25 *Years*
Previous Solved Papers

ESE 2025

UPSC ENGINEERING SERVICES EXAMINATION

Preliminary Examination

MECHANICAL ENGINEERING

Objective Solved Papers

Volume-I

- Topicwise presentation
- Thoroughly revised & updated

Also useful for
State Engineering Services Examinations, Public Sector Examinations & Other Competitive Examinations

MADE EASY PUBLICATIONS

www.madeeasypublications.org

MADE EASY Publications Pvt. Ltd.

Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016

Contact: 9021300500

E-mail: infomep@madeeasy.in

Visit us at: www.madeeasypublications.org

ESE-2025 : Preliminary Examination
Mechanical Engineering : Volume-1
Topicwise Objective Solved Questions : (2000-2024)

1st Edition : 2007
2nd Edition : 2008
3rd Edition : 2009
4th Edition : 2010
5th Edition : 2011
6th Edition : 2012
7th Edition : 2013
8th Edition : 2014
9th Edition : 2015
10th Edition : 2016
11th Edition : 2017
12th Edition: 2018
13th Edition: 2019
14th Edition: 2020
15th Edition: 2021
16th Edition: 2022
17th Edition: 2023

18th Edition: 2024

Director's Message


B. Singh (Ex. IES)

Engineering is one of the most chosen graduating field. Taking engineering is usually a matter of interest but this eventually develops into "purpose of being an engineer" when you choose engineering services as a career option.

Train goes in tunnel we don't panic but sit still and trust the engineer, even we don't doubt on signalling system, we don't think twice crossing over a bridge reducing our travel time; every engineer has a purpose in his department which when coupled with his unique talent provides service to mankind.

I believe *"the educator must realize in the potential power of his pupil and he must employ all his art, in seeking to bring his pupil to experience this power"*. To support dreams of every engineer and to make efficient use of capabilities of aspirant, MADE EASY team has put sincere efforts in compiling all the previous years' ESE-Pre questions with accurate and detailed explanation. The objective of this book is to facilitate every aspirant in ESE preparation and so, questions are segregated chapterwise and topicwise to enable the student to do topicwise preparation and strengthen the concept as and when they are read.

I would like to acknowledge efforts of entire MADE EASY team who worked hard to solve previous years' papers with accuracy and I hope this book will stand up to the expectations of aspirants and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

B. Singh (Ex. IES)
CMD, MADE EASY Group

Volume-I

MECHANICAL ENGINEERING

Objective Solved Questions

of UPSC Engineering Services Examination

Contents

■■■■

UNIT

I

Fluid Mechanics

Syllabus

Fluid Mechanics: Basic concepts and Properties of fluids, Manometry, Fluid statics, Buoyancy, Equations of motion, Bernoulli's equation and applications, Viscous flow of incompressible fluids, Laminar and Turbulent flows, Flow through pipes and head losses in pipes.

Contents

1 Fluid Properties

1.1 **Assertion (A):** If a cube is placed in a liquid with two of its surfaces parallel to the free surface of the liquid, then the pressures on the two surfaces which are parallel to the free surface, are the same.
Reason (R): Pascal's law states that when a fluid is at rest, the pressure at any plane is the same in all directions.
(a) Both **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true [ESE : 2000]

1.2 The shear stress developed in a lubricating oil, of viscosity 9.81 poise, filled between two parallel plates 1 cm apart and moving with relative velocity of 2 m/s is
(a) 20 N/m^2 (b) 196.2 N/m^2
(c) 29.62 N/m^2 (d) 40 N/m^2
[ESE : 2001]

1.3 A capillary tube is inserted in mercury kept in an open container.
Assertion (A): The mercury level inside the tube shall rise above the level of mercury outside.
Reason (R): The cohesive force between the molecules of mercury is greater than the adhesive force between mercury and glass.
(a) Both **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true [ESE : 2001]

1.4 In the phenomenon of cavitation, the characteristic fluid property involved is
(a) surface tension
(b) viscosity
(c) bulk modulus of elasticity
(d) vapour pressure [ESE : 2002]

1.5 The capillary rise at 20°C in clean glass tube of 1 mm diameter containing water is approximately
(a) 15 mm (b) 50 mm
(c) 20 mm (d) 30 mm
[ESE : 2002]

1.6 Match **List-I** (Type of fluid) with **List-II** (Variation of shear stress) and select the correct answer using the codes given below the lists:

List-I
A. Ideal fluid
B. Newtonian fluid
C. Non-Newtonian fluid
D. Bingham plastic

List-II
1. Shear stress varies linearly with the rate of strain
2. Shear stress does not vary linearly with the rate of strain
3. Fluid behaves like a solid until a minimum yield stress beyond which it exhibits a linear relationship between shear stress and the rate of strain
4. Shear stress is zero

Codes:

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

[ESE : 2002]

1.7 The equation of a velocity distribution over a plate is given by $u = 2y - y^2$, where u is the velocity in m/s at a point y meter from the plate measured perpendicularly. Assuming μ = 8.60 poise, the shear stress at a point 15 cm from the boundary is
(a) 1.72 N/m^2 (b) 1.46 N/m^2
(c) 14.62 N/m^2 (d) 17.20 N/m^2
[ESE : 2002]

1.8 **Assertion (A):** In general, viscosity in liquids increases and in gases it decreases with rise in temperature.

Reason (R): Viscosity is caused by intermolecular forces of cohesion and due to transfer of molecular momentum between fluid layers; of which in liquids the former and in gases the later contribute the major part towards viscosity.

(a) Both **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true **[ESE : 2002]**

1.9 Match **List-I** (Rheological equation) with **List-II** (Types of fluids) and select the correct answer using the codes given below the lists:

List-I

A. $\tau = \mu\left(\frac{du}{dy}\right)^n, n = 1$

B. $\tau = \mu\left(\frac{du}{dy}\right)^n, n < 1$

C. $\tau = \mu\left(\frac{du}{dy}\right)^n, n > 1$

D. $\tau = \tau_0 + \mu\left(\frac{du}{dy}\right)^n, n = 1$

List-II

1. Bingham plastic
2. Dilatant fluid
3. Newtonian fluid
4. Pseudo-plastic fluid

Codes:

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

[ESE : 2003]

1.10 Match **List-I** (Flows over or inside the systems) with **List-II** (Type of flow) and select the correct answer using the codes given below the lists:

List-I

A. Flow over a sphere
B. Flow over a long circular cylinder
C. Flow in a pipe bend
D. Fully developed flow in a pipe at constant flow rate

List-II

1. Two dimensional flow
2. One dimensional flow
3. Axisymmetric flow
4. Three dimensional flow

Codes:

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

[ESE : 2003]

1.11 An oil of specific gravity 0.9 has viscosity of 0.28 stokes at 38°C. What will be its viscosity in Ns/m^2?

(a) 0.2520 (b) 0.0311
(c) 0.0252 (d) 0.0206

[ESE : 2004]

1.12 Consider the following statements:

1. Viscosity 2. Surface tension
3. Capillarity 4. Vapour pressure

Which of the above properties can be attributed to the flow of jet of oil in an unbroken stream?

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

[ESE : 2005]

1.13 A vertical clean glass tube of uniform bore is used as a piezometer to measure the pressure of liquid at a point. The liquid has a specific weight of 15 kN/m^3 and a surface tension of 0.06 N/m in contact with air. If for the liquid, the angle of contact with glass is zero and the capillary rise in the tube is not to exceed 2 mm, what is the required minimum diameter of the tube?

(a) 6 mm (b) 8 mm
(c) 10 mm (d) 12 mm **[ESE : 2006]**

1.14 When the pressure on a given mass of liquid is increased from 3.0 MPa to 3.5 MPa, the density of the liquid increases from 500 kg/m^3 to 501 kg/m^3. What is the average value of bulk modulus of liquid over the given pressure range?

(a) 700 MPa (b) 600 MPa
(c) 500 MPa (d) 250 MPa

[ESE : 2006]

1.15 If the relationship between the shear stress τ and the rate of shear strain $\left(\frac{du}{dy}\right)$ is expressed as

$$\tau = \mu\left(\frac{du}{dy}\right)^n$$

then the fluid with exponent $n > 1$ is known as which one of the following?
(a) Bingham plastic
(b) Dilatant fluid
(c) Newtonian fluid
(d) Pseudoplastic fluid
[ESE : 2007]

1.16 What are the dimensions of kinematic viscosity of a fluid?
(a) LT^{-2} (b) L^2T^{-1}
(c) $ML^{-1}T^{-1}$ (d) $ML^{-2}T^{-2}$
[ESE : 2007]

1.17 **Assertion (A):** Blood is a Newtonian fluid.
Reason (R): The rate of strain varies non-linearly with shear stress for blood.
(a) Both **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true
[ESE : 2007]

1.18 In an experiment, the following shear stress-time rate of shear strain values are obtained for a fluid:

Time rate of shear strain (1/s)	:	0	2	3	4
Shear stress (kPa)	:	0	1.4	2.6	4

How can the fluid be classified?
(a) Newtonian fluid (b) Bingham plastic
(c) Pseudo plastic (d) Dilatant
[ESE : 2008]

1.19 Consider the following statements related to the fluid properties:
1. Vapour pressure of water at 373 K is 101.5×10^3 N/m^2.
2. Capillary height in cm for water in contact with glass tube and air is (tube diameter)/0.268.
3. Blood is a Newtonian fluid.
Which of these statements is/are correct?
(a) 1 only (b) 1 and 3
(c) 1 and 2 (d) 2 only
[ESE : 2008]

1.20 What is the unit of dynamic viscosity of a fluid termed 'poise' equivalent to?
(a) dyne/cm^2 (b) gm-s/cm^2
(c) dyne-s/cm^2 (d) gm-cm/s
[ESE : 2008]

1.21 What is the pressure difference between inside and outside of a droplet of water?
(a) $\frac{2\sigma}{d}$ (b) $\frac{4\sigma}{d}$
(c) $\frac{8\sigma}{d}$ (d) $\frac{12\sigma}{d}$
where σ is surface tension and d is the diameter of the droplet. **[ESE : 2008]**

1.22 What is the pressure inside a soap bubble, over the atmospheric pressure if its diameter is 2 cm and the surface tension is 0.1 N/m?
(a) 0.4 N/m^2 (b) 4.0 N/m^2
(c) 40.0 N/m^2 (d) 400.0 N/m^2
[ESE : 2008]

1.23 The capillary rise or depression in a small diameter tube is
(a) directly proportional to the specific weight of the fluid
(b) inversely proportional to the surface tension
(c) inversely proportional to the diameter
(d) directly proportional to the surface area
[ESE : 2008]

1.24 Match **List-I** (Variable) with **List-II** (Dimensional expression) and select the correct answer using the codes given below the lists :
List-I
A. Dynamic viscosity
B. Moment of momentum
C. Power
D. Volume modulus of elasticity
List-II
1. ML^2T^{-3}
2. $ML^{-1}T^{-2}$
3. $ML^{-1}T^{-1}$
4. ML^2T^{-2}
5. ML^2T^{-1}

Codes:

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

[ESE : 2008]

1.25 What is the capillary rise in a narrow two-dimensional slit of width *w*?
(a) Half of that in a capillary tube of diameter *w*
(b) Two-third of that in a capillary tube of diameter *w*
(c) One-third of that in a capillary tube of diameter *w*
(d) One-fourth of that in a capillary tube of diameter *w*
[ESE : 2009]

Direction: Each of the next questions consists of two statements, one labelled as the **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) Both **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true

1.26 Assertion (A) : In a fluid, the rate of deformation is far more important than the total deformation itself.
Reason (R) : A fluid continues to deform so long as the external forces are applied.
[ESE : 2009]

1.27 Assertion (A) : A narrow glass tube when immersed into mercury causes capillary depression, and when immersed into water causes capillary rise.
Reason (R) : Mercury is denser than water.
[ESE : 2009]

1.28 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Lubrication
B. Rise of sap in trees
C. Formation of droplets
D. Cavitation

List-II
1. Capillary
2. Vapour pressure
3. Viscosity
4. Surface tension

Codes:

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

[ESE : 2010]

1.29 Consider the following statements:
1. A small bubble of one fluid immersed in another fluid has a spherical shape.
2. The droplets of a fluid move upward or downward in another fluid due to unbalance between gravitational and buoyant forces.
3. Droplets of bubbles attached to a solid surface can remain stationary in a gravitational fluid if the surface tension exceeds buoyant forces.
4. Surface tension of a bubble is proportional to its radius while buoyant force is proportional to the cube of its radius.

Which of these statements are correct?
(a) 1, 2, 3 and 4
(b) 1, 2 and 4 only
(c) 1 and 3 only
(d) 2, 3 and 4 only
[ESE : 2010]

1.30 The annular space between two coaxial vertical cylinders, of equal length, is filled with an incompressible liquid of constant viscosity. The outer cylinder is held fixed and the inner cylinder is slowly rotated about its axis at a uniform rotational speed. Assuming that Newton's law of viscosity holds good
(a) the tangential velocity of liquid varies linearly across the gap
(b) viscous shear stress in liquid is uniform across the gap
(c) the tangential velocity of liquid varies non-linearly across the gap
(d) viscous shear stress in liquid varies linearly across the gap
[ESE : 2010]

1.31 A thin plane lamina, of area *A* and weight *W*, slides down a fixed plane inclined to the vertical at an angle α and maintains a uniform gap ε from the surface of the plane, the gap being filled with oil of constant viscosity μ. The terminal velocity of the plane is

(a) $\frac{\varepsilon \cos\alpha}{\mu WA}$ (b) $\frac{\varepsilon\mu W}{A\sin\alpha}$

(c) $\frac{\varepsilon W\cos\alpha}{A\mu}$ (d) $\frac{\mu W\sin\alpha}{\varepsilon A}$

[ESE : 2010]

1.32 In a quiescent sea, density of water at free surface is ρ_0 and at a point much below the surface density is ρ. Neglecting variation in gravitational acceleration g and assuming a constant value of bulk modulus K, the depth h of the point from the free surface is

(a) $\frac{K}{g}\left(\frac{1}{\rho_0}+\frac{1}{\rho}\right)$ (b) $\frac{K}{g}\frac{(\rho-\rho_0)}{(\rho+\rho_0)^2}$

(c) $\frac{K}{g}\left(\frac{1}{\rho_0}-\frac{1}{\rho}\right)$ (d) $\frac{K}{g}\left(\frac{\rho\rho_0}{\rho+\rho_0}\right)$

[ESE : 2010]

1.33 Pseudo plastic is a fluid for which
(a) dynamic viscosity decreases as the rate of shear increases
(b) Newton's law of viscosity holds good
(c) dynamic viscosity increases as the rate of shear increases
(d) dynamic viscosity increases with the time for which shearing forces are applied

[ESE : 2010]

1.34 If angle of contact of a drop of liquid is acute then
(a) adhesion is more than cohesion
(b) cohesion is more than adhesion
(c) cohesion is equal to adhesion
(d) adhesion and cohesion have no bearing with angle of contact

[ESE : 2010]

1.35 With increase in pressure, the bulk modulus of elasticity
(a) Decreases (b) Increases
(c) Remains constant (d) None of the above

[ESE : 2011]

1.36 Match **List-I** with **List-II** and select the correct answer using the code given below the lists:

List-I	List-II
A. Capillarity	**1.** Cavitation
B. Vapour pressure	**2.** Density of water
C. Viscosity	**3.** Shear forces
D. Specific gravity	**4.** Surface tension

Codes:

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

[ESE : 2011]

1.37 Newton's law of viscosity relates
(a) Velocity gradient and rate of shear strain
(b) Rate of shear deformation and shear stress
(c) Shear deformation and shear stress
(d) Pressure and volumetric strain

[ESE : 2011]

1.38 In an experiment to determine the rheological behaviour of a material, the observed relation between shear stress, τ, and rate of shear strain, $\frac{du}{dy}$, is $\tau = \tau_0 + c\left(\frac{du}{dy}\right)^{0.5}$. The material is
(a) a Newtonian fluid
(b) a thixotropic substance
(c) a Bingham plastic
(d) an ideal plastic

[ESE : 2011]

1.39 Match **List-I** with **List-II** and select the correct answer using the code given below the lists :

List-I
A. Coaxial cylinder viscometer
B. Capillary tube viscometer
C. Saybolt viscometer
D. Falling sphere viscometer

List-II
1. Hagen Poiseuille equation
2. Stokes law
3. Newton's law of viscosity
4. Efflux viscometer

Codes:

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

[ESE : 2011]

Direction: Each of the next questions consists of two statements, one labelled as the **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) Both **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true

1.40 **Assertion (A) :** In non-Newtonian fluids, the shear stress at any point is not a linear function of normal distance from the surface.
Reason (R) : This behaviour usually arises because the fluid molecules are very large, like polymers or proteins.
[ESE : 2011]

1.41 **Assertion (A) :** The mercury level inside the tube shall rise above the level of mercury outside.
Reason (R) : The cohesive force between the molecules of mercury is greater than the adhesive force between mercury and glass.
[ESE : 2011]

1.42 The vapour pressure is the characteristic fluid property involved in the phenomenon of
(a) water hammer in a pipe flow
(b) cavitation
(c) rise of sap in a tree
(d) spherical shape of rainwater drop
[ESE : 2012]

1.43 Match **List-I** with **List-II** and select the correct answer using the code given below the lists:
List-I (Fluids)
A. Ideal fluid
B. Newtonian fluid
C. Inviscid fluid
D. Real fluid
List-II (Viscosity equal to)
1. Zero
2. Non-zero
3. $\mu \dfrac{du}{dy}$

Code:

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

[ESE : 2012]

1.44 The unit of the following property is not m^2/s
(a) thermal diffusivity
(b) kinematic viscosity
(c) dynamic viscosity
(d) mass diffusivity [ESE : 2013]

1.45 **Statement (I):** In a fluid, the rate of deformation is far more important than the total deformation itself.
Statement (II): A fluid continues to deform so long as the external forces are applied.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is **NOT** the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true.
[ESE : 2013]

1.46 Unlike the viscosity of liquids, the viscosity of gases increases with increasing temperature. This is due to
(a) Increased cohesive force between the molecules
(b) Increased momentum transfer in the molecules
(c) Decreased momentum transfer in the molecules
(d) Increases in both cohesive force and momentum transfer
[ESE : 2014]

1.47 The pressure inside a soap bubble of 50 mm diameter is 25 N/m^2 above the atmospheric pressure. The surface tension in soap film would be
(a) 0.156 N/m (b) 0.312 N/m
(c) 0.624 N/m (d) 0.078 N/m
[ESE : 2014]

1.48 **Statement (I) :** A small insect can sit on the free surface of a liquid though insect's density is higher than that of the liquid.
Statement (II): Liquids have viscosity.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is **NOT** the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true.
[ESE : 2014]

1.49 Which of the following fluids exhibit a certain shear stress at zero shear strain rate followed by a straight line relationship between shear stress and shear strain rate?
(a) Newtonian fluids
(b) Ideal Bingham plastic fluids
(c) Pseudo-plastic fluids
(d) Dilatant fluids [ESE : 2015]

1.50 If angle of contact of a drop of liquid is acute, then
(a) cohesion is equal to adhesion
(b) cohesion is more than adhesion
(c) adhesion is more than cohesion
(d) both adhesion and cohesion have no connection with angle of contact
[ESE : 2016]

1.51 A spherical waterdrop of 1 mm in diameter splits up in air into 64 smaller drops of equal size. The surface tension coefficient of water in air is 0.073 N/m. The work required in splitting up the drop is
(a) 0.96×10^{-6} J (b) 0.69×10^{-6} J
(c) 0.32×10^{-6} J (d) 0.23×10^{-6} J
[ESE : 2017]

1.52 A 150 mm diameter shaft rotates at 1500 rpm within a 200 mm long journal bearing with 150.5 mm internal diameter. The uniform annular space between the shaft and the bearing is filled with oil of dynamic viscosity 0.8 poise. The shear stress on the shaft will be
(a) 1.77 kN/m^2 (b) 2.77 kN/m^2
(c) 3.77 kN/m^2 (d) 4.77 kN/m^2
[ESE : 2018]

1.53 The normal stresses within an isotropic Newtonian fluid are related to
1. Pressure
2. Viscosity of fluid
3. Velocity gradient
Which of the above are correct?
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3 [ESE : 2018]

1.54 A plate weighing 150 N and measuring 0.8 m × 0.8 m just slides down an inclined plane over an oil film of 1.2 mm thickness for an inclination of 30° and velocity of 0.2 m/s. Then the viscosity of the oil used is
(a) 0.3 Ns/m^2 (b) 0.4 Ns/m^2
(c) 0.5 Ns/m^2 (d) 0.7 Ns/m^2
[ESE : 2019]

1.55 A flat plate 0.1 m^2 area is pulled at 30 cm/s relative to another plate located at a distance of 0.01 cm from it, the fluid separating them being water with viscosity of 0.001 Ns/m^2, The power required to maintain velocity will be
(a) 0.05 W (b) 0.07 W
(c) 0.09 W (d) 0.11 W
[ESE : 2020]

1.56 When the pressure of liquid is increased from 3 MN/m^2 to 6 MN/m^2, its volume is decreased by 0.1%. The bulk modulus of elasticity of the liquid will be
(a) 3×10^{12} N/m^2 (b) 3×10^{9} N/m^2
(c) 3×10^{8} N/m^2 (d) 3×10^{4} N/m^2
[ESE : 2020]

1.57 **Statement (I):** The viscosity of liquids decreases with the increase of temperature while the viscosity of gases increases with the increase of temperature.

Statement (II): The viscous forces in a fluid are due to cohesive forces and molecular momentum transfer.
[ESE : 2021]

1.58 A liquid has a specific gravity of 1.9 and a kinematic viscosity of 6 stokes. What is the dynamic viscosity?
(a) 1.14 Ns/m^2 (b) 2.44 Ns/m^2
(c) 3.40 Ns/m^2 (d) 11.40 Ns/m^2
[ESE : 2021]

1.59 A flat plate of area 1.5×10^6 mm^2 is pulled with a speed of 0.4 m/s relative to another plate located at a distance of 0.15 mm from it. What is the power required to maintain this speed, if the fluid separating them is having viscosity as 1 poise?

(a) 160 W (b) 158 W
(c) 145 W (d) 130 W
[ESE : 2022]

1.60 A shaft of diameter 0.35 m rotates at 200 rpm inside a sleeve 100 mm long. The dynamic viscosity of lubricating oil in the 2 mm gap between sleeve and shaft is 8 poises. What is the power lost in the bearing?
(a) 0.59 kW (b) 0.69 kW
(c) 0.88 kW (d) 0.91 kW
[ESE : 2022]

1.61 A spherical water drop of 1 mm in diameter splits up in air into 64 smaller drops of equal size. The surface tension coefficient of water in air = 0.073 N/m. What is the work required in splitting up the drop?
(a) 0.12×10^{-3} J (b) 0.36×10^{-3} J
(c) 0.69×10^{-6} J (d) 0.89×10^{-3} J
[ESE : 2023]

1.62 Consider the following statements:
1. Viscosity of liquid increases with increase in temperature.
2. Viscosity of gas decreases with increase in temperature.
3. In liquids, cohesive forces predominate the molecular momentum transfer.
4. In gases, cohesive forces are small and the molecular momentum transfer predominates.

Which of the above statements are correct?
(a) 1 and 2 only (b) 2 and 3 only
(c) 3 and 4 only (d) 1, 2, 3 and 4
[ESE : 2024]

1.63 A fluid in which shear stress is more than the yield value and shear stress is proportional to the rate of shear strain is known as
(a) non-ideal plastic fluid (b) Newtonian fluid
(c) non-Newtonian fluid (d) ideal plastic fluid
[ESE : 2024]

1.64 Two horizontal plates are placed 1.25 cm apart, the space between them being filled with an oil of viscosity 15 poise. What is the shear stress in the oil if the upper plate is moved with a velocity of 2.5 m/s?
(a) 280 N/m^2 (b) 260 N/m^2
(c) 300 N/m^2 (d) 250 N/m^2
[ESE : 2024]

1.65 What is the capillary rise in a glass tube of 2.0 mm diameter when immersed vertically in mercury? (Take surface tension of mercury as 0.52 N/m. The specific gravity of mercury is 13.6 and the angle of contact is 130°)
(a) –0.25 cm (b) –0.65 cm
(c) –0.8 cm (d) –0.5 cm
[ESE : 2024]

1.66 Consider the following statements :
1. The apparent viscosity of a pseudoplastic fluid decreases with decrease in the shear rate.
2. The apparent viscosity of a dilatant fluid increases with increase in the shear rate.
3. Bingham plastic fluid requires a finite yield stress before beginning to flow.

Which of the above statements are correct?
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3
[ESE : 2024]

■■■■

Answers Fluid Properties

1.1 (d)	1.2 (b)	1.3 (d)	1.4 (d)	1.5 (d)	1.6 (d)	1.7 (b)	1.8 (d)	1.9 (c)
1.10 (c)	1.11 (c)	1.12 (b)	1.13 (b)	1.14 (d)	1.15 (b)	1.16 (b)	1.17 (d)	1.18 (d)
1.19 (a)	1.20 (c)	1.21 (b)	1.22 (c)	1.23 (c)	1.24 (b)	1.25 (a)	1.26 (a)	1.27 (b)
1.28 (d)	1.29 (a)	1.30 (c)	1.31 (c)	1.32 (c)	1.33 (a)	1.34 (a)	1.35 (b)	1.36 (d)
1.37 (b)	1.38 (b)	1.39 (b)	1.40 (c)	1.41 (d)	1.42 (b)	1.43 (c)	1.44 (c)	1.45 (a)
1.46 (b)	1.47 (a)	1.48 (b)	1.49 (b)	1.50 (c)	1.51 (b)	1.52 (c)	1.53 (d)	1.54 (d)
1.55 (c)	1.56 (b)	1.57 (a)	1.58 (a)	1.59 (a)	1.60 (a)	1.61 (c)	1.62 (c)	1.63 (d)
1.64 (c)	1.65 (d)	1.66 (c)						

Explanations Fluid Properties

1.1 (d)

Pressure on the two surfaces which are parallel to free surface are not same.

1.2 (b)

Given: $\mu = 9.81$ poise

$$= \frac{9.81}{10}\ \text{Ns/m}^2 = 0.981\ \text{Ns/m}^2$$

$dy = 1$ cm $= 0.01$ m

$U = 2$ m/s

Shear stress,

$$\tau = \mu\frac{du}{dy} = \frac{\mu U}{dy}$$

$$= 0.981 \times \frac{2}{10^{-2}} = \mathbf{196.2\ N/m^2}$$

1.3 (d)

Assertion is false but Reason is true.

1.4 (d)

Vapour pressure plays very important role in cavitation.

1.5 (d)

Surface tension of water in contact with air at 20°C, $\sigma = 0.0736$ N/m

Diameter, $d = 1$ mm $= 0.001$ m

$$\therefore \text{ Capillary rise, } h = \frac{4\sigma}{\rho g d} = \frac{4 \times 0.0736}{1000 \times 9.81 \times 0.001}$$

$$= 0.030 = 30 \text{ mm}$$

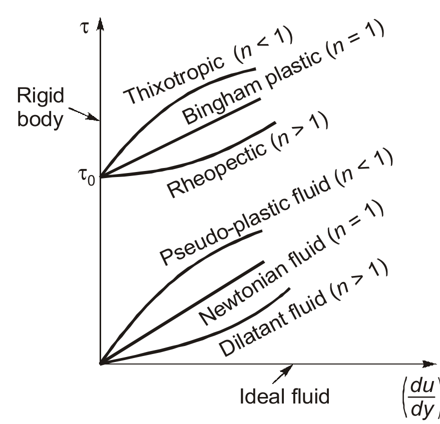
1.6 (d)

$$\tau = \mu\frac{du}{dy}, \text{ Newtonian fluid}$$

$$\tau = \mu\left(\frac{du}{dy}\right)^n, \text{ Non-newtonian fluid}$$

$\tau = 0$, Ideal fluid

$$\tau = \text{Ideal} + \mu\left(\frac{du}{dy}\right), \text{ Bingham plastic}$$



1.7 (b)

Given: $u = 2y - y^2$

$$\frac{du}{dy} = 2 - 2y$$

At $y = 15$ cm $= 0.15$ m

$$\left(\frac{du}{dy}\right)_{y = 0.15\,\text{m}} = 2 - 2 \times 0.15 = 1.7\ \text{s}^{-1}$$

$\mu = 8.60$ poise

$$= \frac{8.60}{10}\ \text{Ns/m}^2 = 0.86\ \text{Ns/m}^2$$

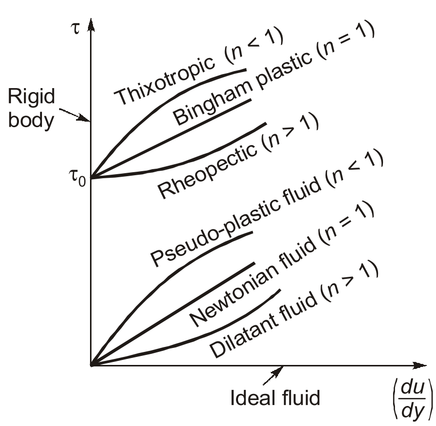
Shear stress,

$$\tau = \mu\left(\frac{du}{dy}\right) = 0.86 \times 1.7 = \mathbf{1.462\ N/m^2}$$

1.8 (d)

In liquid, viscosity is due to cohesion with rise in temperature, volume of liquid increases, the distance between molecules increases, thus decreasing the cohesion. Therefore the viscosity of liquid decreases with rise in temperature.
In case of gases, viscosity is due to molecular momentum exchange with rise in temperature of gas, kinetic energy of molecules increases, thus increasing the molecular momentum exchange. Therefore, the viscosity of gases increases with rise in temperature.

1.9 (c)



1.10 (c)

Given, $S = 0.9$

$\therefore \quad \rho = 0.9 \times 1000$

$= 900\ \text{kg/m}^3$

$\nu = 0.28$ stakes

$= 0.28 \times 10^{-4}\ \text{m}^2/\text{s}$

Kinematic viscosity,

$$\gamma = \frac{\mu}{\rho}$$

$$0.28 \times 10^{-4} = \frac{\mu}{900}$$

or, $\mu = \mathbf{0.0252\ Ns/m^2}$

1.13 (b)

Given: $w = 15\ \text{kN/m}^3$

$= 15000\ \text{N/m}^3$

$\sigma = 0.06\ \text{N/m}$

$h = 2\ \text{mm}$

$= 0.002\ \text{m}$

Capillary rise,

$$h = \frac{4\sigma}{wd} \quad \text{(for clean glass tube)}$$

$$0.002 = \frac{4 \times 0.06}{15000 \times d}$$

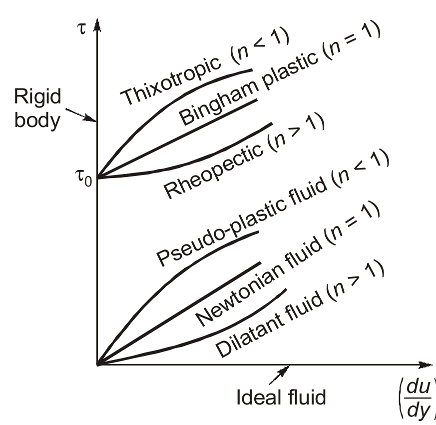
or $d = 0.008\ \text{m} = 8\ \text{mm}$

1.14 (d)

Bulk modulus,

$$K = \frac{\rho dp}{d\rho} = \frac{500 \times (3.5 - 3.0)}{501 - 500} = \mathbf{250\ MPa}$$

1.15 (b)



1.16 (b)

Kinematic viscosity,

$$\nu = \frac{\text{Dynamic viscosity } (\mu)}{\text{Mass density } (\rho)}$$

$$= \frac{\mu}{\rho} = \frac{ML^{-1}T^{-1}}{ML^{-3}}$$

$$= L^2T^{-1}$$

1.17 (d)

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

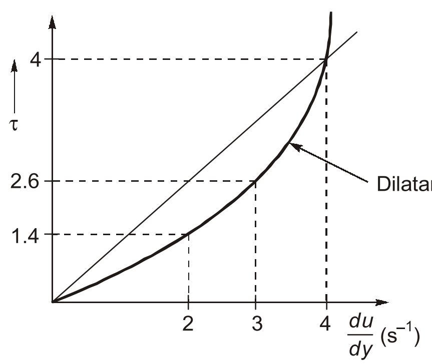
(i) $B = 0$ and $n < 1$
$\Rightarrow$ Pseudo Plastic e.g. Blood and Milk

(ii) $B = 0$ and $n > 1$
$\Rightarrow$ Dilatant Fluid e.g. Rich starch, sugar in water

(iii) $B \neq 0$ and $n = 1$
$\Rightarrow$ Bingham plastic e.g. Tooth paste

(iv) $B = 0$ and $n = 1$
$\Rightarrow$ Newtonian Fluid e.g. water.

1.18 (d)



1.19 (a)

Only first statement is correct.

(i) Vapour pressure of water at 373 K is 101.5×10^3 N/m^2

(ii) Capillary height in cm for water in contact with glass tube $= \dfrac{0.3}{d}$

(iii) Blood is a pseudoplastic fluid.

1.20 (c)

C.G.S. unit of dynamic viscosity,

1 poise = 1 dyne s/cm^2 = $10^{-5} \times 10^4$ Ns/m^2
= 10^{-1} Ns/m^2 = **0.1 Ns/m^2**

1.21 (b)

Pressure difference between inside and outside of a droplet of water $= \dfrac{4\sigma}{d}$

$\because$ Bursting force $= p \times \dfrac{\pi d^2}{4}$

Resisting force $= \sigma \times \pi d$

Bursting force = Resisting force

$$p \times \frac{\pi d^2}{4} = \sigma \times \pi d$$

or $$p = \frac{4\sigma}{d}$$

1.22 (c)

Given: d = 2 cm = 0.02 m; σ = 0.1 N/m

$$\text{Pressure} = \frac{8\sigma}{d} = \frac{8 \times 0.1}{2 \times 10^{-2}}$$

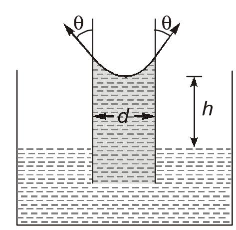
$= 0.4 \times 100 =$ **40 N/m^2**

1.23 (c)

Capillary rise is given by

$$h = \frac{4\sigma\cos\theta}{wd} = \frac{4\sigma\cos\theta}{\rho g d}$$

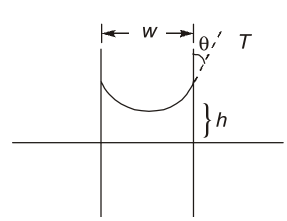
$$h \propto \frac{1}{d}$$



1.24 (b)

Dynamic viscosity	:	M L^{-1} T^{-1}
Moment of momentum	:	M L^2 T^{-1}
Power	:	M L^2 T^{-3}
Volume modulus of elasticity	:	M L^{-1} T^{-2}

1.25 (a)



For narrow slit $\rightarrow$ weight of fluid = surface tension force

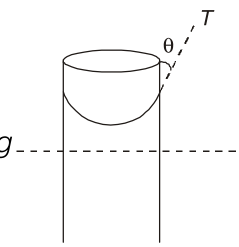
$$(w \times h \times l) \times \rho g = T\cos\theta \times 2l$$

$$\therefore \quad h = \frac{2T\cos\theta}{w\rho g}$$

For capillary tube

$$T\cos\theta \times (w\pi) = \frac{\pi w^2}{4} h\rho g$$

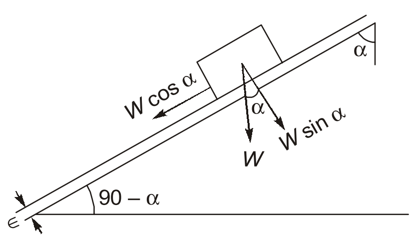
$$h = \frac{4T\cos\theta}{w\rho g}$$



1.28 (d)

- Viscosity is a vital property of the lubricant.
- Rise of sap in trees is due to capillary action.
- Formation of droplets due to surface tension.
- Cavitation is related to the vapour pressure.

1.31 (c)



For zero acceleration

$$W \sin\alpha = \text{drag force}$$

Here

$$\text{Drag force} = \text{shear force} = \mu A \frac{V}{\epsilon}$$

$$W\cos\alpha = \mu A \frac{V}{\epsilon}$$

$$\therefore \quad V = \frac{\epsilon W \cos\alpha}{\mu A}$$

1.32 (c)

Bulk modulus,

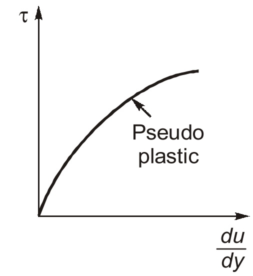
$$K = \frac{\rho\, dp}{d\rho}$$

$$\frac{d\rho}{\rho} = \frac{\rho g dh}{K}$$

$$\left[-\frac{1}{\rho}\right]_{\rho}^{\rho_0} = \frac{gh}{K}$$

$$h = \frac{K}{g}\left[\frac{1}{\rho_0} - \frac{1}{\rho}\right]$$

1.33 (a)



1.34 (a)

When adhesion force is more than cohesion force then fluid will wet the surface and angle of contact between fluid and surface will be less than 90° (acute).

1.35 (b)

$$\text{Bulk modulus: } K = \frac{dp}{\left(-\frac{dv}{v}\right)}$$

∴ Bulk modulus increase with increases in pressure.

1.36 (d)

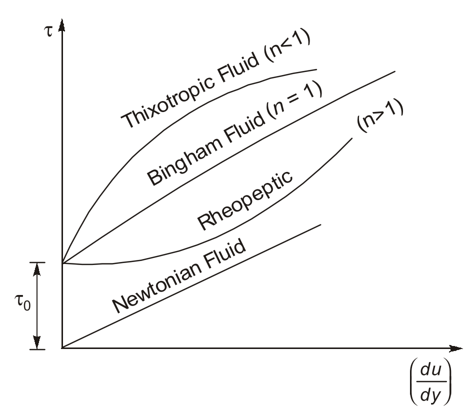
Capillarity	–	Surface tension
Vapour pressure	–	Cavitation
Viscosity	–	Shear forces
Specific gravity	–	Density of water.

1.37 (b)

$$\tau \propto \left(\frac{du}{dy}\right) \propto \frac{d\theta}{dt}$$

∴ Above equation shows the relation between rate of angular deformation and shear stress.

1.38 (b)



Example of Thixotropic fluid : Paint

1.39 (b)

According to Stokes law, the drag force, F, on a sphere of radius r moving through a fluid of viscosity μ at speed V is given by

$$F = 6\pi r\mu V$$

The efflux viscometer, also known as flow cup, type ford is a traditional instrument used world wide for the determination of kinematic viscosity.

1.41 (d)

Cohesive force is the action or property of like molecules sticking together, being mutually attractive. Mercury has large adhesion force with most container materials and strong cohesive forces. This causes the depression in mercury level inside the tube.

1.42 (b)

Water hammer	—	Sudden closure of valve
Cavitation	—	Vapour pressure
Rise of sap in tree	—	Capillarity
Spherical shape of rainwater drop	—	Surface tension

1.43 (c)

Ideal fluid is inviscid *i.e.*, it has zero viscosity. For Newtonian fluid,

Shear stress: $\tau = \mu \dfrac{du}{dy}$

For real fluid viscosity is non zero.

1.44 (c)

Thermal diffusivity: $\alpha = \dfrac{k}{\rho c_p}$ m^2/s

Kinematic viscosity: $\nu = \dfrac{\mu}{\rho}$ m^2/s

Dynamic viscosity, μ has unit **Ns/m^2**

Mass diffusivity has also unit of **Nm^2/s**

1.45 (a)

A fluid is a substance that deforms continuously under the application of shear stress no matter how small the shear stress may be. Fluid can be any substance which cannot resist a shear stress when at rest.

1.46 (b)

For gases, viscosity increases with increase in temperature while for liquids it decreases with increase in temperature. In liquid, the viscosity is governed by the cohesive forces between the molecular of the liquid, whereas in gases, the molecular activity plays a dominant role.

1.47 (a)

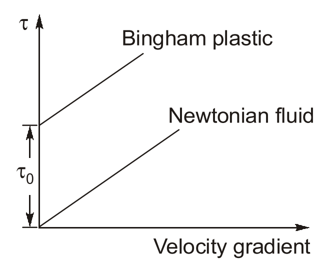
Pressure intensity inside a soap bubble,

$$p = \frac{4\sigma}{r}$$

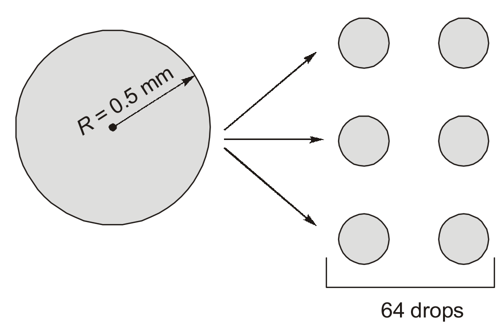
$$\therefore \quad \sigma = \frac{pr}{4} = \frac{25\times 25\times 10^{-3}}{4}$$

$$= 0.15625 \text{ N/m}$$

1.49 (b)



1.51 (b)



Volume before splitting = Volume after splitting

$$\frac{4}{3}\pi R^3 = n\times\frac{4}{3}\pi r^3$$

$$r = \frac{R}{n^{1/3}} = \frac{0.5}{(64)^{1/3}} = \frac{0.5}{4} = 0.125 \text{ mm}$$

$$W = \sigma(\Delta A)$$

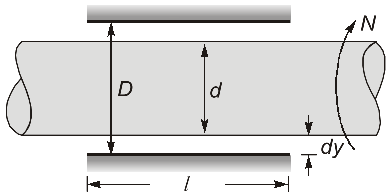
$$= 0.073\times(n\times 4\pi r^2 - 4\pi R^2)$$

$$= 0.073 \times 4\pi\,[64 \times (0.125)^2 - (0.5)^2]$$

$$= 0.073\times 4\pi\,[64\times(0.125)^2 - (0.5)^2]\times 10^{-6}$$

$$= 0.69 \times 10^{-6} \text{ J}$$

1.52 (c)



Given: d = 150 mm, N = 1500 rpm,

l = 200 mm, D = 150.5 mm

μ = 0.8 poise = 0.08 Ns/m^2

Clearance between the bearing and the journal,

$$dy = \frac{D-d}{2} = \frac{150.5-150}{2} = 0.25 \text{ mm}$$

$$= 0.25 \times 10^{-3} \text{ m}$$

The peripheral speed of the shaft,

$$u = \frac{\pi DN}{60} = \frac{\pi \times 0.150 \times 1500}{60}$$

$$= 11.78 \text{ m/s}$$

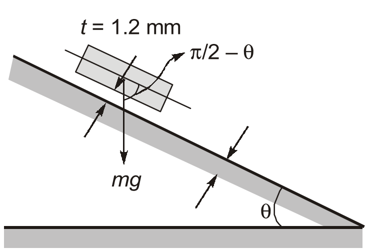
$$du = u - 0 = u = 11.78 \text{ m/s}$$

The Shear stress on the shaft,

$$\tau = \mu \frac{du}{dy} = \frac{0.08 \times 11.78}{0.25 \times 10^{-3}}$$

$$= 3769.6 \text{ N/m}^2 \approx 3.77 \text{ kN/m}^2$$

1.54 (d)



$$mg\cos\left(\frac{\pi}{2} - \theta\right) = \frac{\mu v}{t} \times A$$

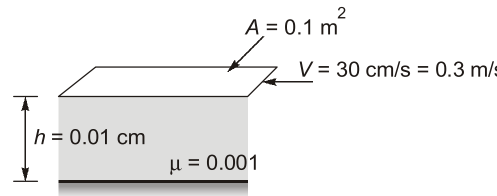
$$\text{mg sin } \theta = \frac{\mu v}{t} \times A$$

$$150 \times \sin 30 = \frac{\mu \times 0.2}{1.2 \times 10^{-3}} \times (0.8 \times 0.8)$$

$$\mu = 0.703 \frac{\text{N} \cdot \text{s}}{\text{m}^2}$$

1.55 (c)

Area of plate, A = 0.1 m^2



$$\text{Power} = F \times V$$

$$= (\tau A)V = \left(\mu \frac{V}{h}\right) \times AV$$

$$= 0.001 \frac{0.3}{0.01 \times 10^{-2}} \times 0.1 \times 0.3$$

$$= 0.09 \text{ W}$$

1.56 (b)

Change in pressure,

$$dp = 6 - 3 = 3 \text{ MN/m}^2$$

$$= 3 \times 10^6 \text{ N/m}^2$$

%change in volume,

$$\frac{dV}{V} = \frac{-0.1}{100}$$

Bulk modulus,

$$K = \frac{dp}{\left(-\frac{dV}{V}\right)} = \frac{(6-3)}{(0.001)}$$

$$= 3 \times 10^9 \text{ N/m}^2$$

1.57 (a)

- In liquids, main cause of viscosity is cohesion between the molecules. With increase in temperature, this cohesive force decreases as the energy of particles become more, hence movement of particles become free and easy. Therefore, viscosity in liquid decreases with temperature.
- In gases, the important cause of viscosity is randomness/molecular collision due to RMS velocity. Due to rise in temperature, K.E. of molecules increases which makes RMS to increase, hence randomness and collision of molecules increased. This makes the flow difficult, therefore viscosity in gases increases with temperature.

1.58 (a)

$S = 1.9,\ \rho = 1900\ \text{kg/m}^3,$

$\nu = 6 \times 10^{-4}\ \text{m}^2/\text{s},$

$\mu = \nu \times \rho = 1.14\ \text{Ns/m}^2$

1.59 (a)

Given: $A = 1.5 \times 10^6\ \text{mm}^2$

$= 1.5 \times 10^6 \times 10^{-6} = 1.5\ \text{m}^2$

$V = 0.4\ \text{m/s}$

$y = 0.15\ \text{mm} = 0.15 \times 10^{-3}\ \text{m}$

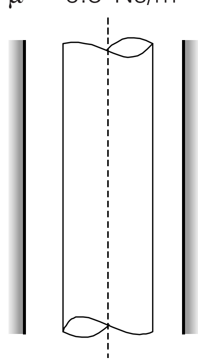
$\mu = 1\ \text{poise} = 0.1\ \text{kg/m-s}$

$$P = F \times V = \frac{\mu AV}{y} \times V = \frac{\mu AV^2}{y}$$

$$P = \frac{0.1 \times 1.5 \times (0.4)^2}{(0.15 \times 10^{-3})} = 160\ \text{W}$$

1.60 (a)

Given: $d = 0.35$ m, $N = 200$ rpm, $L = 100$ mm, $y = 2$ mm, $\mu = 0.8$ Ns/m²



$$\omega = \frac{2\pi \times 200}{60}$$

$$T = F \times R = \frac{\mu AV \times R}{y}$$

$$= \frac{\mu 2\pi RLR\omega}{y} \times R$$

$$= \frac{2\pi\omega LR^3}{y}$$

$$= \frac{2\pi(0.8)(20.44) \times 0.1 \times 5.359375 \times 10^{-3}}{2 \times 10^{-3}}$$

$= 28.20$

$P = T \times \omega = 0.59\ \text{kW}$

1.61 (c)

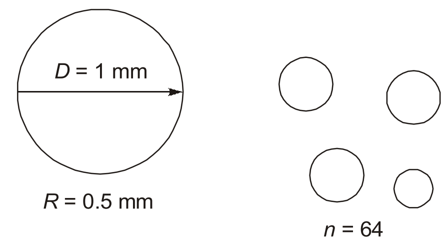
Workdone in splitting the drop is given by,

$W = \sigma \times 4\pi R^2\ [n^{1/3} - 1]$

$W = 0.073 \times 4\pi \times (0.5 \times 10\text{–}3)^2[(64)^{1/3} - 1]$

$W = 0.69 \times 10^{-6}\ \text{J}$

Alternatively,



W.D. = (Change in surface area)σ

$$= 0.073\left[n4\pi r^2 - 4\pi R^2\right]$$

$$= 0.073\left[n \times \frac{4\pi R^2}{n^{2/3}} - 4\pi R^2\right];\ r = \frac{R}{n^{1/3}}$$

$$= 0.073\left[4\pi R^2 n^{1/3} - 4\pi R^2\right]$$

$$= 0.0734\pi R^2\left[n^{1/3} - 1\right]$$

$$= 0.073 \times 4\pi\left(0.5 \times 10^{-3}\right)^2\left[(64)^{1/3} - 1\right]$$

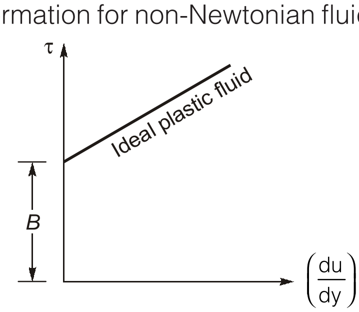
$= 0.69 \times 10^{-6}\text{J}$

1.62 (c)

- Viscosity of liquid decreases with increase in temperature.
- Viscosity of gas increases with increase in temperature.

1.63 (d)

The relation between shear stress and rate of deformation for non-Newtonian fluid is given as



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