress (τ) and velocity gradient (du/dy) is:

$$\tau \text{ and } \frac{\partial u}{dy}$$



4. (a)

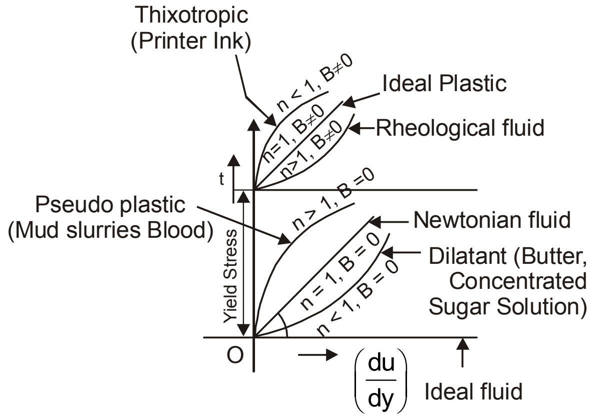
(i) **Dilatant Fluid:** Shear thickening fluid *e.g.*, Solution with suspended sand, conc. sugar solution.

(ii) **Pseudo Plastic Fluid:** Shear thinning fluid. Apparent viscosity decrease with increase in velocity gradient *e.g.*, blood, milk

(iii) **Bingham Plastic/Ideal Plastic:** It has some initial strength beyond which deformation starts *e.g.*, Toothpaste, Sewage sludge.

(iv) **Newtonian fluid:** Water, air, gasoline and oil.

5. (c) Correct sequence should be (c).



General equation for fluid shear stress

$$\tau = A\left(\frac{du}{dy}\right)^n + B$$

$$\therefore \qquad \tau = \underbrace{\left\{A\left(\frac{du}{dy}\right)^{n-1}\right\}}_{\text{Apparent viscosity}}\left(\frac{du}{dy}\right) + B$$

Now when B = 0,

n = 1 ... Newtonian fluid, viscosity invariant of shear stress.

n > 1 ... Shear thickening fluid i.e., apparent viscosity increases with increase in deformation

n < 1 ... Shear thinning i.e., apparent viscosity decreases with increase in shear stress (Psedo plastic)

Now when B ≠ 0,

n = 1 ... Ideal Bingham fluid (tooth paste)

n > 1 ... Rheological fluid *i.e.*, apparent viscosity increases with increase in shear stress

n < 1 ... Thixotropic *i.e.*, apparent viscosity decreases with increase in shear stress.

6. (a) Dynamic viscosity of water is nearly 50 times that of air.

$$\mu_w = 8.90 \times 10^{-4} \text{ Pa.sec}$$

$$\mu_{air} = 1.81 \times 10^{-5} \text{ Pa.sec}$$

$$\frac{\mu_w}{\mu_{air}} = \left(\frac{8.90\times10^{-4}}{1.81\times10^{-5}}\right) = 49.17 \simeq 50$$

- Water in soil is able to rise a considerable distance above ground water table due to capillary action.
- Vapour pressure increases with the increase in temperature

7. (b) Example of Newtonian fluid → Kerosene oil, Air, Water, Diesel oil.

Example of Non-Newtonian fluid → Human blood, Tooth paste etc.

8. (b) Dynamic viscosity of water is approximately 50 times that of air, but density water is around 850 times more than air so kinematic viscosity of air is more than that of water and defined as

$$\text{Kinematic viscosity} = \frac{\text{Dynamic viscosity}}{\text{density}}$$

Hence both the statements are correct but R is not the correct explanation of A.

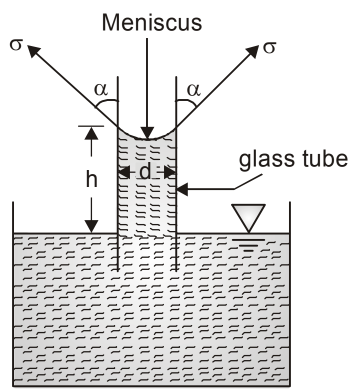
9. (d) Power = force × velocity

$$= \mu A\left(\frac{du}{dy}\right)\times V$$

$$= 0.0014\times0.15\times\left(\frac{20}{0.02}\right)\times20\times10^{-2}$$

$$= 0.042 \text{ W}$$

10. (c)



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Surface tension force in upward direction

$$= \sigma\pi d \cos\alpha \quad \text{... (i)}$$

$\therefore$ Weight of the liquid in the downward direction

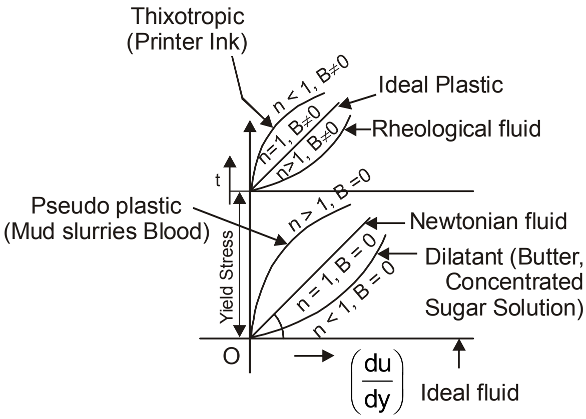
$$= \left(\frac{\pi}{4}d^2h\right)w \quad \text{... (ii)}$$

Equating (i) and (ii)

$$\Rightarrow \quad \sigma\pi d\cos\theta = \left(\frac{\pi}{4}d^2h\right)w$$

$$h = \left(\frac{4\sigma\cos\alpha}{wd}\right) \quad \text{... (iii)}$$

11. (a) Correct sequence should be (c).



General equation for fluid shear stress

$$\tau = A\left(\frac{du}{dy}\right)^n + B$$

$$\therefore \quad \tau = \underbrace{\left\{A\left(\frac{du}{dy}\right)^{n-1}\right\}}_{\text{Apparent viscosity}}\left(\frac{du}{dy}\right) + B$$

Now when B = 0,

n = 1 ... Newtonian fluid, viscosity invariant of shear stress.

n > 1 ... Shear thickening fluid i.e., apparent viscosity increases with increase in deformation

n < 1 ... Shear thinning i.e., apparent viscosity decreases with increase in shear stress (Psedo plastic)

Now when B ≠ 0,

n = 1 ... Ideal Bingham fluid (tooth paste)

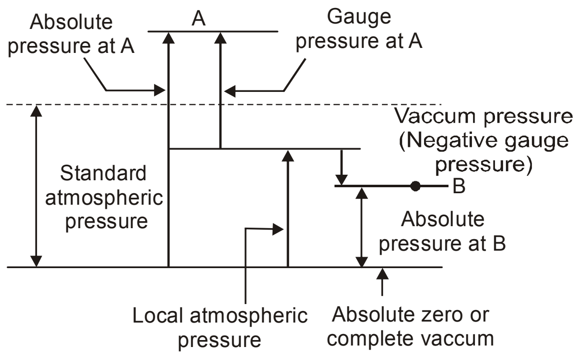
n > 1 ... Rheological fluid *i.e.*, apparent viscosity increases with increase in shear stress

n < 1 ... Thixotropic *i.e.*, apparent viscosity decreases with increase in shear stress.

12. (a) Viscosity of liquids varies inversely with temperature so as the hot glue cools down (dry up) it's viscosity increases so movement of two blocks of wood welted with hot glue would require greater effort.

13. (c) The Standard atmospheric pressure is the mean pressure at the Sea-level at 0° centigrade and at 45° latitude is equal to 76 cm of Mercury, The local atmospheric pressure is measured by mercury barometer.

The figure below shows the relation between standard atmospheric pressure, local atmospheric pressure and gauge pressure.



The barometric pressure depends upon the geographical location of the place, its elevation above the sea level and also the weather condition and it is used to measure local atmospheric pressure

14. (d) Poise is the unit of dynamic viscosity in C.G.S.

$$1 \text{ poise} = 0.1 \text{ Ns/m}^2$$

$$= \frac{0.1\times10^5 \text{ Dynes}\times\text{s}}{10^4\,\text{cm}^2}$$

$$= \text{Dyne-s/cm}^2$$

15. (b)

- Dynamic viscosity is the property of a fluid in motion.
- Cavitation occurs when pressure falls below vapour pressure.
- Real fluids have viscosity while viscosity of ideal fluid is zero
- Surface energy is the fluid property and is responsible for phenomena such as surface tension, capillarity.

16. (d) With an increase in temperature, there is typically an increase in the molecular interchange as molecules move faster in higher temperature. The gas viscosity increases with temperature.

17. (c) Pressure is a scalar quantity. It has defined magnitude but undefined direction.

18. (b) $T \times (2 \times \pi d) = p \times \frac{\pi}{4} d^2$

$\therefore \quad T = \frac{pd}{8}$

$\Rightarrow \quad T = \frac{2.5 \times .05}{8}$ = 0.0156 N/m

19. (c) $h = \frac{4\sigma}{\gamma d}$

$= \frac{4 \times 75 \times 10^{-3}}{9.81 \times 10^3 \times 1 \times 10^{-3}} = 30\text{mm}$

If we take bore as radius then d = 2mm

$\Rightarrow$ h = 15 mm

20. (c) Cavitation occurs when at a point fluid temperature gets too high or the fluid pressure becomes too low.

In cavitation, energy is released with the start of a high intensity wave due to noise and vibration of machine.

21. (c) **Statement (I):** The shear strain graph for a Newtonian fluid is linear.

Statement (II): The coefficient of viscosity μ of the fluid is not a constant.

22. (a) (1) Depression of mercury in capillary tube

$= \frac{2T\cos\theta}{r\rho g}$

(2) In ship model we froude number and Reynolds number both

$\frac{\rho VD}{\mu} = C \qquad \frac{V}{\sqrt{gy}} = C$

(3) Flow of a fluid in a narrow pipe is relatable to both reynolds number and weber number.

(4) In soap bubble

$\Delta p = \frac{8\sigma}{d}$

(5) Flow over the downstream slope of an ogee spillway can not be affected by surface tension.

So option (a) 1, 2 and 4 only.

23. (c) Oil is thin when heated and thickens as it is cooled even to the point that at very cold temperature, oil would thicken such that, it no longer lubricate the engine. Therefore lighter viscosity motor oils is essential when season changes from summer to winter to prevent catastrophic engine failure.

24. (c) $\Delta P = \frac{8\sigma}{D}$

$2\text{N/m}^2 = \frac{8\sigma}{0.02}$

$\Rightarrow \sigma = 5 \times 10^{-3}$ N/m

25. (c) d_j = 0.3cm

σ_{water} = 0.072 N/m

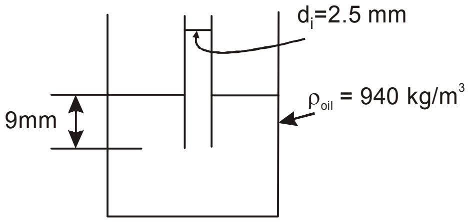
P_{atm} = 101.2N/m^2

$\Delta P = \frac{2\sigma}{D}$ (for jet)

$P_{jet} - P_{atm} = \frac{2 \times 0.072\text{N/m}}{0.3 \times 10^{-2}} = 48\text{N/m}^2 = 0.048\text{KN/m}^2$

$P_{jet} = 101.2 + 0.048 = 101.248 \text{ KN/m}^2$.

26. (a)



$$(P_i - P_0) = \frac{4\sigma}{D}$$

Now $P_0 = 940 \times 9.81 \times 9 \times 10^{-3} = 82.99 \text{N/m}^2$

$$\Rightarrow 148 - 82.99 = \frac{4 \times \sigma}{2.5 \times 10^{-3}}$$

$$\Rightarrow \sigma = \frac{65.01 \times 2.5 \times 10^{-3}}{4} \approx 0.041 \text{N/m}$$

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