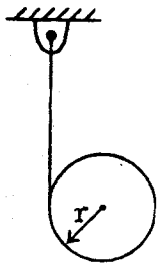
106. A cord is wrapped around a cylinder of radius 'r' and mass 'm' as shown in the given figure. If the cylinder is released from rest, the velocity of the cylinder, after it has moved through a distance 'h' will be



(*a*) $\sqrt{2gh}$ (*b*) $\sqrt{gh}$
(*c*) $\sqrt{4gh/3}$ (*d*) $\sqrt{gh/3}$.

Sol. (*a*). Since cylinder falls freely under effect of gravity, it follows basic law of motion and $v^2 = 2gh$ and $v = \sqrt{2gh}$.

107. Consider the following statements

1. A round bar in a round hole form a turning pair.
2. A square bar in a square hole forms a sliding pair.
3. A vertical shaft in a footstep bearing forms a successful constraint.

Of these statements

(*a*) 1 and 2 are correct (*b*) 2 and 3 are correct
(*c*) 1 and 3 are correct (*d*) 1, 2 and 3 are correct.

Sol. (*d*). All the statements are correct.

108. The connection between the piston and cylinder in a reciprocating engine corresponds to

(*a*) completely constrained kinematic pair (*b*) incompletely constrained kinematic pair
(*c*) successfully constrained kinematic pair (*d*) single link.

Sol. (*a*). Connection between piston and cylinder corresponds to a completely constrained kinematic pair.

109. A bicycle remains stable in running through a bend because of

(*a*) gyroscopic action (*b*) Coriolis' acceleration
(*c*) centrifugal action (*d*) radius of curved path.

Sol. (*c*). A bicycle remains stable in running through a bend because of centrifugal action.

110. The Whitworth quick return mechanism is formed in a slider-crank chain when the

(*a*) coupler link is fixed (*b*) longest link is a fixed link
(*c*) slider is a fixed link (*d*) smallest link is a fixed link.

Sol. (*a*). The Whitworth quick return mechanism is formed in a slider crank chain when the coupler link is fixed.

111. For an involute gear, the ratio, pitch circle radius/base circle radius is (ϕ is the pressure angle)

(*a*) $\sin\phi$ (*b*) $\cos\phi$
(*c*) $\sec\phi$ (*d*) $\operatorname{cosec}\phi$.

Sol. (*b*). $\dfrac{\text{pitch circle radius}}{\text{basic circle radius}} = \cos\phi$.

112. The most suitable bearing for carrying very heavy loads with slow speed is

(*a*) hydrodynamic bearing (*b*) ball bearing
(*c*) roller bearing (*d*) hydrostatic bearing.

Sol. (*d*). The most suitable bearing for carrying very heavy loads with slow speed is hydrostatic bearing.

113. Thrust bearings of the sliding type are often provided with multiple sector-shaped bearing pads of the tilting type instead of a continuous annular bearing surface in order to

(*a*) distribute the thrust load more non-uniformly
(*b*) provide limited adjustments to shaft misalignments
(*c*) enable the formation of a wedge-shaped oil film
(*d*) enable lubricating oil to come into contact with the total bearing area.

Sol. (*c*). Sector-shaped bearing pads of tilting type are produced to enable the formation of a wedge-shaped oil film.

114. A 50 kW motor using six vee belts is used in a pulp mill. If one of the belts breaks after a month of continuous running, then

(*a*) the broken belt is to be replaced by a similar belt
(*b*) all the belts are to be replaced
(*c*) the broken belt and two adjacent belts are to be replaced
(*d*) the broken belt and one adjacent belt are to be replaced.

Sol. (*b*). If one V-belt breaks, all have to be replaced for uniform tension.

115. Static balancing is satisfactory for low speed rotors but with increasing speeds, dynamic balancing becomes necessary. This is because, the

(*a*) unbalanced couples are caused only at higher speeds
(*b*) unbalanced forces are not dangerous at higher speeds
(*c*) effects of unbalances are proportional to the square of the speed
(*d*) effects of unbalances are directly proportional to the speed.

Sol. (*c*). (*c*) is correct reason.

116. The assumption of viscous damping in practical vibrating system is

(*a*) one of reality
(*b*) to make the resulting differential equation linear
(*c*) to make the resulting differential equation non-linear
(*d*) to make the response of the mass linear with time.

Sol. (*a*). Assumption of viscous damping is one of reality.

117. The ratio of the maximum dynamic displacement due to a dynamic force to the deflection due to the static force of the same magnitude is called the

(*a*) displacement ratio (*b*) deflection ratio
(*c*) force factor (*d*) magnification factor.

Sol. (*d*). Max. dynamic displacement/deflection due to static force = magnification factor.

118. For effective vibration isolation, the natural frequency ω_n of the system must be (ω is the forcing frequency)

(*a*) $\omega/4$ (*b*) ω
(*c*) 4ω (*d*) 10ω.

Sol. (a). For effective vibration isolation $\omega_n = \omega/4$.

119. A reed type tachometer uses the principle of

(*a*) torsional vibration (*b*) longitudinal vibration
(*c*) transverse vibration (*d*) damped free vibration.

Sol. (c). A reed type tachometer uses the principle of transverse vibration.

120. Consider the following statements

The critical speed of a shaft is affected by the

1. eccentricity of the shaft 2. span of the shaft
3. diameter of the shaft

Of these statements

(*a*) 1 and 2 are correct (*b*) 1 and 3 are correct
(*c*) 2 and 3 are correct (*d*) 1, 2 and 3 are correct .

Sol. (*d*). Statements 1, 2 and 3 are correct.

Civil Services Examination (Preliminary)

MECHANICAL ENGINEERING—1995

Time Allowed : 2 hours Max. marks : 300

1. Which of the following are the inversions of double slider crank mechanism ?

1. Oldham coupling
2. Whitworth quick return mechanism
3. Beam engine mechanism
4. Elliptic trammel mechanism

Select the correct answer from the codes given below :

Codes :

(*a*) 1 and 2 (*b*) 1 and 4

(*c*) 1, 2 and 3 (*d*) 2, 3 and 4.

Sol. (*b*). The inversions of double slider crank mechanism are

(*i*) First inversion — Elliptic Trammel, (*ii*) Second inversion — Scotch Yoke

(*iii*) Third inversion — Oldham's coupling

Thus out of the choices given, only 1 and 4 are correct and therefore right choice is (*b*).

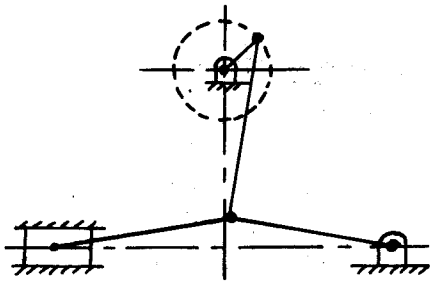
2. Which of the following is a higher pair ?

(*a*) Belt and pulley (*b*) Turning pair

(*c*) Screw pair (*d*) Sliding pair

Sol. (*a*). A higher pair is one having point or line contact. Thus (*a*) is the correct choice.

3. The machanism shown in the given figure represents



(*a*) Hart's mechanism

(*b*) Toggle mechanism

(*c*) Watt's mechanism

(*d*) Beam Engine mechanism

Sol. (*b*). The mechanism shown is of toggle mechanism.

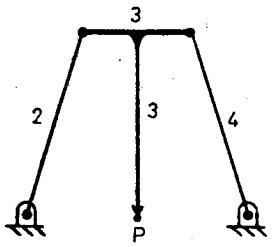
4. A point on a connecting link (excluding end points) of a double slider crank mechanism traces a

(*a*) straight line path (*b*) hyperbolic path

(*c*) parabolic path (*d*) elliptical path.

Sol. (*d*). A point on a connecting link (excluding end points) of a double slider crank mechanism traces an elliptical path.

5. In the four bar mechanism shown in the given figure, links 2 and 4 have equal length. The point *P* on the coupler 3 will generate a/an



(*a*) ellipse (*b*) parabola

(*c*) approximately straight line (*d*) circle.

Sol. (*a*) Point P being rigidly connected to point 3, will trace same path as point 3, *i.e.* ellipse.

6. Deep groove ball bearings are used for

(*a*) heavy thrust load only

(*b*) small angular displacement of shafts

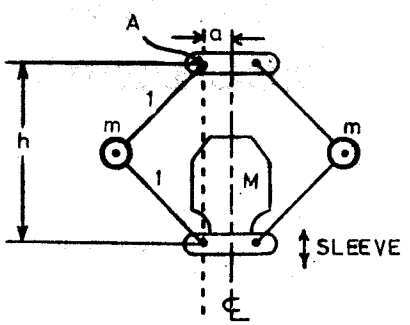
(*c*) radial load at high speed (*d*) combined thrust and radial loads at high speed.

Sol. (*d*). Deep groove ball bearings are primarily designed to support radial loads at high speeds. However, this type of construction permits the bearing also to support relatively high thrust loads in either direction.

7. The sensitivity dh/dN of a given Porter Governor, where 'h' is the height of the pin point A from the sleeve and N is the r.p.m., is proportional to

(*a*) N^2 (*b*) N^3

(*c*) $\frac{1}{N^2}$ (*d*) $\frac{1}{N^3}$



Sol. (*d*). For Porter governer,

$$h \propto \frac{1}{N^2} \qquad \therefore \qquad \frac{dh}{dN} \propto \frac{1}{N^3}$$

8. Balancing of a rigid rotor can be achieved by appropriately placing balancing weights in

(*a*) a single plane (*b*) two planes

(*c*) three planes (*d*) four planes

Sol. (*b*). An unbalance rigid rotor behaves as if several masses are there in different planes. Such a situation can be handled by fixing balancing weights in two planes.

9. A machine mounted on a single coil spring has a period of free vibration of T. If the spring is cut into four equal parts and placed in parallel and the machine is mounted on them, then the period of free vibration of the new system will become

(*a*) $16\,T$ (*b*) $4\,T$

(*c*) $\frac{T}{4}$ (*d*) $\frac{T}{16}$

Sol. (*c*). Period of free vibration of a spring $T \propto \sqrt{\frac{1}{k}}$ (k = spring stiffness). When a spring is cut into 4 equal pieces, spring stiffness of each cut spring will be $4k$.

When four such springs are placed in parallel, spring stiffness of combination will be $4 \times (4k) = 16k$.

Thus new $T \propto \sqrt{\frac{1}{16k}}$ or $\frac{T}{4}$.

10. Which one of the following pairs is correctly matched.

(*a*) Coulomb ..... Energy Principle

(*b*) Rayleigh ..... Dynamic Equilibrium

(*c*) D'Alembert ..... Damping Force

(*d*) Fourier ..... Frequency domain analysis

Sol. (*d*). Coulomb is concerned with damping force, Rayleigh with energy principle, D'Alembert with dynamic equilibrium, and Fourier with frequency domain analysis. Thus the correctly matched pair is (*d*) only.

11. Whirling speed of a shaft coincides with the natural frequency of its

(*a*) longitudinal vibration (*b*) transverse vibration

(*c*) torsional vibration (*d*) coupled bending torsional vibration

Sol. (*a*). Whirling speed of shaft $= \sqrt{g/\delta}$, which is the natural frequency of its longitudinal vibration.

12. There are six gears A, B, C, D, E, F in a compound train. The numbers of teeth in the gears are 20, 60, 30, 80, 25 and 75 respectively. The ratio of the angular speeds of the driven (F) to the driver (A) of the drive is

(*a*) $\frac{1}{24}$ (*b*) $\frac{1}{8}$

(*c*) $\frac{4}{15}$ (*d*) 12

Sol. **(a).** The ratio of angular speeds of

$$F \text{ to } A \qquad = \frac{T_A \cdot T_C \cdot T_E}{T_B \cdot T_D \cdot T_F} = \frac{20 \times 30 \times 25}{60 \times 80 \times 75} = \frac{1}{24}$$

13. A fixed gear having 100 teeth meshes with another gear having 25 teeth, the centre lines of both the gears being joined by an arm so as to form an epicyclic gear train. The number of rotations made by the smaller gear for one rotation of the arm is

(*a*) 3 (*b*) 4

(*c*) 5 (*d*) 6

Sol. **(c).** Revolution of 25 teeth gear $= 1 + \frac{T_{100}}{T_{25}}$ (for one rotation of arm) $= 1 + \frac{100}{25} = 5$

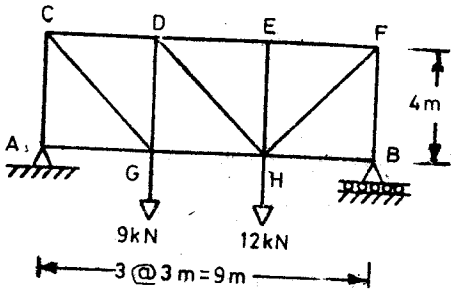
14. A truss of span 9 m is loaded as shown in the given figure. The number of two-force members carrying zero force is

(*a*) one

(*b*) two

(*c*) three

(*d*) four



Sol. **(d).** The vertical and horizontal reactions at any point have to be zero. Considering the points at *A*, *B*, and *E*, it will be noted that there are no horizontal force acting on these points. Thus there are no stresses in members *AG*, *HB*, *ED* and *EF*. Thus number of zero force members are four.

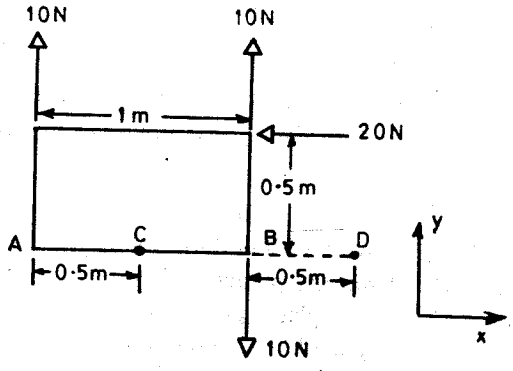
15. A system of forces acting on a lamina is shown in the given figure. The resultant of the force system will meet *AB* at

(*a*) *A*

(*b*) *B*

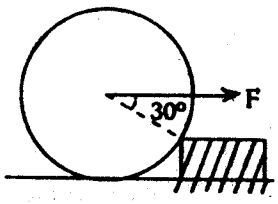
(*c*) *C*

(*d*) *D*.

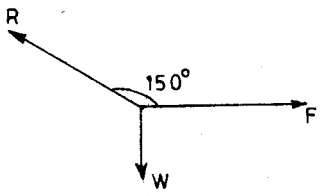


Sol. **(c).** The resultant force will meet at *C*.

16. A roller of weight *W* is rolled over the wooden block shown in the given figure. The pull *F* required to just cause the said motion is



(*a*) $W/2$ (*b*) W
(*c*) $\sqrt{3}\,W$ (*d*) $2W$.



Sol. (*c*). $R\cos 60° = W$, or $R = \dfrac{W}{1/2} = 2W$

Also $R\cos 30° = F$, and $F = 2W \times \dfrac{\sqrt{3}}{2} = \sqrt{3}\,W$.

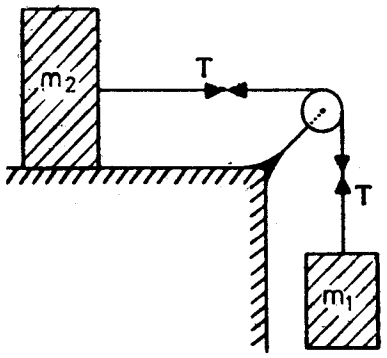
17. In the given figure, two bodies of masses m_1 and m_2 are connected by a light inextensible string passing over a smooth pulley. Mass m_2 lies on a smooth horizontal plane. When mass m_1 moves downwards, the accleration of the two bodies is equal to

(*a*) $\dfrac{m_1 g}{m_1 + m_2}$ m/s^2

(*b*) $\dfrac{m_2 g}{m_1 - m_2}$ m/s^2

(*c*) $\dfrac{m_2 g}{m_1 + m_2}$ m/s^2

(*d*) $\dfrac{m_1 g}{m_1 - m_2}$ m/s^2



Sol. (*a*). $m_1 - T = m_1 \times a$

Also $m_2 a = T - m_2$

From these equations, $a = \dfrac{m_1 g}{m_1 + m_2}$

18. A ball is projected vertically upward with a certain velocity. It takes 40 seconds for its upward journey. The time taken for its downward journey is

(*a*) 10 s (*b*) 20 s
(*c*) 30 s (*d*) 40 s.

Sol. (*d*). Time in upward journey is same as in downward journey.

19. Match List I with List II and select the correct answer using the codes given below the lists :

List I	*List II*
A. Two parallel forces acting on a body, moving with uniform velocity	1. Kinetic energy
B. A moving particle	2. Couple
C. Two coplanar parallel forces equal in magnitude and opposite in direction acting on a body	3. Forces in equilibrium
D. Two unequal forces acting on a body	4. Cause acceleration

Codes :

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

Sol. (*c*). Code (*c*) provides correct matching.

20. A spring of stiffness 1000 N/M is stretched initially by 10 cm from the undeformed position. The work required to stretch it by another 10 cm is

(*a*) 5 Nm (*b*) 7 Nm
(*c*) 10 Nm (*d*) 15 Nm.

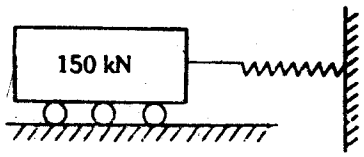
Sol. (*d*). Initial stretch of spring is 10 cm

$\therefore$ Force in spring $= 1000 \times 0.1 = 100\,N$

To further stretch it by 10 cm, new force will be 200 N

$\therefore$ Work to stretch by 10 cm $= \dfrac{100 + 200}{2} \times 0.1 \text{ m} = 15 \text{ Nm}.$

21. A truck weighing 150 kN and travelling at 2m/sec impacts with a buffer spring which compresses 1.25 cm per 10 kN. The maximum compression of the spring is



(*a*) 20.00 cm (*b*) 22.85 cm
(*c*) 27.66 cm (*d*) 30.00 cm.

Sol. (*c*). Spring constant for each bumper = 10 kN/1.25 cm $= \dfrac{10 \times 1000 \times 100}{1.25} = \text{N/m}$

Let the compression of each spring be x m

Energy stored in each spring $= \dfrac{kx^2}{2} = 8 \times 10^5 \times \dfrac{x^2}{2} = 4x^2 \times 10^6$ J

Weight of wagon = 150 kN, m = mass $= \dfrac{150 \times 10^3}{9.81}$ kg ; $\therefore$ $\dfrac{150 \times 2 \times 10^3}{9.81} = 4 \times x^2 \times 10^5$

or $$x = \sqrt{\frac{15}{20 \times 9.81}} = \sqrt{\frac{15}{196.2}} = 0.2766 = 27.66 \text{ cm}$$

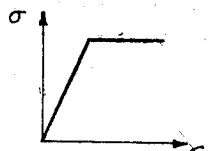
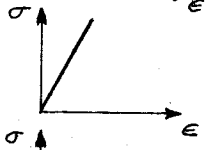
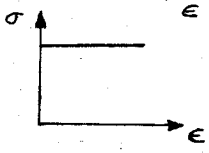
22. In an axi-symmetric plane strain problem, let u be the radial displacement at r. Then the strain components ε_r, ε_θ, $\gamma_{r\theta}$ are given by

(*a*) $\varepsilon_r = \dfrac{u}{r}, \varepsilon_\theta = \dfrac{\partial u}{\partial r}, \gamma_{r\theta} = \dfrac{\partial^2 u}{\partial r \partial \theta}$ (*b*) $\varepsilon_r = \dfrac{\partial u}{\partial r}, \varepsilon_\theta = \dfrac{u}{r}, \gamma_{r\theta} = 0$

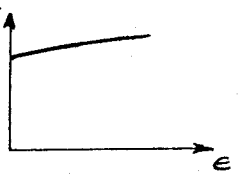
(*c*) $\varepsilon_r = \dfrac{u}{r}, \varepsilon_\theta = \dfrac{\partial u}{\partial r}, \gamma_{r\theta} = 0$ (*d*) $\varepsilon_r = \dfrac{\partial u}{\partial r}, \varepsilon_\theta = \dfrac{\partial u}{\partial \theta}, \gamma_{r\theta} = \dfrac{\partial^2 u}{\partial r \partial \theta}.$

Sol. (*a*). The strain components specified in choice (*a*) are correct.

23. Match List I with List II and select the correct answer using the codes given below the lists :

List I		*List II*
A. Rigid-Perfectly plastic	1.	
B. Elastic-Perfectly plastic	2.	
C. Rigid-Strain hardening	3	

D. Linearly elastic

4. 

Codes

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

Sol. (a). A rigid-perfectly plastic material will not yield till a particular load is applied, after which it keeps on stretching as same stresses maintained. This situation is reflected in figure 3 above. An elastic-perfectly plastic material would behave as shown in figure 1. The behaviour of rigid-strain hardening and linearly elastic materials is as per figures 4 and 2 respectively. Thus correct choice is (a).

24. The independent elastic constants for a homogenous and isotropic material are

(a) E, G, K, ν (b) E, G, K
(c) E, G, ν (d) E, G

Sol. (a). The independent elastic constants for a homogeneous and isotropic materials are E, G, K, ν.

25. Which one of the following materials is highly elastic ?

(a) Rubber (b) Brass
(c) Steel (d) Glass.

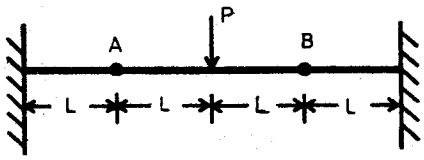
Sol. (c). Steel is the highly elastic material because it is deformed least on loading, and retains its original form on removal of the load.

26. In a homogenous, isotropic elastic material, the modulus of elasticity E in terms of G and K is equal to

(a) $\frac{G+3K}{9KG}$ (b) $\frac{3G+K}{9KG}$
(c) $\frac{9KG}{G+3K}$ (d) $\frac{9KG}{K+3G}$

Sol. (c). The relationship between E, K and G is $E=\frac{9KG}{G+3K}$

27. A beam AB of length $2L$ having a concentrated load P at its mid-span is hinge-supported at its two ends A and B on two identical cantilevers as shown in the given figure. The correct value of bending moment at A is



(a) zero
(b) PL/2
(c) PL
(d) 2 PL

Sol. (a). Because of hinge support between beam AB and cantilevers, the bending moment can't be transmitted to cantilever. Thus bending moment at points A and B is zero.

28. For the loaded beam shown in figure I, the correct shear force diagram is

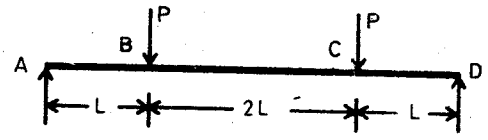
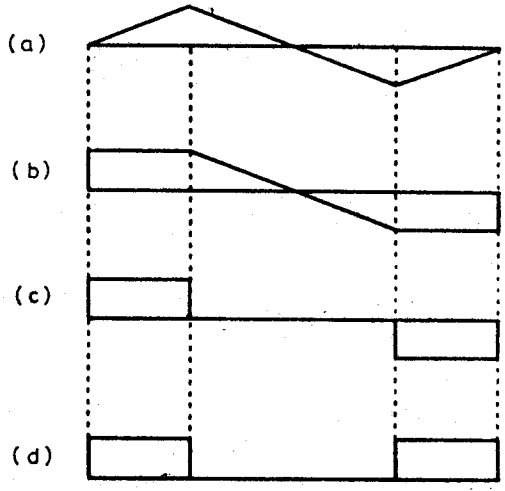


Fig.1



Sol. (*d*). Figure (*d*) represents the correct shear force diagram for the type of loading shown.

29. Two shafts of same length and material are joined in series. If the ratio of their diameters is 2, then the ratio of their angles of twist will be

(*a*) 2 (*b*) 4

(*c*) 8 (*d*) 16

Sol. (*d*). In a shaft, angle of twist is proportional to $\frac{1}{J}$ or $\frac{1}{d^4}$.

Thus for shafts having diameters in ratio of 2, polar moment of inertias will be in the ratio of 16 and thus angle of twists will be in the ratio of 16.

30. Total strain energy stored in a simply supported beam of span '*L*' and flexural rigidity '*EI*' subjected to a concentrated load '*W*' at the centre is equal to

(*a*) $\frac{W^2L^3}{40EI}$ (*b*) $\frac{W^2L^3}{60EI}$

(*c*) $\frac{W^2L^3}{96EI}$ (*d*) $\frac{W^2L^3}{240EI}$

Sol. (*c*). Total strain energy of beam $= \int_0^L \frac{M^2 dx}{2EI}$. For simply supported beam of length L having a concentrated load W, bending moment upto middle of shaft $= \frac{W}{2}x$

$$\therefore \text{Energy stored in half shaft} = \frac{1}{2EI}\int_0^{L/2}\left(\frac{W}{2}\times x\right)^2 dx = \frac{W}{8EI}\left[\frac{x^3}{3}\right]_0^{1/2} = \frac{W}{24EI}\left[\frac{L^3}{8}\right] = \frac{WL^3}{192EI}$$

$\therefore$ Total strain energy stored in total shaft $= \dfrac{WL^3}{96EI}$

31. A column of length 'l' is fixed at its both ends. The equivalent length of the column is

(*a*) $2\,l$ (*b*) $0.5\,l$

(*c*) $4\,l$ (*d*) l.

Sol. (*b*). The equivalent length of a column fixed at both ends is $l/2$ (l = length of column).

32. A solid circular shaft is subjected to a maximum shearing stress of 140 MPa. The magnitude of the maximum normal stress developed in the shaft is

(*a*) 140 MPa (*b*) 80 MPa

(*c*) 70 MPa (*d*) 60 MPa.

Sol. (*a*). Maximum shear stress $s_s = \dfrac{s_{n1} - s_{n2}}{2}$

where s_{n1} and s_{n2} are maximum and minimum normal stresses.

s_{n1} can be maximum when $s_{n2} = 0$ and $s_{n1} = 2s_s$

Now s_s = 140 MPa and the four possible answers given have maximum value of only 140 MPa.

Thus maximum normal stress = 140 MPa.

33. The shear stress at a point in a shaft subjected to a torque is

(*a*) directly proportional to the polar moment of inertia and to the distance of the point from the axis

(*b*) directly proportional to the applied torque and inversely proportional to the polar moment of inertia

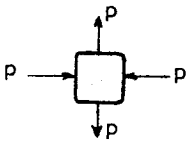
(*c*) directly proportional to the applied torque and polar moment of inertia

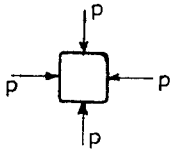
(*d*) inversely proportional to the applied torque and the polar moment of inertia

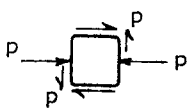
Sol. (*b*). For shaft, $\dfrac{T}{J} = \dfrac{s_s}{r}$ or $s_s \propto \dfrac{T}{J}\dfrac{\text{(torque)}}{\text{(Polar M.I.)}}$.

34. A solid thick cylinder is subjected to an external hydrostatic pressure p. The state of stress in the material of the cylinder is represented as

(*a*) 

(*b*) 

(*c*) 

(*d*) 

Sol. (*b*). Whenever a solid thick cylinder is subjected to an external hydrostatic pressure p, it is compressed equally from all sides. Thus figure (*b*) gives the state of stress.

35. An open-coiled helical spring of mean diameter D, number of coils N and wire diameter d is subjected to an axial force P. The wire of the spring is subject to

(*a*) direct shear only (*b*) combined shear and bending only

(*c*) combined shear, bending and twisting (*d*) combined shear and twisting only

Sol. (*d*). The wire of an open coiled helical spring is subjected to combined shear and twisting.

36. Match List I with List II and select the correct answer using the codes given below the lists :

List I (Property)	*List II (Testing Machine)*
A. Tensile strength	1. Rotating Bending Machine
B. Impact strength	2. Three-Point Loading Machine
C. Bending strength	3. Universal Testing Machine
D. Fatigue strength	4. Izod Testing Machine

Codes :

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

Sol. (*d*). Tensile strength is measured on universal testing machine, impact strength on izod testing machine, bending strength on three-point loading machine, and fatigue strength on rotating bending machine. Thus the correct choice is (*d*).

37. Thrust force will increase with the increase in

(*a*) side cutting edge angle (*b*) tool nose radius
(*c*) rake angle (*d*) end cutting edge angle.

Sol. (*a*). Thrust force will increase with increase in side cutting edge angle.

38. In an orthogonal cutting, the depth of cut is halved and the feed rate is doubled. If the chip thickness ratio is unaffected with the changed cutting conditions, the actual chip thickness will be

(*a*) doubled (*b*) halved
(*c*) quadrupled (*d*) unchanged.

Sol. (*a*). Chip thickness ratio $= \dfrac{\text{depth of cut}}{\text{chip thickness}}$

Since chip thickness ratio remains same, and depth of cut is halved, therefore the chip thickness will be doubled.

39. In a single point turning operation with a cemented carbide and steel combination having a Taylor exponent of 0.25, if the cutting speed is halved, then the tool life will become

(*a*) half (*b*) two times
(*c*) eight times (*d*) sixteen times.

Sol. (*d*). $V_2T_2^{0.25} = V_1T_1^{0.25} = C = \left(\dfrac{V_1}{2}\right)T_2^{0.25}$, or $\left(\dfrac{T_2}{T_1}\right)^{0.25} = 2$, or $\left(\dfrac{T_2}{T_1}\right) = 2^4 = 16$.

Thus new tool life will become 16 times.

40. Size of a shaper is given by

(*a*) stroke length (*b*) motor power
(*c*) weight of the machine (*d*) rate size.

Sol. (*a*). Size of shaper is given by stroke length.

41. A drill bit of 20 mm diameter rotating at 500 rpm with a feed rate of 0.2 mm/revolution is used to drill a through-hole in a MS plate of 20 mm thickness. The depth of cut in this drilling operation is

(*a*) 100 mm (*b*) 20 mm
(*c*) 10 mm (*d*) 0.2 mm.

Sol. (*b*). Since the thickness of MS plate is 20 mm, the depth of cut should also be 20 mm.

42. Match List I with List II and select the correct answer using the codes given below the lists :

List I (Material/Part)	*List II (Techniques)*
A. Ductile iron	1. Inoculation
B. Malleable iron	2. Chilled
C. Rail steel joints	3. Annealing
D. White cast iron	4. Thermit welding
	5. Isothermal annealing

Codes :

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

Sol. (*a*). The correct matching is provided by code (*a*).

43. In blanking operation the clearance provided is

(*a*) 50% on punch and 50% on die (*b*) on die

(*c*) on punch

(*d*) on die or punch depending upon designer's choice

Sol. (*c*). In blanking operation, die should be given exact size and clearance is provided on the punch.

44. Consider the following states of stress :

1. Compressive stress in flange, 2. Tensile stress in the wall,
3. Tensile stress in the bottom part.

During drawing operation, the states of stress in cup would include

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

(*c*) 2 and 3 (*d*) 1, 2 and 3.

Sol. (*a*). In drawing operation, no cold operation is done in the bottom area and thus tensile stress in bottom part is not experienced. States of stress at 1 and 2 are correct. Thus (*a*) is right choice.

45. The following operations are performed while preparing the billets for extrusion process :

1. Alkaline cleaning, 2. Phosphate coating,
3. Pickling, 4. Lubricating with reactive soap.

The correct sequence of these operation is

(*a*) 3, 1, 4, 2 (*b*) 1, 3, 2, 4

(*c*) 1, 3, 4, 2 (*d*) 3, 1, 2, 4

Sol. (*d*). The correct sequence for preparing a billet for extrusion process is picking, alkaline cleaning, phosphate coating, and lubricating with reactive soap.

46. Which one of the following techniques is used for determining allowances in time study ?

(*a*) Acceptance sampling (*b*) Linear regression

(*c*) Performance rating (*d*) work sampling

Sol. (*d*). Work sampling technique is used for determining allowances in time study.

47. Match List with List II and select the correct answer using the codes given below the lists :

List I (Industrial problem)	*List II (Appropriate technique)*
A. Factory layout – movement of workers	1. Multiple activity process chart
B. Factory layout – movement of materials	2. String diagram

C. Workplace layout
D. Gang work

3. Films
4. Two handed process chart
5. Flow diagram

Codes :

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

Sol. (*a*). Code at (a) provides correct matching.

48. From the point of motion economy it is preferable to move

(*a*) both hands in the same direction
(*b*) right hand first and then the left hand
(*c*) only one hand at a time
(*d*) both hands in opposite directions.

Sol. (*d*). From the point of motion economy, it is preferable to move both hands in opposite direction.

49. Production cost per unit can be reduced by

(*a*) producing more with increased inputs
(*b*) producing more with the same inputs
(*c*) eliminating idle time
(*d*) minimising resource waste.

Sol. (*b*). Production cost per unit can be reduced by producing more with the same inputs.

50. Match List I with List II and select the correct answer using the codes given below the lists :

List I

A. Statistic
B. MTM
C. Stop Watch
D. Man Machine Chart
E. Standard Time

List II

1. Performance Rating
2. Motion Study
3. Work Measurement
4. Work Sampling

Codes :

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

Sol. (*b*). Code (b) provides correct matching.

51. The variable cost per unit associated with automated assembly line (V_A), cellular manufacturing (V_B), and job shop production (V_C), will be such that

(*a*) $V_A > V_B > V_C$
(*b*) $V_B > V_A > V_C$
(*c*) $V_C > V_B > V_A$
(*d*) $V_C > V_A > V_B$.

Sol. (*c*). Variable cost per unit is least with automated assembly line, and maximum with job shop production. Thus $V_C > V_B > V_A$.

52. To avoid excessive multiplication of facilities, the layout preferred is

(*a*) product layout
(*b*) group layout
(*c*) static layout
(*d*) process layout.

Sol. (*d*). To avoid excessive multiplication of facilities, process layout should be used.

53. For moving materials in varying paths, the material handling equipment that is not suitable is

(*a*) crane (*b*) conveyor
(*c*) truck (*d*) hand trolley.

Sol. (*b*). For moving materials is varying paths, conveyor is not suited which is used for fixed path.

54. Which of the following characteristics are more important in the equipment selected for mass production shops ?

1. Fast output. 2. Low tooling cost.
3. Low labour cost. 4. Versatility.

Sol. (*a*). Fast output and low labour cost are more important characteristics for mass production shop.

55. Which one of the following charts gives simultaneously, information about the progress of work and machine loading ?

(*a*) Process chart (*b*) Machine load chart
(*c*) Man-machine chart (*d*) Gantt chart.

Sol. (*c*) Man-machine chart gives simultaneously information about the progress of work and machine loading.

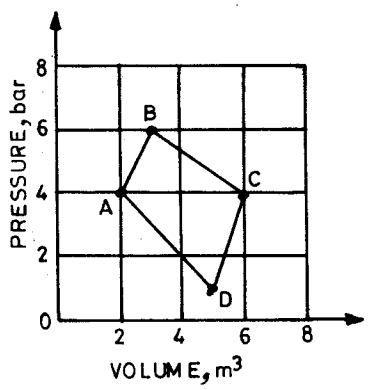
56. Which one of the following pairs is not correctly matched ?

(*a*) SPT Rule ..... fairness to all jobs
(*b*) EDD rule ..... lateness minimization
(*c*) Johnsons Rule ..... two machine sequencing
(*d*) FIFO Rule ..... fairness to all jobs

Sol. (*a*). SPT Rule and fairness to all jobs is not the correct matching.

57. The net work done for the closed cycle shown in the given pressure-volume diagram, is

(*a*) 600 kN-m (*b*) 700 kN-m
(*c*) 900 kN-m (*d*) 1000 kN-m



Sol. (*d*). Net workdone is area of closed loop $ABCD$ = Area of trapezium $AB32$ + Area $BC63$ – area $CD56$ – area $AD52$

$$= \frac{(4+6)}{2} \times (3-2) + \frac{(6+4)}{2} \times (6-3) - \left(\frac{1+4}{2}\right)(6-5) - \frac{1+4}{2} \times (5-2)$$

$$= 5 \times 1 + 5 \times 3 - 2.5 \times 1 - 2.5 \times 3$$

$$= 5 + 15 - 2.5 - 7.5 = 10 \text{ bar m}^3$$

$$= 10 \times 10^5 \frac{N}{m^2} \times m^3 = 10^6 \text{ Nm} = 1000 \text{ kNm}$$

58. The following are examples of some intensive and extensive properties :

1. Pressure 2. Temperature
3. Volume 4. Velocity
5. Electric charge 6. Magnetisation
7. Viscosity 8. Potential energy.

Which one of the following sets gives the correct combinations of intensive and extensive properties?

	Intensive	Extensive
(*a*)	1, 2, 3, 4	5, 6, 7, 8
(*b*)	1, 3, 5, 7	2, 4, 6, 8

(c) 1, 2, 4, 7 3, 5, 6, 8
(d) 2, 3, 6, 8 1, 4, 5, 7

Sol. (*c*). Intensive properties, *i.e.* independent of mass are pressure, temperature, velocity and viscosity. Extensive properties, *i.e.* dependent on mass of system are volume, electric charge, magnetisation, and potential energy. Thus correct choice is (*c*).

59. A new temperature scale in degrees *N* is to be defined. The boiling and freezing points on this scale are 400° N and 100° N respectively.

What will be the reading on new scale corresponding to 60° C?

(*a*) 120° N (*b*) 180° N
(*c*) 220° N (*d*) 280° N.

Sol. (*d*). The boiling and freezing points on new scale are 400°N and 100°N, *i.e.* range is 300° N correponding to 100° C. Thus conversion equation is

$$°N = 100 + 3 \times °C = 100 + 3 \times 60 = 100 + 180 = 280°N$$

60. If a heat engine gives an output of 3 kW when the input is 10,000 J/s, then the thermal efficiency of the engine will be

(*a*) 20% (*b*) 30%
(*c*) 70% (*d*) 76.7%.

Sol. (*b*). Thermal efficiency $= \frac{W}{Q} = \frac{3 \times 10^3 \text{ watts}}{10{,}000 \text{ J/s}} = 0.3 = 30\%.$

61. A heat engine is supplied with 250 KJ/s of heat at a constant fixed temperature of 227° C. The heat is rejected at 27° C. The cycle is reversible, if the amount of heat rejected is

(*a*) 273 KJ/s (*b*) 200 KJ/s
(*c*) 180 KJ/s (*d*) 150 KJ/s.

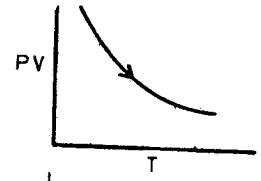
Sol. (*d*). Efficiency of reversible engine $= \frac{T_1 - T_2}{T_1}$

$$= \frac{500 - 300}{500} = \frac{200}{500} = 0.4 = \frac{\text{Work}}{\text{Heat}} = \frac{\text{Heat supplied} - \text{Heat rejected}}{\text{Heat supplied}}$$

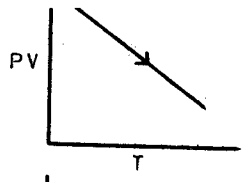
or $0.4 = \frac{250 - Q_R}{250}$, or $250 - Q_R = 100$ and $Q_R = 250 - 100 = 150$ kJ

62. Which one of the following PV-T diagrams correctly represents that of an ideal gas ?

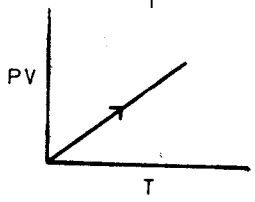
(*a*)



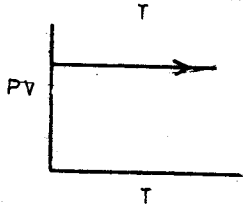
(*b*)



(*c*)

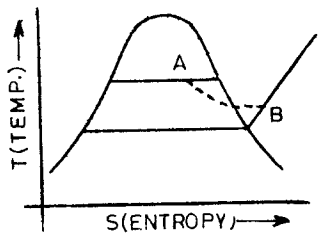


(*d*)



Sol. (*c*). For an ideal gas $PV = mRT$ *i.e.* PV and T follow direct straight line relationship, which is depicted in figure (*c*).

63. In the temperature-entropy diagram of a vapour shown in the given figure, the thermodynamic process shown by the dotted line AB represents



(*a*) hyperbolic expansion
(*b*) free expansion
(*c*) constant volume expansion
(*d*) polytropic expansion

Sol. (*b*). The curve in dotted line in the given figure on T-S diagram represents free expansion process.

64. The loss of available energy associated with the transfer of 1000 kJ of heat from a constant temperature system at 600 K to another at 400 K when the environmental temperature is 300 K is

(*a*) 166.67 kJ (*b*) 250 kJ
(*c*) 500 kJ (*d*) 750 kJ.

Sol. (*a*). Heat rejected to 400° K will be

$$\frac{600-400}{600}=\frac{Q_{1000}-Q_{400}}{Q_{1000}}=\frac{1000-Q_{400}}{1000}=\frac{1}{3}$$

or $$Q_{400}=1000-333.33=666.67 \text{ kJ}$$

Heat rejected to 300° K will be $\frac{600-300}{600}=\frac{1000-Q_{300}}{1000}=0.5$

or $$Q_{300}=1000-500=500 \text{ kJ}$$

Thus loss of available energy = 666.67 – 500 = 166.67 kJ.

65. Which one of the following pairs best expresses a relationship similar to that expressed in the pair 'pressure-volume' for a thermodynamic system undergoing a process ?

(*a*) Enthalpy-entropy (*b*) Pressure-enthalpy
(*c*) Pressure- temperature (*d*) Temperature-entropy.

Sol. (*d*). Temperature–entropy relationship is as commonly used as pressure-volume.

66. In a reversible cycle, the source temperature is 227° C and the sink temperature is 27° C. The maximum available work for a heat input of 100 kJ will be

(*a*) 100 kJ (*b*) 60 kJ
(*c*) 40 Kj (*d*) 88 kJ.

Sol. (*c*). Maximum efficiency for 227° and 27° C sources is $\frac{500-300}{500}=0.4$

$\therefore$ Max. work available for a heat input of 100 kJ is $0.4 \times 100 = 40$ kJ.

67. Consider the following statements regarding superheating in Rankine Cycles :

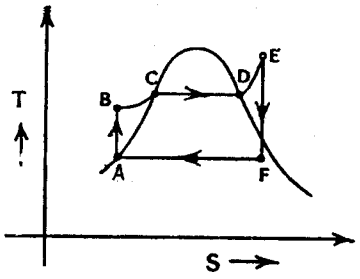
1. It reduces the specific steam consumption.
2. It increases the dryness fraction of steam at the exhaust for the same value of condenser pressure.
3. It reduces the cycle efficiency.

Of the these statements

(*a*) 1 and 2 are correct (*b*) 2 and 3 are correct
(*c*) 1 and 3 are correct (*d*) 1,2 and 3 are correct.

Sol. (*a*). Superheating in Rankine cycle increases efficiency and thus statement 3 is incorrect. Statements at 1 and 2 are correct. Thus choice (*a*) is correct.

68. A superheat Rankine Cycle is shown in the given T-S diagram. Starting from the feed pump, the fluid flow upto the boiler exit is represented by state-line



(*a*) *ABCD* (*b*) *BCDE*
(*c*) *ABDEFA* (*d*) *ABCDE*

Sol. (*c*). The state line *ABCDE* represents cycle from feed sump upto the boiler exit.

69. The correct sequence of vapour compression (VC), vapour absorption (VA) and steam ejector (SE) refrigeration cycles in increasing order of the C.O.P. is

(*a*) *VC, VA, SE* (*b*) *VA, SE, VC*
(*c*) *SE, VC, VA* (*d*) *SE, VA, VC.*

Sol. (*b*). The correct sequence of *VC, VA* and *SE* in increasing order of COP is *VA, SE* and *VC*, the value being of the order of 0.3 to 0.4, 0.5 to 0.8 and 4 to 5 respectively.

70. Match List I with List II and select the correct answers using the codes given below the lists :

List I	*List II*
A. Two constant volumes and two adiabatics	1. Ericsson
B. Two constant pressures and two adiabatics	2. Stirling
C. Two constant volumes and two isothermals	3. Joule
D. Two constant pressures and two isothermals	4. Otto

Codes :

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

Sol. (*d*). Code (*d*) provides the right matching of various cycles.

71. A nuclear reactor is said to be "critical" when the neutron population in the reactor core is

(*a*) rapidly increasing leading to the point of explosion
(*b*) decreasing from the specified value
(*c*) constant (*d*) reduced to zero.

Sol. (*c*). A nuclear reactor is critical when the neutron propultion in the reactor core is constant.

72. Consider the following statements regarding the features of a Breeder reactor :

1. It produces more fuel than it consumes.
2. It converts fertile fuel into fissile fuel.
3. It requires liquid sodium metal as moderator.
4. It requires highly enriched fuel.

Of these statements

(*a*) 1, 2 and 3 are correct (*b*) 1, 2 and 4 are correct
(*c*) 1, 3 and 4 are correct (*d*) 2, 3 and 4 are correct

Sol. (*c*). Statements 1, 3 and 4 are correct about breeder reactors.

73. Which one of the following indicates the correct order in the path of flue gas ?

(*a*) Super-heater, economiser, air pre-heater, precipitator

(*b*) Super-heater, economiser, precipitator, air preheater
(*c*) Super-heater, precipitator, economiser, air pre-heater
(*d*) Super-heater, air pre-heater, economiser, precipitator

Sol. (*a*). The correct sequence in the path of flue gas is superheater, economiser, air preheater and precipitator.

74. Match List I with List II and select the correct answer using the codes given below the lists :

List I (Name of Steam Turbine)	*List II (Type of turbine)*
A. De Laval Turbine	1. Velocity compounded impulse turbine
B. Curtis Turbine	2. Reaction turbine
C. Parsons Turbine	3. Simple impulse turbine

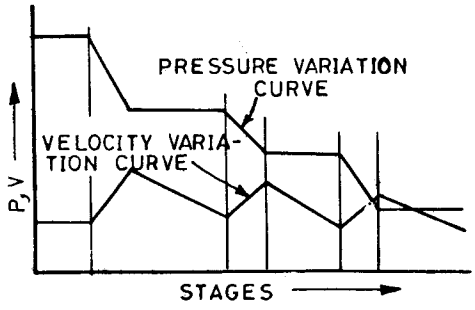
Codes :

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

Sol. (*c*). Code (*c*) provides the right matching.

75. The given figure represents pressure and velocity variation for a

(*a*) reaction type turbine
(*b*) velocity compounded impulse turbine
(*c*) pressure-velocity compounded impulse turbine
(*d*) pressure compounded impulse turbine



Sol. (*d*). The pressure and velocity variations in given figure correspond to pressure compounded impulse turbine because total pressure gets dropped in three stages and in each stage the velocity increases in passing through nozzle and then decreases in passing through blades (impulse stage).

76. In a reaction turbine, the enthalpy drop in the fixed blade ring is 50 kJ per Kg and the enthalpy drop in the moving blade ring is 25 kJ per Kg. The degree of reaction of the turbine is

(*a*) 66.7% (*b*) 50.0%
(*c*) 33.3% (*d*) 6.0%

Sol. (*c*). Degree of reaction $= \dfrac{\Delta h \text{ (moving blades)}}{\Delta h \text{ (moving blades)} + \Delta h \text{ (fixed blades)}} = \dfrac{25}{25+50} = \dfrac{25}{75} = 33.3\%.$

77. Match List I with List II and select the correct answer using the codes given below the lists :

List I (Variable area devices)	*List II (Name of device)*
A. $\rightarrow$ Pr increases	1. Supersonic nozzle
B. $\rightarrow$ Pr increases	2. Supersonic diffuser
C. $\rightarrow$ Pr decreases	3. Rayleigh flow device
D. $\rightarrow$ Pr decreases	4. Subsonic nozzle
	5. Subsonic diffuser

Codes :

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

Sol. (*a*). Code (*a*) provides correct matching.

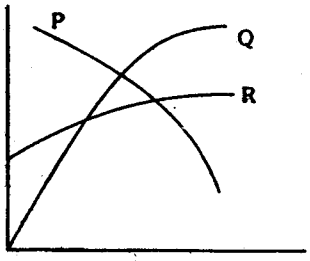
78. Symmetrical blading is used in a turbine when its degree of reaction is

(*a*) 25% (*b*) 50%

(*c*) 75% (*d*) 100%.

Sol. (*b*). Symmetrical blading is used in a turbine when its degree of reaction is 50%.

79. The characteristics of a pump are as shown in the given figure. Based on this figure, match List I with List II and choose the correct answer using the codes given below the lists :



List I

A. Curve P
B. Curve Q
C. Curve R

List II

1. Discharge versus head
2. Head versus discharge
3. Power versus discharge
4. Efficiency versus discharge

Codes :

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

Sol. (*a*). Code (a) provides the correct matching.

80. If the maximum temperature is T_3 and minimum temperature is T_1 then the optimum pressure ratio in a gas turbine is given by

(*a*) $r_p = \left(\frac{T_3}{T_1}\right)^{\frac{\gamma}{\gamma-1}}$ (*b*) $r_p = \left(\frac{T_3}{T_1}\right)^{\frac{\gamma-1}{2\gamma}}$

(*c*) $r_p = \left(\frac{T_3}{T_1}\right)^{\frac{\gamma}{2(\gamma-1)}}$ (*d*) $r_p = \left(\frac{T_3}{T_1}\right)^{\frac{2(\gamma-1)}{\gamma}}$

Sol. (*c*). $r_p = \left(\frac{T_3}{T_1}\right)^{\frac{\gamma}{2(\gamma-1)}}$ provides the optimum pressure ratio.

81. Cooling tower in a steam power station is a device for

(*a*) condensing the steam into water
(*b*) cooling the exhaust gases coming out of the boiler
(*c*) reducing the temperature of superheated steam
(*d*) reducing the temperature of cooling water used in condenser.

Sol. (*d*). Cooling tower in a steam power station is provided to reduce the temperature of cooling water used in condenser.

82. A reversible engine has ideal thermal efficiency of 30%. When it is used as a refrigerating machine with all other conditions unchanged, the coefficient of performance will be

(*a*) 3.33 (*b*) 3.00
(*c*) 2.33 (*d*) 1.33.

Sol. (*c*). $\eta_{\text{Carnot Engine}} = \frac{T_1 - T_2}{T_1} = 0.3, \quad 1 - \frac{T_2}{T_1} = 0.3$

$$COP_{\text{Carnot Refrigerator}} = \frac{T_2}{T_1 - T_2} = \frac{T_2}{0.3T_1} = \frac{1}{0.3} = \frac{T_2}{T_1}$$

$$= \frac{1}{0.3} \times 0.7 = \frac{7}{3} = 2.33$$

83. Which of the following are the reasons for the volumetric efficiency of reciprocating compressor being less than 100% ?

1. Deviations from isentropic process.
2. Pressure drop across the valves.
3. Superheating in compressor.
4. Clearance volume.
5. Deviations from isothermal process.
6. leakages.

Select the correct answer from the codes given below :

Codes :

(*a*) 1, 2, 3 and 5 (*b*) 2, 3, 4 and 5
(*c*) 1, 4, 5 and 6 (*d*) 2, 3, 4 and 6

Sol. (*d*). The reason for volumetric efficiency of reciprocating compressor being less that 100% are — pressure drop across the valves, superheating in compressor, clearance volume and leakages.

84. The presence of air in a condenser

(*a*) increases the pressure in the condenser and decrease the condensing coefficient
(*b*) decreases the pressure in the condenser but increases the condensing coefficient
(*c*) increases the pressure in the condenser as well as the condensing coefficient
(*d*) decreases the pressure in the condenser as well as the condensing coefficient

Sol. (*a*). The presence of air in a condenser and decrease the condensing coefficient.

85. Match List I with List II and select the correct answer using the codes given below the lists :

List I (Material)	*List II (Purpose/application)*
A. Glass wool	1. Cold storage
B. Ammonia	2. Domestic refrigerators
C. G.I. Sheet	3. Insulation
D. Polyurethane	4. Ducting

Codes :

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

Sol. **(a).** The correct matching is provided by code (a).

86. Two streams of moist air '1' and '2' mix together to give another stream of unsaturated air '3'. Let 'm' denote the rate of total mass flow of moist air, 'm_ω' denote the rate of mass flow of associated water vapour, 'ω' denote the specific humidity and 't' the temperature of a stream. Then 't_3' the temperature of stream '3' will be

(a) $\dfrac{(m_1 - m_{\omega_1})\,\omega_1 t_1 + (m_2 - m_{\omega_2})\,\omega_2 t_2}{(m_3 - m_{\omega_3})\,\omega_3}$ (b) $\dfrac{(m_1 - m_{\omega_1})\,t_1 + (m_2 - m_{\omega_2})\,t_2}{(m_3 - m_{\omega_3})}$

(c) $\dfrac{\omega_1 t_1 + \omega_2 t_2}{\omega_3}$ (d) $\dfrac{m_1\omega_1 t_1 + m_2\omega_2 t_2}{m_3\omega_3}$

Sol. **(b).** The temperature of stream can be determined from relationship (b).

87. To cool and dehumidify a stream of moist air, it must be passed over the coil at a temperature

(a) which lies between the dry bulb and wet bulb temperature of the incoming stream
(b) which lies between the wet bulb and dew point temperature of the incoming stream
(c) which is lower than the dew point temperature of the incoming stream
(d) of adiabatic saturation of incoming steam

Sol. **(c).** For cooling and dehumidification, the air should pass over a cooling coil whose effective surface temperature is below the dew point temperature of entering air.

88. Consider the following statements :

1. Dew point is reached by cooling air at constant moisture content.
2. Wet bulb temperature changes by addition of moisture at constant enthalpy.
3. For saturated air, the dry bulb temperature, wet bulb temperature and dew point are the same.
4. Dehumidification of air is achieved by heating.

Of these statements

(a) 1 and 3 are correct (b) 1 and 2 are correct
(c) 3 and 4 are correct (d) 3 alone is correct

Sol. **(a).** The statements at 1 and 3 are correct and all others are wrong.

89. Which one of the following statements is correct ?

(a) The sensible heat gain is due to the difference in humidity
(b) The latent heat gain is due to the temperature difference between the fresh air and the air in space
(c) The heat gain through the walls of ducts carrying conditioned air through unconditioned space in the building adds to the sensible heat gain
(d) Maximum heat gain to a building occurs through walls

Sol. **(d).** Statement at (d) is correct.

90. For air-conditioning the operation theatre in a hospital, the percentage of outside air in the air supplied is

(a) zero (b) 20
(c) 50 (d) 100

Sol. (*d*). It is not advisable to recirculate infected air of operation theatre and accordingly %age of outside air is 100%.

91. The vertical force on a submerged curved surface is equal to the

(*a*) force on the vertical projection of the curved surface
(*b*) force on the horizontal projection of the curved surface
(*c*) weight of the liquid vertically above the curved surface
(*d*) product of the pressure at the centroid and the area of the curved surface

Sol. (*c*). The vertical force on a submerged curved surface is equal to the weight of the liquid vertically above the curved surface.

92. Consider the following statements regarding a plane area submerged in a liquid :

1. The total force is the product of specific weight of the liquid, the area and the depth of its centroid.
2. The total force is the product of the area and the pressure at its centroid.

Of these statements

(*a*) 1 alone is correct
(*b*) 2 alone is correct
(*c*) both 1 and 2 are false
(*d*) both 1 and 2 are correct

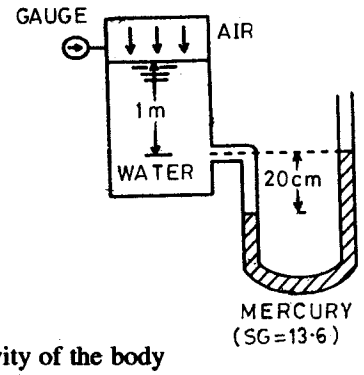
Sol. (*d*). Both the statements 1 and 2 are correct since pressure at the centroid of submerged body = specific weight × depth of the centroid.

93. A vertical dock gate 2 meter wide remains in position due to horizontal force of water on one side. The gate weighs 800 Kg and just starts sliding down when the depth of water upto the bottom of the gate decreases to 4 meters. Then the coefficient of friction between dock gate and dock wall will be

(*a*) 0.5
(*b*) 0.2
(*c*) 0.05
(*d*) 0.02.

Sol. (*d*). Coefficient of friction will be 0.02.

94. The pressure gauge reading in meter of water column shown in the given figure will be



(*a*) 3.20 m
(*b*) 2.72 m
(*c*) 2.52 m
(*d*) 1.52 m

Sol. (*d*). If P = gauge reading in m of water column then

$$p + 1 + 0.2 = \frac{20}{100} \times 13.6 \text{ or } p = 2.72 - 1.2 = 1.52 \text{ m}$$

95. The buoyant force acting on a floating body passes through the

(*a*) metacentre of the body
(*b*) centre of gravity of the body
(*c*) centroid of volume of the body
(*d*) centroid of the displaced volume

Sol. (*d*). The buoyant force acting on a floating body passes through the centroid of the displaced volume.

96. Which one of the following sets of conditions clearly apply to an ideal fluid ?

(*a*) Viscous and compressible
(*b*) Nonviscous and incompressible
(*c*) Nonviscous and compressible
(*d*) Viscous and incompressible

Sol. (*b*). An ideal fluid is non viscous and incompressible.

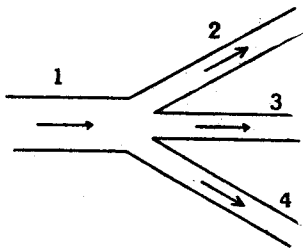
97. In a Newtonian fluid, laminar flow between two parallel plates, the ratio (τ) between the shear stress and rate of shear strain is given by

(*a*) $\mu \frac{d^2u}{dy^2}$
(*b*) $\mu \frac{du}{dy}$
(*c*) $\mu \left(\frac{du}{dy}\right)^2$
(*d*) $\mu \left(\frac{du}{dy}\right)^{1/2}$

Sol. (*b*). For Newtonian fluid and laminar flow between two parallel plates, the ratio τ between shear stress and rate of shear strain is given by $\mu \frac{du}{dy}$.

98. Pipe 1 branches to three pipes as shown in the given figure. The areas and corresponding velocities are as given in the following table.

Pipe	*Velocity (cm per second)*	*Area (sq cm)*
1.	50	20
2.	V_2	10
3.	30	15
4.	20	10



The value of V_2 in cm per second will be

(*a*) 15 (*b*) 20
(*c*) 30 (*d*) 35.

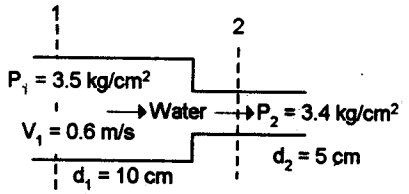
Sol. (*d*). $Q_1 = Q_2 + Q_3 + Q_4$

$$50 \times 20 = V_2 \times 10 + 30 \times 15 + 20 \times 10 ; \quad \text{or} \quad 1000 = 10V_2 + 450 + 200$$

$$10V_2 = 1000 - 650 = 350 \quad \text{and} \quad V_2 = 35 \text{ cm/sec.}$$

99. The energy loss between sections (1) and (2) of the pipe shown in the given figure is

(*a*) 1.276 Kg-m (*b*) 1.00 Kg-m
(*c*) 0.724 Kg-m (*d*) 0.15 Kg-m.



Sol. (*c*). Energy loss between sections 1 and 2

$$= \frac{p_1 - p_2}{\rho g} + \frac{V_1^2}{2g} - \frac{V_2^2}{2g} \quad \text{Also} \quad V_1 \times A_1 = V_2 \times A_2$$

or $$0.6 \times \frac{\pi}{4} \times (0.1)^2 = V_2 \times \frac{\pi}{4} (0.05)^2 \text{ or } V_2 = 0.6 \times 4 = 2.4 \text{ m/s}$$

$$\text{Energy loss} = \frac{(3.5 - 3.4) \times 10000 \times 9.81}{9.81 \times 1000} + \frac{0.6^2}{2g} (1 - 16) = 0.1 \times 10 - \frac{15 \times 0.36}{2 \times 9.81} = 1 - 0.266 = 0.724$$

100. For flow through a horizontal pipe, the pressure gradient dp/dx in the flow direction is

(*a*) +ve (*b*) 1
(*c*) zero (*d*) –ve.

Sol. (*d*). For flow through a horizontal pipe, the pressure gradient *dp/dx* in the flow direction is –ve.

101. In a pipe flow, the head lost due to friction is 6m. If the power transmitted through the pipe has to be the maximum, then the total head at the inlet of the pipe will have to be maintained at

(*a*) 36 m (*b*) 30 m
(*c*) 24 m (*d*) 18 m.

Sol. (*d*). Head lost due to friction is 6 m. Power transmitted is maximum when friction head is 1/3 of the supply head. ∴ Supply head should be 18 m.

102. The lower critical Reynolds number for a pipe flow is

(*a*) different for different fluids
(*b*) the Reynolds number at which the laminar flow changes to turbulent flow
(*c*) more than 2000
(*d*) the least Reynolds number ever obtained for laminar flow

Sol. (*a*). The lower critical Reynolds number for a pipe flow is different for different fluids.

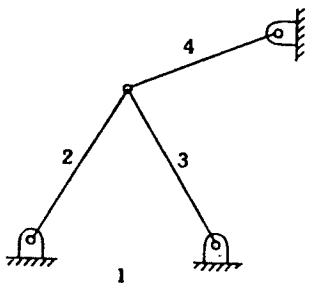
Directions : The following eighteen items consist of two statements, one labelled the 'Assertion A' and the other labelled the 'Reason R'. You are to examine these two statements carefully and decide if the Assertion A and the Reason R are individually true and if so, whether the Reason is a correct explanation of the Assertion. Select your answer to these items using the codes given below and mark your answer sheet accordingly.

Codes :

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

103. Assertion (A) : The mechanism shown in the given figures has mobility.

Reason (R) : A mechanism is mobile when it has a single degree freedom.



Sol. (*d*). The given mechanism has no mobility since it has zero degree of freedom. A is thus false but statement given for reason R is true. Thus answer is (*d*).

104. Assertion (A) : A flywheel is attached to a punching press so as to reduce its speed fluctuations.

Reason (R) : The flywheel stores energy when its speed increase.

Sol. (*a*). Both A and R are correct and further R is the correct explanation of A. Thus answer is (*a*).

105. Assertion (A) : The automatic traffic control is an open- loop system.

Reason (R) : The input is independent of the output.

Sol. (*a*). Automatic traffic control is an open-loop system, being of sequential nature. Assertion is thus true. In this case input is generated by a relay logic and is not dependent on output. Thus (R) is also true and appears to be an explanation for A. Thus answer is (*a*).

106. Assertion (A) : Many times the weight of a body is treated as negligible while calculating total forces acting on it.

Reason (R) : The body is weightless.

Sol. (*c*). Assertion (A) is true but reason (R) is false because body can't be weightless. Thus answer is (*c*).

107. Assertion (A) : An increase in depth of cut shortens the tool life.

Reason (R) : Increase in depth of cut gives rise to relatively small increase in tool temperature.

Sol. (*a*). Both A and R are true and R is also explanation for A.

108. Assertion (A) : A pattern is made exactly similar to the part to be cast.

Reason (R) : Pattern is used to make the mould cavity for pouring in molten metal for casting.

Sol. (*c*). Pattern is not made exactly similar to the part to be cast as various allowances have to be incorporated. Thus A is false but R is true.

109. Assertion (A) : In high speed steels, alloying elements tungsten, chromium and vanadium are added to make them suitable to work at higher cutting speeds than tool steel or low alloy steels.

Reason (R) : Vanadium adds to the property of red hardness and tungsten and chromium add to high wear resistance.

Sol. (*a*). Both A and R are true and R is correct explanation for A.

110. Assertion (A) : If neutral flame is used in oxy-acetylene welding, both oxygen and acetylene cylinders of same capacity will be emptied at the same time.

Reason (R) : Neutral flame uses equal amounts of oxygen and acetylene.

Sol. (*a*). Both A and R are correct. Further R provides correct explanation for A.

111. Assertion (A) : In a multispindle automat, the turret is indexed to engage each of the cutting tool mounted on it.

Reason (R) : Turret is a multiple tool holder so that the machining can be continued with each tool without the need to change the tool.

Sol. (*d*). In a multispindle automat, the turret in indexed to engage the desired tool and not each of the cutting tool mounted on it. Thus A is false. However (R) is correct statement.

112. Assertion (A) : The open cycle gas turbines are preferred over closed cycle when the gas is air.

Reason (R) : The expansion of combustion products can take place upto atmospheric pressure.

Sol. (*a*). Both A and R are correct statements and R is correct explanation for A.

113. Assertion (A) : In Mollier chart for steam, the constant pressure lines are straight lines in wet region.

Reason (R) : The slope of constant pressure lines in wet region is equal to T.

Sol. (*c*). Here A is true but R is false.

114. Assertion (A) : Temperature and pressure are sufficient to fix the state of a two-phase system.

Reason (R) : Two independent and intensive properties are required to be known to define the state of a pure substance.

Sol. (*a*). Both A and R are correct and R is correct explanation for A.

115. Assertion (A) : In a convergent-divergent nozzle, once sonic conditions are established at the throat, any amount of reduction of pressure at the exit will not be effective in increasing the flow rate.

Reason (R) : The reduction of upstream pressure caused by the depletion of the reservoir compensates for the acceleration of flow due to lowering of back pressure.

Sol. (*d*). A is false but R is true.

116. Assertion (A) : The steam discharge through a nozzle can be increased only after the pressure at throat attains a value equal to critical pressure.

Reason (R) : A maximum discharge is obtained at the critical pressure ratio.

Sol. (*d*). Steam discharge in conventional nozzle can't be increased after the pressure at throat attains critical pressure. Thus A is false. Reason (R) is true.

117. Assertion (A) : Benson boiler is much lighter than other boilers.

Reason (R) : Boiler pressure raised to the critical pressure in Benson boiler permits doing away with steam (separating) drums.

Sol. (*a*). Benson boiler is lighter and one of the reasons is absence of boiler drum. However lightness is due to elimination of water walls also. Thus both A and R are true and R is also explanation for A.

118. Assertion (A) : On the psychrometric chart, constant enthalpy lines and constant wet bulb lines are the same.

Reason (R) : For the same wet bulb temperature, the moisture content remains constant.

Sol. (*a*). Both A and R are true and R is correct explanation for A.

119. Assertion (A) : To reduce the rolling motion of a ship, the metacentric height should be low.

Reason (R) : Decrease in metacentric height increases the righting couple.

Sol. (*c*). Since high metacentric height will result in faster restoring action, rolling will be more. Thus to reduce rolling metacentric height should be low. However reason (R) is reverse of true statement.

120. In flow over immersed bodies,

Assertion (A) : drag can be created without lift.

Reason (R) : lift cannot be created without drag.

Sol. (*b*). Both the statements of A and R are true, but R is not necessarily the explanation for A.

Indian Engineering Services (IES)
Examination
MECHANICAL ENGINEERING-1994
PAPER–I (Objective)

1. A steam pipe is to be lined with two layers of insulating materials of different thermal conductivities. For minimum heat transfer

(*a*) the better insulation must be put inside (*b*) the better insulation must be put outside

(*c*) one could place either insulation on either side

(*d*) one should take into account the steam temperature before deciding as to which insulation is put where.

Sol. (*a*) For minimum heat transfer, the better insulation must be put inside.

2. The temperature distribution, at a certain instant of time in a concrete slab during curing is given by $T = 3x^2 + 3x + 16$, where x is in cm and T is in K. The rate of change of temperature with time is given by (assume diffusivity to be 0.0003 cm^2/s).

(*a*) + 0.0009 K/s (*b*) + 0.0048 K/s (*c*) – 0.0012 K/s (*d*) – 0.0018 K/s

Sol. (*d*) Temperature distribution is $T = 3x^2 + 3x + 16$, $dT/dx = 6x + 3°K/cm$

Rate of change of is $dT/dx = 6°$ K/cm^2, $\therefore$ Rate of change of temperature with time $= -6 \times 0.0003$
$= -0.0018$ °K/s.

3. Consider a hydrodynamically fully developed flow of cold air through a heated pipe of radius r_0. The velocity and temperature distributions in the radial direction are given by $u(r)$ and $T(r)$ respectively. If u_m is the mean velocity at any section of the pipe, then the bulk-mean temperature at that section is given by

(*a*) $\int_0^{r_0} u(r)\, T(r)\, r^2\, dr$ (*b*) $\int_0^{r_0} \frac{u(r)}{3r}\frac{T(r)}{2r}\, dr$ (*c*) $\frac{4\int_0^{r_0} u(r)\, T(r)\, dr}{2\pi r_0^3}$ (*d*) $\frac{2}{u_m r_0^2}\int_0^{r_0} u(r)\, T(r)\, r\, dr$

Sol. (*d*) Bulk-mean temperature $= \frac{\text{total thermal energy crossing a section pipe in unit time}}{\text{heat capacity of fluid crossing same section in unit tim}}$

$$= \frac{\int_0^{r_0} u(r)\, T(r)\, rdr}{u_m \int_0^{r_0} rdr} = \frac{\int_0^{r_0} \mu(r)\, T(r)\, rdr}{u_m \times \frac{r_0^2}{2}} = \frac{2}{u_m r_0^2}\int_0^{r_0} u(r)\, T(r)\, rdr$$

4. The transition Reynolds number for flow over a flat plate is 5×10^5. What is the distance from the leading edge at which transition will occur for flow of water with a uniform velocity of 1 m/s ? [For water, the kinematic viscosity, $\nu = 0.858 \times 10^{-6}$ m^2/s

(*a*) 1 m (*b*) 0.43 m (*c*) 43 m (*d*) 103 m

Sol. (*b*) $R_N = 5 \times 10^5$, $R_N = \frac{Vx}{\nu}$, or $x = \frac{R_N \times \nu}{V} = \frac{5 \times 10^5 \times 0.858 \times 10^{-6}}{1} = 0.429$ m $\cong$ 0.43 m

5. What is the net radiant interchange per square metre for two very large plates at temperatures 800 K and 500 K respectively ? (The emissivity of the hot and cold plates are 0.8 and 0.6 respectively. Stefan Boltzmann constant is 5.67×10^{-8} $W/m^2 K^4$).

(*a*) $1.026 \frac{kW}{m^2}$ (*b*) $10.26 \frac{kW}{m^2}$ (*c*) $102.6 \frac{kW}{m^2}$ (*d*) $1026 \frac{kW}{m^2}$

Sol. (*b*) Heat transfer $Q = \sigma F_e F_A (T_1^4 - T_2^4) \frac{W}{m^2}$

$$\sigma = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$$

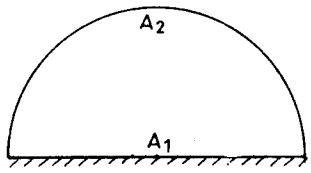
$$F_e = \text{effective emissivity coefficient} = \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} = \frac{1}{\frac{1}{0.8} + \frac{1}{0.6} - 1} = \frac{12}{23}$$

Shape factor $F_A = 1$

$$\therefore Q = 5.67 \times 10^{-8} \times 1 \times \frac{12}{23} (800^4 - 500^4) = 5.67 \times 10^{-8} \times \frac{12}{23} [(800 + 500)(800 - 500)(800^2 + 500^2)$$

$$= 5.67 \times 10^{-8} \times \frac{12}{23} \times 1300 \times 300 \times 890000 = 10268 \text{ W/m}^2 = 12.26 \text{ kW/m}^2$$

6. A long semi-circular duct is shown in the given figure. What is the shape factor F_{22} for this case ?

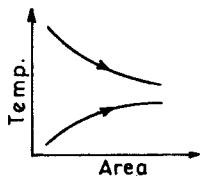


(*a*) 1.36 (*b*) 0.73
(*c*) 0.56 (*d*) 0.36

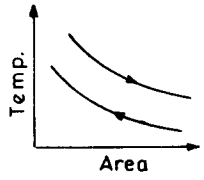
Sol. (*d*) Shape factor $F_{22} = \frac{A_2 - A_1}{A_2} = \frac{\pi rl - 2rl}{\pi rl} = \frac{3.14 - 2}{3.14} = 0.36$

7. Which one of the following diagrams represents correctly the gas-gas counterflow heat exchange ?

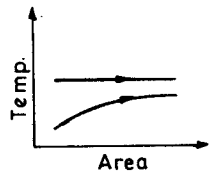
(*a*)



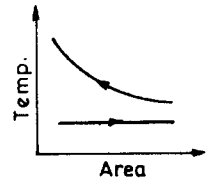
(*b*)



(*c*)



(*d*)



Sol. (*b*) Figure (*b*) represents correctly the gas-gas counter flow exchanger since temperature of hot stream continuously falls and that of cold stream continuously increases.

8. Which of the following would lead to a reduction in thermal resistance ?

1. In conduction; reduction in the thickness of the material and an increase in the thermal conductivity.
2. In convection, stirring of the fluid and cleaning the heating surface.
3. In radiation, increasing the temperature and reducing the emissivity.

Codes :

(*a*) 1, 2 and 3 (*b*) 1 and 2 (*c*) 1 and 3 (*d*) 2 and 3.

Sol. (*b*)

1. In conduction, heat resistance $= \Delta x/kA$

Thus reduction in thickness and increase in area result in reduction of thermal resistance.

2. Stirring of fluid and cleaning the heating surface increases value of h, and thus reduces thermal resistance.
3. In radiation, heat flow increases with increase in temperature and reduces with reduction in emissivity. Thus thermal resistance does not decrease.

Thus 1 and 2 are correct.

9. Match List I with List II and select the correct answer

List I	*List II*
A. Number of transfer units	1. Recuperative type heat exchanger.
B. Periodic flow heat exchanger	2. Regenerator type heat exchanger.
C. Chemical additive	3. A measure of the heat exchanger size.
D. Deposition on heat exchanger surface	4. Prolongs drop-wise condensation.
	5. Fouling factor.

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

Sol. (*c*) The correct matching is A-3, B-2, C-4, D-5.

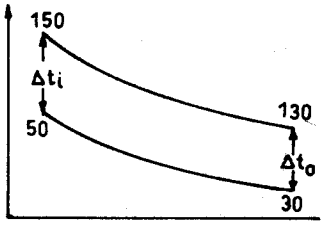
10. Consider the following statements:

In a shell and tube heat exchanger, baffles are provided on the shell side to
1. prevent the stagnation of shell side fluid.
2. improve heat transfer. 3. provide support for tubes. 4. prevent fouling of tubes.

Of these statements
(*a*) 1, 2, 3 and 4 are correct (*b*) 1,2 and 3 are correct.
(*c*) 1 and 2 are correct (*d*) 2 and 3 are correct.

Sol. (*d*) Baffles help in improving heat transfer and also provide support for tubes.

11. In a counterflow heat exchanger, cold fluid enters at 30°C and leaves at 50°C, whereas the hot fluid enters at 150°C and leaves at 130°C. The mean temperature difference for this case is
(*a*) indeterminate
(*b*) 20°C
(*c*) 80°C
(*d*) 100°C.



Sol. (*a*) Mean temperature difference $= \dfrac{\Delta t_o - \Delta t_i}{\log_e (\Delta t_0 / \Delta t_i)}$

$$= \frac{100 - 100}{\log_e 1} = \text{Indeterminate}$$

12. Inspite of large heat transfer coefficients in boiling liquids, fins are used advantageously when the entire surface is exposed to
(*a*) nucleate boiling (*b*) film boiling. (*c*) transition boiling (*d*) all modes of boiling.

Sol. (*d*) Fins are used advantageously in all modes of boiling.

13. The temperature distribution in a stainless fin (thermal conductivity 0.17 W/cm°C) of constant cross - sectional area of 2 cm^2 and length of 1-cm, exposed to ambient of 40°C (with a surface heat transfer coefficient of 0.0025 $W/cm^{2\circ}C$) is given by $(T - T_\infty) = 3x^2 - 5x + 6$, where T is in°C and x is in cm. If the base temperature is 100°C, then the heat dissipated by the fin surface will be
(*a*) 6.8 W (*b*) 3.4 W (*c*) 1.7 W (*d*) 0.17 W.

Sol. (*b*) Heat dissipated by fin surface

$$= \sqrt{\frac{hA}{kp}}\ \frac{t_1 - t_2}{x/kA} = \sqrt{\frac{0.0025 \times 2}{0.17 \times 1}} \times \frac{100 - 40}{1/0.17 \times 2} = 3.4 \text{ W}$$

14. The ratio of the thickness of thermal boundary layer to the thickness of hydrodynamic boundary layer is equal to (Prandtl number)n, where n is

(*a*) – 1/3 (*b*) – 2/3 (*c*) 1 (*d*) – 1.

Sol. (*a*) $\dfrac{\text{Thickness of thermal boundary layer}}{\text{Thickness of hydrodynamic layers}} = (\text{Prandtl Numbe})^{-1/3}$

15. The operating temperature of a cold storage is – 2°C. Heat leakage from the surrounding is 30 k W for the ambient temperature of 40°C. The actual COP of the refrigeration plant used is one-fourth that of an ideal plant working between the same temperatures. The power required to drive the plant is

(*a*) 1.86 kW (*b*) 3.72 kW (*c*) 7.44 kW (*d*) 18.60 kW

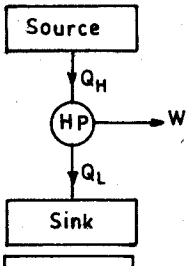
Sol. (*d*) COP of ideal plant working between limits –2 and 40°C, *i.e.* 271 and 313°K is

$$\frac{T_1}{T_2 - T_1} = \frac{271}{313 - 271} = \frac{271}{42} = 6.45, \quad \text{COP of refrigeration plant} = \frac{1}{4} \times 6.45 = 1.61$$

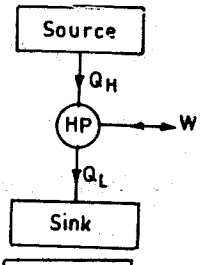
$$\text{COP} = \frac{\text{heat abstracted}}{\text{work done}} \quad \text{or} \quad \text{Work required} = \frac{30}{1.61} = 1.86 \text{ kW}$$

16. A heat pump is shown schematically as

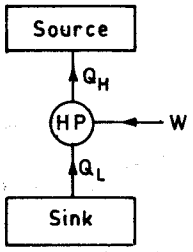
(*a*)



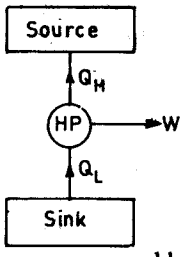
(*b*)



(*c*)



(*d*)



Sol. (*c*) In heat pump, heat is rejected to source, work done on compressor, and heat absorbed from sink.

17. In a domestic refrigerator, a capillary tube controls the flow of refrigerant from the

(*a*) expansion valve to the evaporator (*b*) evaporator to the thermostat

(*c*) condenser to the expansion valve (*d*) condenser to the evaporator.

Sol. (*d*) In domestic refrigerator, a capillary tube controls the flow of refrigerant from condensor to evaporator.

18. The coefficient of performance (COP) of a refrigerator working as a heat pump is given by

(*a*) $(\text{COP})_{\text{heat pump}} = (\text{COP})_{\text{refrigerator}} + 2$ (*b*) $(\text{COP})_{\text{heat pump}} = (\text{COP})_{\text{refrigerator}} + 1$

(*c*) $(\text{COP})_{\text{heat pump}} = (\text{COP})_{\text{refrigerator}} - 1$ (*d*) $(\text{COP})_{\text{heat pump}} = (\text{COP})_{\text{refrigerator}}$

Sol. (*b*) The COP of refrigerator is one less than COP of heat pump, if same refrigerator starts working as heat pump *i.e.* $(\text{COP})_{heat\ pump} = (\text{COP})_{refrigerator} + 1$

19. Consider the following steps:

1. Starting of compressor.
2. Starting of cooling tower pump.
3. Starting of chiller water pump.
4. Starting of blower motor of cooling coil.

The correct sequence of these steps in the starting of a cell airconditioning plant using chilled water cooling coil, is

(*a*) 3,1,4,2 (*b*) 1,3,2,4 (*c*) 3,2,1,4 (*d*) 1,3,4,2

Sol. (*c*) The correct sequence in starting of a central air conditioning plant using chilled water cooling coil is starting of chiller water pump, starting of cooling tower pump, starting the compressor, starting of blower motor of cooling coil.

20. Match List I with List II and select the correct answer

List I

A. Freon 12
B. Freon 22
C. Freon 11
D. Ammonia

List II

1. Centrifugal systems.
2. Low temperature cold storage.
3. Window type a/c units
4. Ice plants.

Codes :	A	B	C	D
(*a*)	3	2	1	4
(*c*)	1	2	4	3

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

Sol. (*a*) The correct matching is A-3, B-2, C-1 and D-4.

21. The equivalent diameter (D) of a circular duct corresponding to a rectangular duct having longer side '*a*' and shorter side '*b*', for the same velocity and pressure drop is given by

(*a*) $D=\frac{a+b}{ab}$ (*b*) $D=\frac{ab}{a+b}$ (*c*) $D=\frac{(a+b)}{2ab}$ (*d*) $D=\frac{2ab}{a+b}$

Sol. (*d*) The equivalent diameter $D=\frac{2ab}{a+b}$

22. Consider the following statements:

During sensible heating

1. moisture content increases.
2. dry bulb temperature and wet bulb temperature increase.
3. dew point remains constant.
4. relative humidity increases.

Of these statements

(*a*) 1,2 and 3 are correct (*b*) 2,3 and 4 are correct. (*c*) 2 and 3 are correct (*d*) 1 and 2 are correct.

Sol. (*c*) During sensible heating, dry bulb temperature and wet bulb temperature increase, dew point remains unchanged. Moisture content remains same and relative humidity decreases. This statements 2 and 3 are correct.

23. Which of the following statements are correct ?

1. The human body can lose heat even if its temperature is less than the atmospheric temperature.
2. Relative humidity can be increased by cooling and dehumidification.
3. Warm air increases the rate of radiation of heat from the human body.
4. Increase in air movement increases the evaporation from the human body.

Codes :

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

Sol. (*a*) Statements 1 and 4 are correct.

24. When the air is passed through an insulated chamber having sprays of water maintained at a temperature higher than the dew point temperature of entering air but lower than its dry bulb temperature, then the air is said to be

(*a*) cooled and humidified (*b*) cooled and dehumidified
(*c*) heated and humidified (*d*) heated and dehumidified

Sol. (*a*) When air is passed through spray of water at temperature higher than dew point temperature of entering air and lower than its dry bulb temperature, then air is cooled and humidified.

25. The atmosphere air at dry bulb temperature of 15°C enters a heating coil maintained at 40°C. The air leaves the heating coil at 25°C. The bypass factor of the heating coil is
(*a*) 0.375 (*b*) 0.4 (*c*) 0.6 (*d*) 0.67

Sol. (*d*) Bypass factor of heating coil $= \frac{40-25}{40-15} = \frac{15}{25} = 0.67$

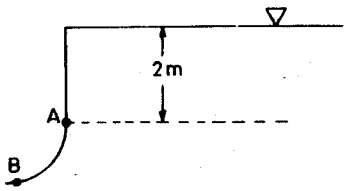
26. If the specific heats of dry air and water vapour are 1.00 kJ/kg-K and 1.88 kJ/kg-K respectively and the humidity ratio is 0.011, then the specific heat of moist air at 25°C and 50% relative humidity will be
(*a*) 1.0207 kJ/kg-K (*b*) 1.869 kJ/kg-K (*c*) 1.891 kJ/kg-K (*d*) 0.9793 kJ/kg-K

Sol. (*a*) Specific heat of moist air = specific heat of dry air + humidity ratio × specific head of water vapour
$= 1.00 + 0.011 \times 1.88 = 1.00 + 0.0207 = 1.0207$ kJ/kg°K.

27. Consider the following factors:
1. Wind velocity 2. Type of activity. 3. Indoor design conditions 4. Door openings.
Occupancy load in cooling load calculations depends upon
(*a*) 1 and 2 (*b*) 1 and 3 (*c*) 1 and 4 (*d*) 2 and 3.

Sol. (*d*) Occupancy load in cooling load calculation depend upon type of activity and indoor design conditions.

28. The hydrostatic force on the curved surface AB shown in given figure acts.
(*a*) vertically downwards
(*b*) vertically upwards
(*c*) downwards, but at an angle with the vertical plane.
(*d*) upwards, but at an angle with the vertical plane.



Sol. (*d*) The hydrostatic force on the curved surface is upwards, but at an angle with the vertical plane.

29. For stable equilibrium of a floating body,
(*a*) the body should be lighter in weight.
(*b*) the body should be made up of material whose specific gravity is less than that of the liquid in which it is floating .
(*c*) the metacentre should be above the centre of gravity of the body.
(*d*) the metacentre should be above the centre of buoyancy.

Sol. (*c*) For stable equilibrium of a floating body, the metacentre should be above the centre of gravity of the body.

30. Consider the following statements :
For a two-dimensional potential flow
1. Laplace equation for stream function must be satisfied.
2. Laplace equatic for velocity potential must be satisfied.
3. Streamlines and equipotential lines are mutually perpendicular.
4. Stream function and potential function are not interchangeable.
(*a*) 1 and 4 are correct (*b*) 2 and 4 are correct.
(*c*) 1,2 and 3 are correct (*d*) 2,3 and 4 are correct.

Sol. (*c*) Statements 1,2 and 3 are correct.

31. The pressure distribution for an ideal flow over a circular cylinder is such that
(*a*) the maximum positive pressure intensity occurs at either of the stagnation points.
(*b*) the maximum negative pressure is less than the maximum positive pressure.
(*c*) the net force on the cylinder is in the direction of flow.
(*d*) there is no lift whether the cylinder is at rest or rotating.

Sol. (*a*) The pressure distribution for an ideal flow over a circular cylinder is such that the maximum positive pressure intensity occurs at either of the stagnation points.

32. The Euler equations of motion for the flow of an ideal fluid is derived considering the principle of conservation of
(*a*) mass and the fluid as incompressible and inviscid.
(*b*) momentum and the fluid as incompressible and viscous.
(*c*) momentum and the fluid as incompressible and inviscid.
(*d*) energy and the fluid as incompressible and inviscid.

Sol. (*a*) The Euler equations of motion for the flow of an ideal fluid is derived considering the principle of conservation of mass and the fluid as incompressible and inviscid.

33. The continuity equation for a steady flow states that
(*a*) velocity field is continuous at all points in flow field.
(*b*) the velocity is tangetial to the streamlines.
(*c*) the stream function exists for steady flows.
(*d*) the net efflux rate of mass through the control surfaces is zero.

Sol. (*c*) The continuity equation for a steady flow states that the stream function exists for steady flows.

34. Bernoulli's equation represents the
(*a*) forces at any point in the flow field and is obtained by intergrating the momentum equation for viscous flows.
(*b*) energies at any point in the flow field and is obtained by integrating the Euler equations.
(*c*) momentum at any point in the flow field and is obtained by integrating the equation of continuity.
(*d*) moment of momentum and is obtained by integrating the energy equation.

Sol. (*b*) Bernoulli's equation represents the energies at any point in the flow field and is obtained by integrating the Euler equations.

35. A fully developed laminar viscous flow through a circular tube has the ratio of maximum velocity to average velocity as
(*a*) 3.0 (*b*) 2.5 (*c*) 2.0 (*d*) 1.5.

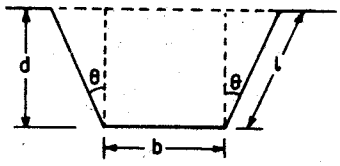
Sol. (*c*) Ratio $\frac{\text{Maximum velocity}}{\text{Average velocity}}$ for fully developed laminar viscous flow through a circular tube has value of 2.0.

36. In a laminar flow through a pipe of diameter D, the total discharge Q, is expressed as (μ is the dynamic viscosity of the fluid and $\left(-\frac{dp}{dx}\right)$ is the pressure gradient).

(*a*) $-\frac{\pi D^4}{128\mu}\frac{dp}{dx}$ (*b*) $-\frac{\pi D^4}{64\,\mu}\frac{dp}{dx}$ (*c*) $-\frac{\pi D^4}{32\,\mu}\frac{dp}{dx}$ (*d*) $-\frac{\pi D^4}{16\,\mu}\frac{dp}{dx}$

Sol. (*a*) In a laminar flow through a pipe, $Q = \frac{-\pi D^4}{128\,\mu}\left(\frac{dp}{dx}\right)$

37. A trapezoridal open channel has the cross-section as shown in the given figure. In order to have maximum hydraulic efficiency, the hydraulic radius, R and the length of the side, l should be.



(*a*) $\frac{d}{4}$ and $\frac{2}{\sqrt{3}}d$ respectively (*b*) $\frac{d}{4}$ and $\frac{\sqrt{2}}{3}d$ respectively.

(*c*) $\frac{d}{2}$ and $\frac{2}{\sqrt{3}}d$ respectively (*d*) $\frac{d}{2}$ and $\frac{\sqrt{2}}{3}d$ respectively.

Sol. (*c*) For trapezoidal open channel, for maximum hydraulic efficiency, the hydraulic radius $R = d/2$ and length of side $l = 2d/\sqrt{3}$.

38. The universal velocity distribution for turbulent flow in a channel is given by (u^* is the friction velocity and η is given by yu^*/ν. The kinematic viscosity is ν and y is the distance from the wall).

(*a*) $\frac{u}{u^*} = 2.5 \ln \eta + 5.5$ (*b*) $\frac{u}{u^*} = \eta$

(*c*) $\frac{u}{u_{max}} = 5.75 \ln \eta + 5.5$ (*d*) $\frac{d}{u} = 5.75 \ln \eta + 5.5$

Sol. (*a*) (*a*) is correct choice.

39. Flow separation at a solid surface takes place due to

(*a*) friction at the solid surface.

(*b*) decrease in pressure along the flow direction.

(*c*) increase in pressure along the flow direction.

(*d*) positive pressure gradient along the flow direction and friction at the boundary.

Sol. (*b*) Flow separation at a solid surface takes place due to decrease in pressure along the flow direction.

40. Reynolds stress may be defined as the

(*a*) stresses (normal and tangential) due to viscosity of the fluid.

(*b*) additional normal stresses due to fluctuating velocity components in a turbulent flow.

(*c*) additional shear stresses due to fluctuating velocity components in a turbulent flow.

(*d*) additional normal and shear stresses due to fluctuating velocity components in the flow field.

Sol. (*c*) Reynolds stress may be defined as additional shear stresses due to fluctuating velocity components in a turbulent flow.

41. When we consider the momentum exchange between two adjacent layers in a turbulent flow, can it be postulated that if at an instant there is an increase in u' in the x direction it will be followed by a change in v' in the y direction ?

(*a*) yes, in such a manner that $\overline{u'v'} = 0$

(*b*) yes, in such a manner that $\overline{u'v'}$ = non-zero and positive.

(*c*) yes, in such a manner that $\overline{u'v'}$ = non - zero and negative.

(*d*) no, as u' and v' are not dependent on each other.

Sol. (*a*) (*a*) is correct choice.

42. According to Prandtl's mixing length theory, the turbulent kinematic viscosity, ν is expressed in terms of the mixing length, l and the velocity gradient, $\frac{\partial u}{\partial y}$ as

(*a*) $\nu_t = l\left(\frac{\partial \bar{u}}{\partial y}\right)$ (*b*) $\nu_t = l^2\left(\frac{\partial \bar{u}}{\partial y}\right)$ (*c*) $\nu_t = l^2\left(\frac{\partial \bar{u}}{\partial y}\right)$ (*d*) $\nu_t = l\left(\frac{\partial \bar{u}}{\partial y}\right)^2$

Sol. (*a*) (*a*) is correct choice.

43. In the case of laminar boundary layer on a flat plate, the local skin friction coefficient is given by (symbols have the usual meaning).

(*a*) $C_f = \frac{4.91x}{\sqrt{Re_x}}$ (*b*) $C_f = \frac{0.664}{\sqrt{Re_x}}$ (*c*) $C_f = \frac{1.328}{\sqrt{Re_x}}$ (*d*) $C_f = 0.332\sqrt{Re_x}$

Sol. (*b*) (*b*) is right choice.

44. The energy thickness for a laminar boundary layer flow depends on local and free stream velocities within and outside the boundary layer δ. The expression for the energy thickness is given by (symbols have the usual meaning).

(*a*) $\int_0^{\delta}\left(1-\frac{u}{U_\infty}\right)dy$ (*b*) $\int_0^{\delta}\frac{u}{U_\infty}\left(1-\frac{u}{U_\infty}\right)dy$ (*c*) $\int_0^{\delta}\left(1-\frac{u}{U_\infty}\right)^2 dy$ (*d*) $\int_0^{\delta}\left(1-\frac{u^2}{U_\infty^2}\right)dy$.

Sol. (*d*) Energy thickness for a laminar boundary layer flow $= \int_0^{\delta}\frac{u}{u_\infty}\left(1-\frac{u^2}{U_\infty^2}\right)dy$

45. For laminar flow over a flat plate, the thickness of the boundary layer at a distance from the leading edge is found to be 5 mm. The thickness of the boundary layer at a downstream section, which is at twice the distance of the previous section from the leading edge will be

(*a*) 10 mm (*b*) $5\sqrt{2}$ mm (*c*) $5/\sqrt{2}$ mm (*d*) 2.5 mm

Sol. (*b*) Thickness of boundary layer for laminar flow over a flat plate is proportional to square root of ratio of distances from the leading edge. Thus new thickness $= 5 \times \sqrt{2}$ mm

46. Consider the following two statements on the flow over immersed bodies:

Statement 1 : Drag can be created without lift.

Statement 2 : Lift cannot be created without drag.

(*a*) 1 is correct and 2 is incorrect

(*b*) 1 is incorrect and 2 is correct

(*c*) both 1 and 2 are correct

(*d*) both 1 and 2 are incorrect.

Sol. (*c*) Both statements 1 and 2 are correct.

47. In the design of a tall chimmey for a factory in addition to strength and rigidity considerations, care should be taken to check its safety against wind, because

(*a*) the wind creates a large bending moment on the chimney.

(*b*) the wind can have any direction.

(*c*) additional forces are exerted on chimney due to mixing of the effluent gases with the surrounding air.

(*d*) of the effect of vortex shedding on the chimney.

Sol. (*a*) In tall Chimney design, safety against wind is important because it creates a large bending moment.

48. In the case of a falling sphere in a fluid, for the Stoke's law to be valid, the

(*a*) sphere must be metallic.

(*b*) fluid density should be constant.

(*c*) flow around the sphere should be turbulent.

(*d*) the Reynolds number based on sphere diameter should be less than unity.

Sol. (*a*) Statement (*a*) is correct.

49. Match List I with List II and select the correct answer.

List I (Forces)	*List II (Dimensionless groups).*
A. Viscous Force	1. Reynolds number.
B. Elastic force	2. Froude number.
C. Surface tension	3. Waber number.
D. Gravity	4. Mach number.

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

Sol. (*d*) The correct matching is A-1, B-4, C-3, D-2.

50. If two flows are specified as

(*i*) $u = y, v = -\frac{3}{2}x$ and (*ii*) $u = xy^2, v = x^2y$,

then it can be concluded that

(*a*) both the flows are rotational. (*b*) both the flows are irrotational.

(*c*) flow (*i*) is rotational while flow (*ii*) is irrotational

(*d*) flow (*i*) is irrotational while flow (*ii*) is rotational.

Sol. (*a*) Both flows are rotational.

51. The streamlines and the lines of constant velocity potential in an inviscid irrotational flow field form.

(*a*) parallel grid lines placed in accordance with their magnitude.

(*b*) intersecting grid-net with arbitrary orientation.

(*c*) an orthogonal grid system (*d*) none of the above.

Sol. (*a*) Statement at (*a*) is correct.

52. The Magnus effect is defined as

(*a*) the generation of lift per unit drag force. (*b*) the circulation induced in an aircraft wing.

(*c*) the separation of boundary layer near the trailing edge of a slender body.

(*d*) the generation of lift on a rotating cylinder in a uniform flow.

Sol. (*d*) The Magnus effect is defined as the generation of lift on a rotating cylinder in a uniform flow.

53. Specific speed of a pump and specific speed of a turbine an (symbols have the usual meaning).

(*a*) $\frac{N\sqrt{Q}}{H^{3/4}}$ and $\frac{N\sqrt{P}}{H^{5/4}}$ respectively (*b*) $\frac{N\sqrt{Q}}{H^{3/4}}$ and $\frac{N\sqrt{P}}{H^{3/4}}$ respectively

(*c*) $\frac{N\sqrt{Q}}{H^{5/4}}$ and $\frac{N\sqrt{P}}{H^{5/4}}$ respectively (*d*) $\frac{N\sqrt{Q}}{H^{5/4}}$ and $\frac{N\sqrt{P}}{H^{3/4}}$ respectively.

Sol. (*a*) Specific speed of pump and turbine are $\frac{N\sqrt{Q}}{H^{3/4}}$, and $\frac{N\sqrt{P}}{H^{5/4}}$

54. The following lists refer to fluid machinery. Match List I with List II and select the correct answer.

List I	*List II*
A. Draft tube	1. Impulse turbine.
B. Surging	2. Reciprocating pump
C. Air vessel	3. Reaction turbine.
D. Nozzle	4. Centrifugal pump.

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

Sol. (*b*) The correct matching is Draft tube-reaction turbine, surging-centrifugal pump, air vessel-reciprocating pump, and nozzle - impulse turbine.

55. Match List I List II and select the correct answer.

List I (Types of turbines)	*List II (Characteristics of turbines)*
A. Propeller	1. Inward flow reaction.
B. Francis	2. Tangential flow impulse.
C. Kaplan	3. Axial flow reaction with fixed vanes.
D. Pelton	4. Axial flow reaction with adjustable vanes.

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

Sol. (*d*) Correct matching is A-3, B-1, C-4 D-2.

56. Which of the following are the functions of a volute casing in a centrifugal pump?
1. To collect water from the periphery of the impeller and to transmit it to the delivery pipe at constant velocity.
2. To increase the discharge of the pump.
3. To increase the efficiency of the pump.
4. To reduce the loss of head in discharge.

Codes :
(*a*) 1,2 and 3 (*b*) 2, 3 and 4 (*c*) 1,3 and 4 (*d*) 1 and 2

Sol. (*c*) Statements 1, 3 and 4 are correct.

Direction : The following fourteen items consist of two statements, one labelled the 'Assertion A' and the other labelled the 'Reason R'. You are to examine these two statements carefully and decide if the Assertion A and the Reason R are individually true and if so, whether the Reason is a correct explanation of the Assertion. Select your answer to these items using the codes given below and mark your answer sheet accordingly.

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

57. Assertion A : The thermal efficiency of a regenerative Rankine cycle is always higher than that of a cycle without regeneration.

Reason R : In regeneration cycle the work output is more.

Sol. (*c*) Thermal efficiency of Regenerating Rankine cycle is higher than without regeneration. However, work output is less due to partial extraction of steam. Thus A is true but R is false.

58. Assertion A : Self-ignition temperature of the end charge must be higher to prevent knocking of an SI engine.

Reason R : Higher compression ration increases the temperature of the air-fuel mixture.

Sol. (*d*) Self ignition temperature of end of charge must be lower to prevent knocking. Higher compression ratio increases temperature of air fuel mixture. Thus A is false and R is correct.

59. Assertion A : Air injection system finds wide application in modern diesel engines.

Reason R : Very good atomisation of fuels is attained by the air injection system.

Sol. (*a*) Both A and R are correct and R is correct explanation of A.

60. Assertion A : Turbojet engine is superior to turboprop engine at all operating conditions.

Reason R : Efficiency of the propeller is low at high altitude and at high speeds.

Sol. (*d*) A is false but R is true.

61. Assertion A : A rocket engine can operate even in vacuum and in any fluid medium.

Reason R : Rocket engine is a pure reaction engine, wherein a propulsive thrust is obtained as a reaction of momentum of ejected matter.

Sol. (*a*) Both A and R are true and R provides correct explanation for A.

62. Assertion A : A throttle-governed steam engine has a high thermal efficiency.

Reason R : In a throttle-governed steam engine, the speed of the engine is maintained constant with the help of a governor irrespective of the load on the engine.

Sol. (*d*) A cut off governing engine has better efficiency than throttle governed engine. Statement at R is correct.

63. Assertion A : In modern boilers, a combination of convection superheater and radiant superheater maintains a constant steam temperature at the stop valve at all loads.

Reason R : The radiant superheater absorbs more heat as the load increases and convection superheater absorbs less heat as the load increases.

Sol. (*c*) Statement at A is correct. Radiant superheater absorbs less heat as load increases and convection superheater absorbs more heat as the load increases. Thus R is false.

64. Assertion A : Excess air supplied to a combustor increases the efficiency of combustion.

Reason R : Excess air tends to lower the temperature of the products of combustion.

Sol. (*d*) Excess air upto a limit increases efficiency, but beyond that the efficiency decreases for the reason given in R.

65. Assertion A : Throttle governing is generally adopted to maintain constant speed of a small turbine, irrespective of load.

Reason R : In throttle governing, with the help of a valve, the number of steam passages is reduced by leaving just the required number of passages uncovered depending upon the load.

Sol. (*c*) A is correct. R is true for nozzle governing.

66. Assertion A : During the operation of a steam turbine, it is necessary to maintain the moisture content of steam below 10%. Hence, the steam quality at turbine exit must be greater than 0.9.

Reason R : The precaution has to be taken in order to prevent corrosion and the consequent damage to the turbine.

Sol. (*c*) A is correct. R is true for erosion more than corrosion.

67. Assertion A : The rate of heat transfer drops heavily in condensation of vapours containing air and this necessitates the use of a deaeratng pump in surface condensers.

Reason R : The air accumulating at the heat transfer surface serves as a serious obstacle to vapour reaching the wall.

Sol. (*a*) Both A and R are true and R is right explanation for A.

68. Assertion A : Quick freezing of food materials helps retain the original texture of food materials and taste of juices.

Reason R : Quick freezing causes the formation of smaller crystals of water which does not damage the tissue cells of food materials.

Sol. (*c*) A is true but R is false.

69. Assertion A : Dehumidification and humidification respectively are needed in winter and summer airconditioning.

Reason R : In winter, the air is to be heated and in summer, the air is to be cooled and moisture control is necessary to maintain the relative humidity within limits.

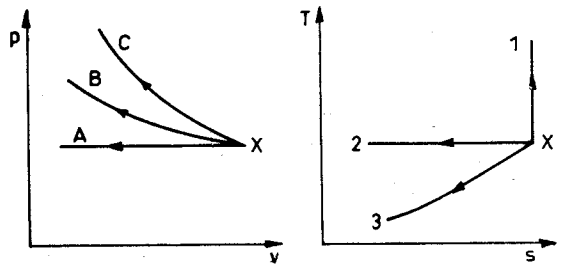
Sol. (*a*) Both A and R are true and R provides correct explanation for A.

70. Assertion A : Two table tennis balls hang parallelly maintaining a small gap between them. If air is blown into the gap between the balls, the balls will move apart.

Reason R : Bernoulli's theorem is applicable in this case.

Sol. (*a*) Both A and R are true and R provides correct explanation for A.

71. Three processes are represented on the p-v and T-s diagrams in the following figures. Match processes in the two diagrams and select the correct answer using the codes given below the diagrams:



Codes :	A	B	C		A	B	C
(*a*)	1	2	3	(*b*)	2	3	1
(*c*)	3	2	1	(*d*)	1	3	2

Sol. (*c*) Right matching is A-3, B-2, C-1.

72. A system at a given state undergoes change through the following expansion processes to reach the same final volume

1. Isothermal 2. Isobaric.
3. Adiabatic ($\gamma = 1.4$) 4. Polytropic ($n = 1.3$).

The correct ascending order of the work output in these four processes is

(*a*) 1,2,4,3 (*b*) 1,4,3,2 (*c*) 4,1,3,2, (*d*) 4,1,2,3.

Sol. (*a*) (*a*) is right choice.

73. For an irreversible cycle

(*a*) $\oint \frac{dQ}{T} \leq 0$ (*b*) $\oint \frac{dQ}{T} > 0$ (*c*) $\oint \frac{dQ}{T} < 0$ (*d*) $\oint \frac{dQ}{T} \geq 0$

Sol. (*b*) For irreversible cycle $\int \frac{dQ}{T} > 0$.

74. The values of heat transfer and work transfer for four processes of a thermodynamic cycle are given below:

Process	Heat Transfer (kJ)	Work Transfer (kJ)
1	300	300
2	zero	250
3	–100	–100
4	zero	–250

The thermal efficiency and work ratio for the cycle will be respectively.

(*a*) 33% and 0.66 (*b*) 66% and 0.36. (*c*) 36% and 0.66 (*d*) 33% and 0.36.

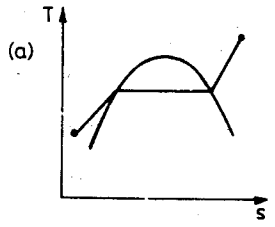
Sol. (*b*) $\eta_{th} = \frac{\text{work done}}{\text{heat added}} = \frac{300 - 100}{300} = 0.66$, work ratio $= \frac{\Sigma (+w) - \Sigma (-w)}{\Sigma (+w)} = \frac{550 - 350}{550} = \frac{200}{550} = 0.36$

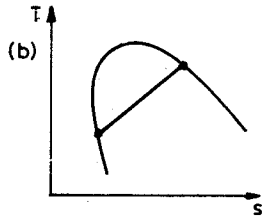
75. Which one of the following statements is correct ?

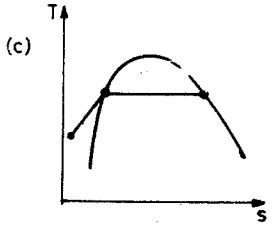
(*a*) Pressure and temperature are independent during phase change.
(*b*) An isothermal line is also a constant pressure line in the wet vapour region.
(*c*) Entropy decreases during evaporation.
(*d*) The term dryness fraction is used to specify the fraction by mass of liquid in a mixture of liquid and vapour.

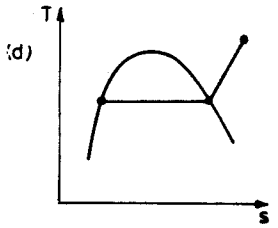
Sol. (*b*) Statement (*b*) is correct.

76. The conversion of water from 40°C to steam at 200°C pressure of 1 bar is best represented as



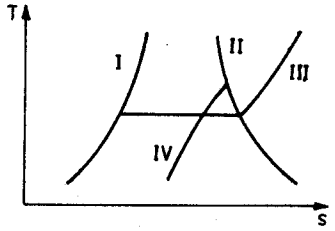






Sol. (*a*) Figure at (*a*) is correct.

77. The following figure shows the T-s diagram for steam. With respect to this figure, match List I with List II and select the correct answer using the codes given below the Lists:



List I		*List II*
A. Curve I	1.	Saturated liquid line.
B. Curve II	2.	Saturated vapour line.
C. Curve III	3.	Constant pressure line.
D. Curve IV	4.	Constant volume line.

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

Sol. (*c*) The correct choice is A-1, B-2, C-3, D-4.

78. Which one of the following changes/sets of changes in the source and sink temperatures (T_1 and T_2 respectively) of a reversible engine will result in the maximum improvement in efficiency ?

(*a*) $T_1 + \Delta T$

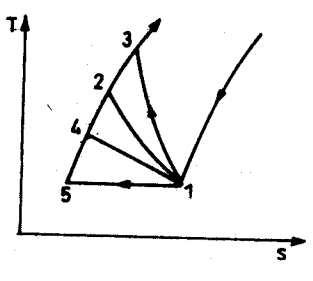
(*b*) $T_2 - \Delta T$

(*c*) $(T_1 - \Delta T)$ and $(T_2 - \Delta T)$

(*d*) $(T_1 - \Delta T)$ and $(T_2 - \Delta T)$

Sol. (*c*) For maximum improvement in efficiency source temperature should be raised and sink temperature lowered.

79. Consider the T-s diagram shown in the following figure : Actual compression process in gas turbines is indicated by the process.



(*a*) 1-2

(*b*) 1-3

(*c*) 1-4

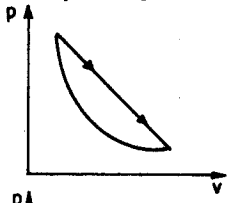
(*d*) 1-5.

Sol. (*b*) Curve 1-3 is actual compression process in gas turbine.

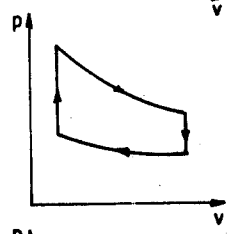
80. Match figures of Column I with those given in Column II and select the correct answer using the codes given below the columns :

Column I (p-v diagram)

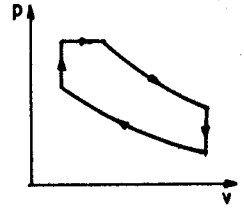
A.



B.

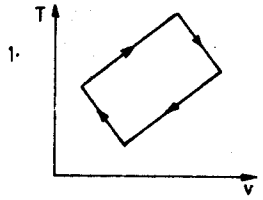


C.

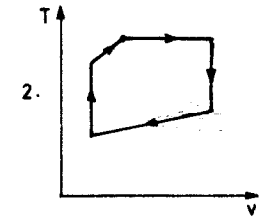


Column II (T-s diagram)

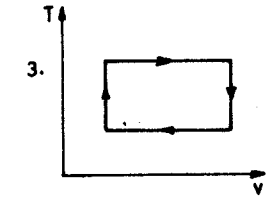
1.



2.



3.



Codes :	A	B	C		A	B	C
(*a*)	1	2	3	(*b*)	2	3	1
(*c*)	3	1	2	(*d*)	3	2	1

Sol. (*c*) Right matching is A-3, B-1, C-2.

81. The object of providing masked inlet valve in the air passage of compression- ignition engines is to
(*a*) enhance flow rate
(*b*) control air flow.
(*c*) induce primary swirl
(*d*) induce secondary turbulence.

Sol. (*a*) (*a*) is correct choice.

82. Which one of the following events would reduce the volumetric efficiency of a vertical compression - ignition engine ?
(*a*) Inlet valve closing after bottom dead centre.
(*b*) Inlet valve closing before bottom dead centre.
(*c*) Intet valve opening before top dead centre.
(*d*) Exhaust valve closing after top dead centre.

Sol. (*b*) Volumetric efficiency will reduce if fresh charge filled is reduced, *i.e.* inlet valve closes before bottom dead centre.

83. As compared to air standard cycle, in actual working, the effect of variations in specific heats is to
(*a*) increase maximum pressure and maximum temperature.
(*b*) reduce maximum pressure and maximum temperature.
(*c*) increase maximum pressure and decrease maximum temperature.
(*d*) decrease maximum pressure and increase maximum temperature.

Sol. (*b*) Statement at (*b*) is correct.

84. Reference fuels for knock rating of SI engine fuels would include
(*a*) iso- octane and alpha-methyl naphthalene. (*b*) normal octane and aniline.
(*c*) iso-octane and n-hexane (*d*) n-heptane and iso - octane.

Sol. (*d*) Reference fuel for knock rating of SI engine fuels would include n-heptane and iso-octane.

85. Consider the following measures :
1. Increasing the compression ratio. 2. Increasing the intake air temperature.
3. Increasing the length to diameter ratio of the cylinder.
4. Increasing the engine speed.

The measures necessary to reduce the tendency to knock in CI engines would include
(*a*) 1,2 and 3 (*b*) 1,2 and 4 (*c*) 1,3 and 4 (*d*) 2,3 and 4

Sol. (*b*) Measures at 1, 2 and 4 would reduce the tendency to knock in CI engine.

86. Match List I with List II and select the correct answer.

List I (Operating condition)	*List II (Approximate air fuel ratio)*
A. Idling	1. 16
B. Part load operation	2. 10
C. Full load	3. 12.5
D. Cold start	4. 3

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

Sol. (*a*) Correct matching is A-2, B-1, C-3 and D-4.

87. Generally, in Bosch type fuel injection pumps, the quantity of fuel is increased or decreased with change in load, due to change in
(*a*) timing of start of fuel injection. (*b*) timing of end of fuel injection.
(*c*) injection pressure of fuel (*d*) velocity of flow of fuel.

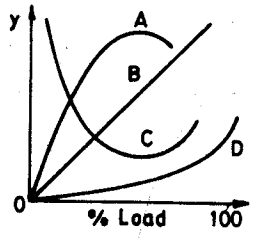
Sol. (*b*) The quantity of fuel is varied by rotating helix on pump plunger, i.e. timing the end of fuel injection.

88. If the approximate average mean pressures during induction, compression, power and exhaust strokes of an internal combustion engine are respectively 15 kN/m^2 below atmosphere, 200 kN/m^2 above atmosphere, 1000 kN/m^2 above atmosphere and 20 kN/m^2 above atmosphere, then the resultant mean effective pressure, in kN/m^2, is
(*a*) 765 (*b*) 795 (*c*) 800 (*d*) 805.

Sol. (*a*) Resultant mean effective pressure = 1000 – 200 – (15 + 20) = 800 – 35 = 765 kN/m^2

89. Match List I (performance curves, labelled A, B, C and D, for a constant speed diesel engine) with List II (performance parameter) and select the correct answer.

List I



List II

1. Smoke level
2. Brake specific fuel consumption.
3. Brake thermal efficiency
4. Brake power

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

Sol. (*a*) Correct matching is A-3, B-4, C-1 and D-2.

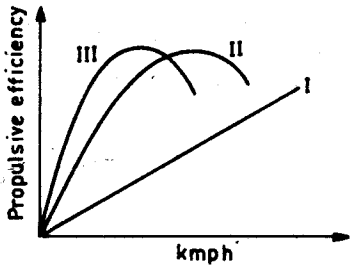
90. Which one of the following quantities is assumed constant for an internal combustion engine while estimating its friction power by extrapolation through Willan's line ?
(*a*) Brake thermal efficiency
(*b*) Indicated thermal efficiency.
(*c*) Mechanical efficiency
(*d*) Volumetric efficiency.

Sol. (*b*) (*b*) is right choice.

91. The following figure shows the propulsive efficiencies of three different engines. Based on this figure, match List I with List II and select the correct answer using the codes given below the Lists :

List I	*List II*
A. Rocket	1. Curve I
B. Turboject	2. Curve II
C. Propeller	3. Curve III

Codes :	A	B	C
(*a*)	1	2	3
(*b*)	2	1	3
(*c*)	1	3	2
(*d*)	3	1	2



Sol. (*a*) Right choice is A-1, B-2 and C-3.

92. If V_j is the jet velocity and V_0 is the vehicle velocity, the propulsive efficiency of a rocket is given by

(*a*) $\dfrac{2(V_0/V_j)}{1+\left(\dfrac{V_0}{V_j}\right)^2}$ (*b*) $\dfrac{V_0/V_j}{1+\left(\dfrac{V_0}{V_j}\right)^2}$ (*c*) $\dfrac{V_0}{V_0+V_j}$ (*d*) $\dfrac{V_j}{V_0+v_j}$

Sol. (*a*) Propulsive efficiency of rocket is $2(V_o/V_j)/1+(V_o/V_j)^2$

93. Match List I with List II in respect of chemical rocket engine and select the correct answer

List I	*List II*
A. Ethyl alcohol	1. Liquid oxidiser
B. Nitrocellulose	2. Liquid fuel
C. Ammonium perchlorate	3. Solid oxidiser
D. Hydrogen peroxide	4. Solid fuel.

Codes :	A	B	C	D
(*a*)	1	3	2	4
(*c*)	2	4	3	1

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

Sol. (*c*) Correct matching is A-2, B-4, C-3 and D-1.

94. Enriched uramium is required as fuel in a nuclear reactor, if light water is used as moderator and coolant, because light water has
(*a*) high neutron absorption cross- section.
(*b*) low moderating efficiency.
(*c*) high neutron scatter cross-section.
(*d*) low neutron absorption cross - section.

Scl. (*c*) Right choice is (*c*).

95. Match List I with List II and select the correct answer (these pertain to nuclear reactors).

List I	*List II*
A. Coolant	1. Carbon dioxide
B. Control rod	2. Zirconium
C. Poison	3. Cadmium
D. Cladding	4. Graphite
	5. Hafnium

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

Sol. (*c*) Correct matching is A-1, B-3, C-5 and D-2.

96. The output of a boiler is normally stated as
(*a*) evaporative capacity in tonnes of steam that can be produced from and at 100°C.
(*b*) weight of steam actually produced at rated pressure in tonnes per hour.
(*c*) boiler horse power.
(*d*) weight of steam produced per kg of fuel.

Sol. (*b*) Output of boiler is stated as weight of steam at rated pressure.

97. Match List I with List II and select the correct answer.

List I	*List II*
A. Bin system	1. Dust collection.
B. Cyclone furnace	2. High turbulence
C. Tangential burners	3. High slag recovery
D. Scrubber	4. Pulverised fuel.

Codes :

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

Sol. (*b*) Correct matching is A-4, B-3, C-2 and D-1.

98. Match List I (turbines) with List II (classification) and select the correct answer using the codes given below the Lists:

List I	*List II*
A. Parson's	1. Pressure compounded.
B. De Laval	2. Reaction.
C. Rateau	3. Simple impulse.
D. Curtis	4. Velocity compounded.

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

Sol. (*c*) Correct matching is A-2, B-3, C-1 and D-4.

99. The outward radial flow turbine in which there are two rotors rotating in opposite directions is known as
(*a*) 50% reaction radial turbine
(*b*) cantilever turbine.
(*c*) Ljungstrom turbine
(*d*) pass-out turbine.

Sol. (*c*) Description of turbine given is for Ljungstrom turbine.

100. When compared to stable flow, for supersaturated flow of steam through a nozzle the available enthalpy drop.

(*a*) remains the same (*b*) increases (*c*) decreases (*d*) is unpredictable.

Sol. (*c*) Right choice is at (*c*).

101. Which of the following statements are correct ?

1. Impulse turbine rotor blades are thick at the centre.
2. Rateau turbine is more efficient than Curtis turbine.
3. Blade velocity coefficient for an impulse turbine is of the order of 60%.

Codes :

(*a*) 1,2 and 3 (*b*) 1 and 2 (*c*) 1 and 3 (*d*) 2 and 3.

Sol. (*b*) Statements 1 and 2 are correct.

102. The critical pressure ratios for the flow of dry saturated and superheated steam through a nozzle are respectively.

(*a*) 0.5279 and 0.528 (*b*) 0.577 and 0.550

(*c*) 0.577 and 0.546 (*d*) 0.5279 and 0.546.

Sol. (*c*) Critical pressure ratio for dry saturated and superheated steam through a nozzle are 0.577 and 0.546.

103. Given that

α_1 = nozzle angle,

n = number of rows of moving blades, in a velocity compounded impulse turbine, the optimum blade speed ratio is

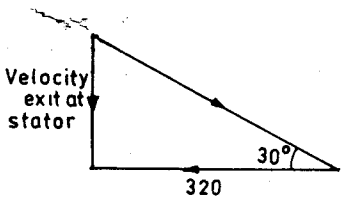
(*a*) $2 \cos \alpha_1 \cdot n$ (*b*) $\frac{n \cos \alpha_1}{2}$ (*c*) $\frac{\cos \alpha_1}{2(n+1)}$ (*d*) $\frac{\cos \alpha_1}{2n}$

Sol. (*d*) Optimum blade speed ratio for velocity compounded impulse turbine is $(\cos \alpha_1)/2n$.

104. In a Parson's turbine stage, blade velocity is 320 m/s at the mean radius and the rotor blade exit angle is 30°. For minimum kinetic energy of the steam leaving the stage, the steam velocity at the exit of the stator will be

(*a*) $640/\sqrt{3}$ m/s (*b*) 640 m/s.

(*c*) $320/\sqrt{3}$ m/s (*d*) $160\sqrt{3}$ m/s.



Sol. (*c*) Steam velocity at exit of stator

$= 320 \tan 30° = 320/\sqrt{3}$ m/s

105. For a free vortex design of blade in the rotor of a reaction axial turbine, the specific work along the blade height is

(*a*) higher at the blade hub and lower at the blade tip.

(*b*) constant from hub to tip.

(*c*) lower at the hub and higher at the tip.

(*d*) same at the hub and tip but different from the mean section.

Sol. (*a*) (*a*) is right choice.

106. A reaction turbine stage has angles α, β, γ as nozzle angle, inlet blade angle and outlet blade angle respectively. The expression for maximum efficiency of the turbine is given by

(*a*) $\frac{2\cos^2\beta}{1+\cos^2\beta}$ (*b*) $\frac{2\cos^2\gamma}{1+\cos^2\gamma}$ (*c*) $\frac{2\cos^2\alpha}{1+\cos^2\alpha}$ (*d*) $\frac{\cos(\alpha+\beta)}{\cos^2\gamma}$

Sol. (*c*) Relationship at (*c*) is correct.

107. Consider the following :
1. Safety valve 2. Steam trap. 3. Steam separator 4. Economiser.
Among these, the boiler accessories would include.
(*a*) 1,2 and 3 (*b*) 2,3 and 4 (*c*) 1 and 4 (*d*) 1,2,3 and 4.

Sol. (*a*) Safety valve, steam trap, and steam separator are boiler accessories.

108. For a two-stage reciprocating compressor, compression from pressure p_1 to p_3 is with perfect intercooling and no pressure losses. If compression in both cylinders follows the same prolytropic process and the atmospheric pressure is p_a, than the intermediate pressure p_2 is given by
(*a*) $p_2 = (p_1 + p_3)/2$ (*b*) $p_2 = \sqrt{p_1 \cdot p_3}$ (*c*) $p_2 = p_a p_3/p_1$ (*d*) $p_2 = p_a \cdot \sqrt{p_3/p_1}$

Sol. (*b*) Correct relationship is as per (*b*).

109. If two geometrically similar impellers of a centrifugal compressor are operated at the same speed, then their head, discharge and power will vary with their diameter ratio '*d*' as
(*a*) d, d^2 and d^3 respectively (*b*) d^2, d^3 and d^5 respectively.
(*c*) d, d^3 and d^5 respectively (*d*) d^2, d and d^3 respectively.

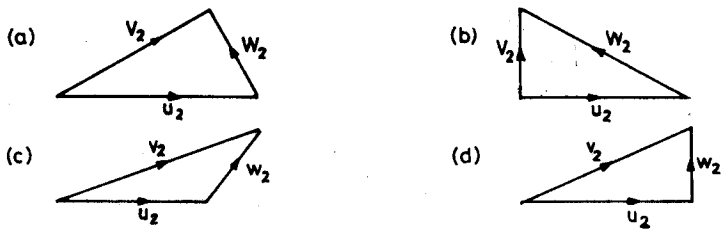
Sol. (*d*) Head, discharge and power are proportional to d^2, d and d^3.

110. High positive incidence in an axial compressor blade row leads to
(*a*) suppression of separation of flow on the blade.
(*b*) choking of the flow.
(*c*) separation of flow on the suction side of the blade.
(*d*) separation of flow on the pressure side of the blade.

Sol. (*a*) (*a*) is right choice.

111. Which one of the following velocity triangles represents the one at the exit of a radial impeller with forward curved blades ?
(u_2 = peripheral velocity, v_2 = absolute velocity, w_2 = relative velocity).

Sol. (*b*)



Velocity triangle at (*b*) is correct. Actual velocity v_2 is at right angle and angle between u_2 and w_2 is acute.

112. The stagnation pressure rise in a centrifugal compressor stage takes place.
(*a*) only in the diffuser (*b*) in the diffuser and impeller.
(*c*) only in the impeller (*d*) only in the inlet guide vanes.

Sol. (*a*) (*a*) is right choice.

113. For 15 m^3/s air flow at 10 mm WG head, which one of the following would be the best choice ?
(*a*) Centrifugal fan with forward curved blades. (*b*) Axial fan with a large number of blades in rotor.
(*c*) Axial propeller fan with a few blades in rotor.
(*d*) Cross-flow fan.

Sol. (*a*) (*a*) is right choice.

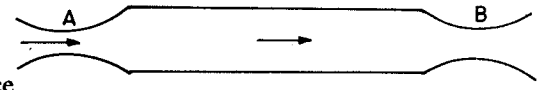
114. Two identical convergent divergent nozzles A and B are connected in series, as shown in the given figure, to carry a compressible fluid. Which one of the following statements regarding the velocities at the throats of the nozzles is correct ?

(*a*) Sonic and supersonic velocities exist at the throats of nozzles A and B respectively.

(*b*) Sonic velocity can exist at throats of both nozzles A and B.

(*c*) Sonic velocity will always exist at the throat of nozzle A while subsonic velocity will exist at throat of nozzle B.

(*d*) Sonic velocity exists at the throat of nozzle B while subsonic velocity exists at throat of nozzle A.



Sol. (*b*) (*b*) is right choice.

115. Semi-angle of a Mach cone is

(*a*) $\sin^{-1}\left(\frac{1}{\sqrt{M}}\right)$ (*b*) $\sin^{-1} M$ (*c*) $\sin^{-1}\left(\frac{1}{M}\right)$ (*d*) $\cos^{-1}\left(\frac{1}{M}\right)$

Sol. (*c*) Semi-angle of a Mach cone is $\sin^{-1}(1/M)$.

116. Which of the following statements are correct ?

1. Mach wave is a very weak shock wave.
2. Entropy change across a shock wave is nearly zero.
3. Total pressure behind a shock wave is less than that ahead of it.
4. Mach number behind a normal shock is less than one.

Codes :

(*a*) 1, 2 and 3 (*b*) 1, 3 and 4 (*c*) 1, 2 and 4 and (*d*) 2, 3 and 4.

Sol. (*a*) Statements 1,2 and 3 are correct.

117. Consider the following statements :

1. Intercooling is effective only at lower pressure ratios and high turbine inlet temperatures.
2. There is very little gain in thermal efficiency when intercooling is used without the benefit of regeneration.
3. With high values of 'γ' and c_p of the working fluid, the net power output of Brayton cycle will increase.

(*a*) 1,2 and 3 are correct (*b*) 1 and 2 are correct (*c*) 1 and 3 are correct (*d*) 2 and 3 are correct.

Sol. (*d*) Statements 2 and 3 are correct.

118. Introduction of a Pitot tube in a supersonic flow would produce

(*a*) normal shock at the tube nose. (*b*) curved shock at the tube nose.

(*c*) normal shock at the upstream of the tube nose.

(*d*) curved shock at the upstream of the tube nose.

Sol. (*a*) (*a*) is right choice.

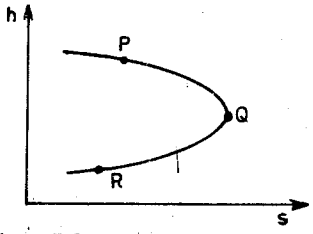
119. In the Fanno line shown in the given figure

(*a*) subsonic flow proceeds along PQR.

(*b*) supersonic flow proceeds along PQR.

(*c*) subsonic flow proceeds along PQ and supersonic flow proceeds along RQ.

(*d*) subsonic flow proceeds along RQ and supersonic flow proceeds along PQ.



Sol. (*c*) (*c*) is right choice.

120. Given k = ratio of specific heats, for Rayleigh line, the temperature is maximum at a Mach number of

(*a*) $\frac{1}{\sqrt{k}}$ (*b*) $\sqrt{k}$ (*c*) $1/k$ (*d*) k.

Sol. (*a*) Temperature is maximum when Mach no. is $1/\sqrt{k}$.

Indian Engineering Services (IES) Examination

MECHANICAL ENGINEERING–1994

PAPER–II (Objective)

1. A state of pure shear in a biaxial state of stress is given by

(*a*) $\begin{pmatrix} \sigma_1 & 0 \\ 0 & \sigma_2 \end{pmatrix}$ (*b*) $\begin{pmatrix} \sigma_1 & 0 \\ 0 & -\sigma_1 \end{pmatrix}$ (*c*) $\begin{pmatrix} \sigma_x & \tau_{xy} \\ \tau_{yx} & \sigma_y \end{pmatrix}$ (*d*) none of the above.

Sol. (*c*) A state of pure shear in a biaxial state of stress is given by $\begin{bmatrix} \sigma_x & \tau_{xy} \\ \tau_{yx} & \sigma_y \end{bmatrix}$

2. The number of strain readings (using strain gauges) needed on a plane surface to determine the principal strains and their directions is

(*a*) 1 (*b*) 2 (*c*) 3 (*d*) 4

Sol. (*c*) Three strain gauge are needed on a plane surface to determine the principal strains and their directions.

3. When two mutually perpendicular principal stresses are unequal but like, the maximum shear stress is represented by

(*a*) the diameter of the Mohr's circle (*b*) half the diameter of the Mohr's circle
(*c*) one-third the diameter of the Mohr's circle (*d*) one-fourth the diameter of the Mohr's circle.

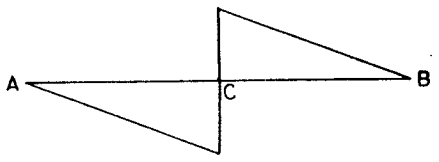
Sol. (*b*) The maximum shear stress is represented by half the diameter of Mohr's circle when two mutually perpendicular principal stresses are unequal but alike.

4. If the value of Poisson's ratio is zero, then it means that

(*a*) the material is rigid. (*b*) the material is perfectly plastic.
(*c*) there is no longitudinal strain in the material.
(*d*) the longitudinal strain in the material is infinite.

Sol. (*a*) If Poisson's ratio is zero, then material is rigid.

5. If the bending moment diagram for a simply supported beam is of the form given below. Then the load acting on the beam is

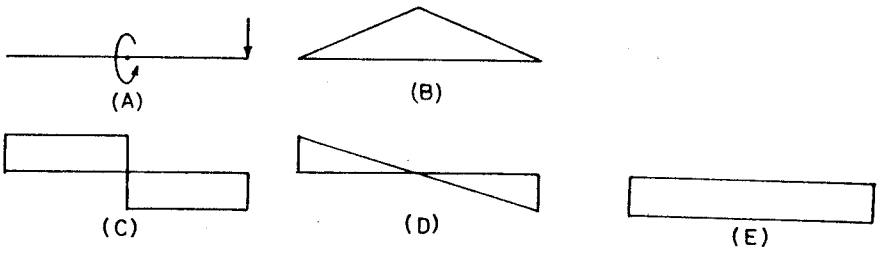


B.M. Diagram

(*a*) a concentrated force at *C*
(*b*) a uniformly distributed load over the whole length of the beam
(*c*) equal and opposite moments applied at *A* and *B*
(*d*) a moment applied at *C*.

Sol. (*d*) A vertical line in centre of B.M. diagram is possible when a moment is applied there.

6. A beam is simply supported at its ends and is loaded by a couple at its mid-span as shown in figure A. Shear force diagram for the beam is given by the figure.



(*a*) B (*b*) C (*c*) D (*d*) E

Sol. (*c*) Figure at(*c*)represents correct shear force for loading at A.

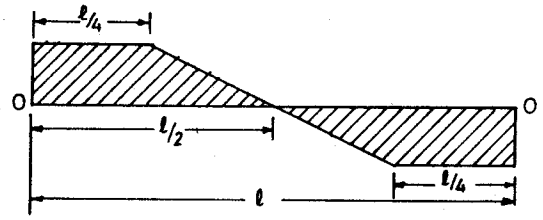
7. The shear force diagram shown in the following figure is that of a

(*a*) freely supported beam with symmetrical point load about mid-span.

(*b*) freely supported beam with symmetrical uniformly distributed load about mid-span.

(*c*) simply supported beam with positive and negative point loads symmetrical about the mid-span.

(*d*) simply supported beam with symmetrical varying load about mid-span.



Sol. (*d*) The shear force diagram is possible on simply supported beam with symmetrical varying load about mid span.

8. A solid shaft of diameter '*D*' carries a twisting moment that develops maximum shear stress τ. If the shaft is replaced by a hollow one of outside diameter '*D*' and inside diameter *D*/2, then the maximum shear stress will be.

(*a*) 1.067 τ (*b*) 1.143 τ (*c*) 1.333 τ (*d*) 2 τ.

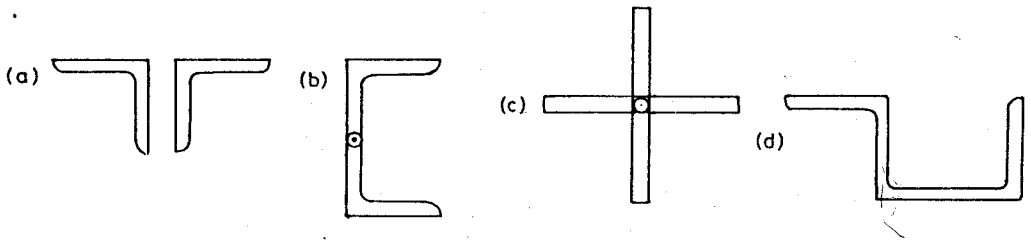
Sol. (*a*) Maximum shear stress in hollow shaft of outer and inner diameters *D* and *D*/2 in comparison to solid shaft of diameter *D* is 1.067 times the maximum stress in solid shaft.

9. A circular shaft can transmit a torque of 5kNm. If the torque is reduced to 4 kNm, then the maximum value of bending moment that can be applied to the shaft is

(*a*) 1 kNm (*b*) 2 kNm (*c*) 3 kNm (*d*) 4 kNm

Sol. (*c*) $T_e = \sqrt{T^2 + M^2}$ or $5^2 = \sqrt{4^2 + M^2}$, $\therefore$ $M = 3$ kNm

10. Which one of the following combinations of angles will carry the maximum load as a column?



Sol. (*d*) Column at (*d*) will carry maximum load as column because it has maximum moment of inertia.

11. A steel hub of 100 mm internal diameter and uniform thickness of 10mm was heated to a temperature of 300 deg. C to shrink-fit it on a shaft. On cooling, a crack developed parallel to the direction of the length of the hub. Consider the following factors in this regard :

1. Tensile hoop stress.
2. Tensile radial stress.
3. Compressive hoop stress.
4. Compressive radial stress.

The cause of failure is attributable to

(*a*) 1 alone (*b*) 1 and 3 (*c*) 1, 2 and 4 (*d*) 2,3 and 4

Sol. (*a*) A crack parallel to the direction of length of hub suggests that failure was due to tensile hoop stress alone.

12. A compound cylinder with inner radius 5 cm and outer radius 7 cm is made by shrinking one cylinder on to the other cylinder. The junction radius is 6 cm and the junction pressure is 11 kgf/cm^2. The maximum hoop stress developed in the inner cylinder is

(*a*) 36 kgf/cm^2 compression (*b*) 36 kgf/cm^2 tension
(*c*) 72 kgf/cm^2 compression (*d*) 72 kgf/cm^2 tension.

Sol. (*c*) Using normal formulae for compound cylinder, maximum hoop stress in the inner cylinder = 72 kg/cm^2 compression.

13. Cracks in helical springs used in Railway carriages usually start on the inner side of the coil because of the fact that

(*a*) it is subjected to the higher stress than the outer side.
(*b*) it is subjected to a higher cyclic loading than the outer side.
(*c*) it is more stretched than the outer side during the manufacturing process.
(*d*) it has a lower curvature than the outer side.

Sol. (*d*) Cracks in helical springs start on inner side because it has lower curvature than outside.

14. Two helical springs of the same material and of equal circular cross-section and length and number of turns, but having radii 20 mm and 40 mm, kept concentrically (smaller radius spring within the larger radius spring), are compressed between two parallel planes with a load P. The inner spring will carry a load equal to

(*a*) $P/2$ (*b*) $2P/3$ (*c*) $P/9$ (*d*) $8P/9$.

Sol. (*d*) $\frac{W_o}{W_i} = \frac{R_i^3}{R_o^3} = \left(\frac{20}{40}\right)^3 = \frac{1}{8}$; $W_o = \frac{W_i}{8}$, $W_i + \frac{W_i}{8} = P$, $\frac{9}{8} W_i = P$ and $W_i = \frac{8}{9} P$

15. Rankine Gordon formula for buckling is valid for

(*a*) long column (*b*) short column
(*c*) short and long column (*d*) very long column.

Sol. (*d*) Rankine Gordon formula for buckling load is valid for very long column.

16. If failure in shear along 45° planes is to be avoided, then a material subjected to uniaxial tension should have its shear strength equal to at least

(*a*) tensile strength (*b*) compressive strength
(*c*) half the difference between the tensile and compressive strengths.
(*d*) half the tensile strength.

Sol. (*c*) It failure in shear along 45 deg. is to be avoided, then a material subjected to uniaxial tension should have its shear strength equal to at least half the difference between the tensile and compressive strengths.

17. A shaft is subjected to a maximum bending stress of 80 N/ mm^2 and maximum shearing stress equal to 30 N/mm^2 at a particular section. If the yield point in tension of the material is 280 N/mm^2, and the maximum shear stress theory of failure is used, then the factor of safety obtained will be

(*a*) 2.5 (*b*) 2.8 (*c*) 3.0 (*d*) 3.5.

Sol. (*b*) Max shear stress $= \sqrt{\left(\frac{80-0}{2}\right)^2 + 30^2} = 50\ \text{N/mm}^2$

According to maximum shear stress theory $\tau = \frac{\sigma_y}{2}$, $\therefore \quad F.S. = \frac{280}{2 \times 50} = 2.8$

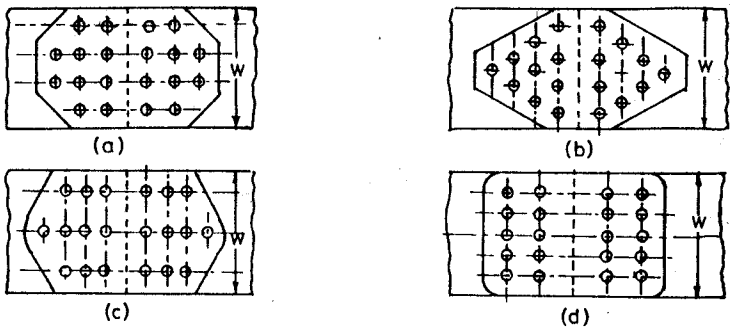
18. If σ_y is the yield strength of a particular material, then the distortion energy theory is expressed as

(*a*) $(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2\sigma_y^2$ (*b*) $(\sigma_1^2 - \sigma_2^2 + \sigma_3^2) - 2\nu\,(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1) = \sigma_y^2$

(*c*) $(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 3\sigma_y^2$ (*d*) $(1 - 2\nu)(\sigma_1 + \sigma_2 + \sigma_3)^2 = 2(1 + \nu) = \sigma_y^2$

Sol. (*a*) Distortion energy theory is expressed as $(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2\sigma_y^2$

19. Which one of the following structural joints with 10 rivets and same size of plate and material will be the most efficient ?



Sol. (*b*) The most efficient rivetted joint for 10 rivets is at (*b*).

20. Match List-I with List II and select the correct answer.

List I (Types of joints)	*List II (An element of the joint)*
A. Riveted joint	1. Pin
B. Welded joint	2. Strap
C. Bolted joint	3. Lock washer
D. Knuckle joint	4. Fillet

Codes :	A	B	C	D
(*a*)	4	3	2	1
(*c*)	2	4	3	1

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

Sol. (*c*) Correct matching is A-2, B-4, C-3, D-1.

21. Consider the following statements regarding power screws:

1. The efficiency of a self-locking screw cannot be more than 50%.
2. If the friction angle is less than the helix angle of the screw, then the efficiency will be more than 50%.
3. The efficiency of ACME (trapezoidal thread is less than that of a square thread.

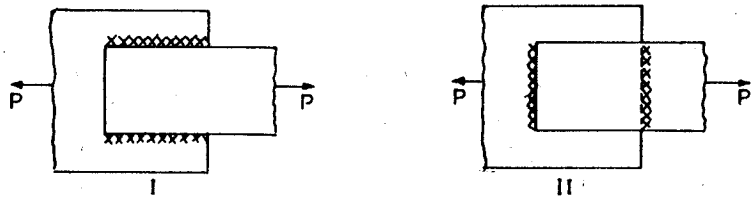
Of these statements

(*a*) 1, 2 and 3 are correct (*b*) 2 and 3 are correct

(*c*) 1 and 3 are correct (*d*) 1 and 2 are correct

Sol. (*a*) Statements 1, 2 and 3 are correct about power screws.

22. The following two figures show welded joints (x x x x x indicates welds), for the same load and same dimensions of plate and weld.



The joint shown in

(*a*) fig. I is better because the weld is in shear and the principal stress in the weld is not in line with *P*
(*b*) fig. I is better because the load transfer from the tie bar to the plate is not direct
(*c*) fig. II is better because the weld is in tension and safe stress of weld in tension is greater than that in shear
(*d*) fig. II is better because it has less stress concentration.

Sol. (*c*) Figure II is better because the weld is in tension and safe stress of weld in tension is greater than shear.

23. Given that P = chain pitch, c = centre distance,
N, n = number of teeth on large and small sprocket respectively
the length of chain in terms of pitches can be approximated by

(*a*) $\frac{2c}{P}$ (*b*) $\frac{2c}{P}+(N+n)/2$ (*c*) $\frac{2c}{P}+[(N-n)/2p]^2\frac{p}{c}$

(*d*) $\frac{2c}{P}+(N+n)/2p+[(N-n)/2p]^2\frac{p}{c}$

Sol. (*d*) Length of chain $=\frac{2C}{p}+\frac{(N+n)}{2p}+\left[\frac{(N-n)}{2p}\right]^2\frac{p}{C}$

24. When compared to a rod of the same diameter and material, a wire rope
(*a*) is less flexible. (*b*) has a much smaller load carrying capacity.
(*c*) does not provide much warning before failure.
(*d*) provides much greater time for remedial action before failure.

Sol. (*d*) A wire rope provides much greater time for remedial action before failure.

25. A shaft is subjected to fluctuating loads for which the normal torque (T) and bending moment (M) are 1000 N-m and 500 N-m respectively. If the combined shock and fatigue factor for bending is 1.5 and combined shock and fatigue factor for torsion is 2, then the equivalent twisting moment for the shaft is
(*a*) 2000 N-m (*b*) 2050 N-m (*c*) 2100 N-m (*d*) 2136 N-m.

Sol. (*d*) $T_{eq}=\sqrt{(15\times500)^2+(2\times1000)^2}=\sqrt{(750)^2+(2000)^2}=2136$ Nm

26. The lead angle of a worm is 22.5 deg. C. Its helix angle will be
(*a*) 22. 5 deg. (*b*) 45 deg. (*c*) 67.5 deg. (*d*) 90°C.

Sol. (*c*) α = Pressure angle $\cong$ lead angle; $\alpha+\beta=90°$; β = helix angle $=90°-22.5°=67.5°$

27. Consider the following statements about anti-friction bearings:
1. They have low starting and low running friction at moderate speeds.
2. They have high resistance to shock loading. 3. They can carry both radial and thrust loads.
4. Their initial cost is high. 5. They can accommodate some amount of misalignments of shaft.

Of these statements

(*a*) 1,2, 3 and 4 are correct
(*b*) 1, 3 and 4 are correct
(*c*) 1, 4 and 5 are correct
(*d*) 1, 2, 3 and 5 are correct.

Sol. (*a*) For anti-friction bearings, statements 1 to 4 are correct.

28. A thin circular disc is rolling with a uniform linear speed, along a straight path on a plane surface. Consider the following statements in this regard:

1. All points on the disc have the same velocity.
2. The centre of the disc has zero acceleration.
3. The centre of the disc has centrifugal acceleration.
4. The point on the disc making contact with the plane surface has zero acceleration.

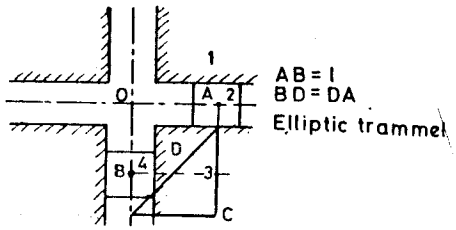
Of these statements

(*a*) 1 and 4 are correct
(*b*) 3and 4 are correct.
(*c*) 3 alone is correct
(*d*) 2 alone is correct.

Sol. (*d*) Statement 2 alone is correct.

29. An elliptic trammel is shown in the given figure. Associated with the motion of the mechanism are fixed and moving centrodes. It can be established analytically or graphically that the moving centrode is a circle with the radius and centre respectively of

(*a*) *l* and *O*
(*b*) *l*/2 and *B*
(*c*) *l*/2 and *C*
(*d*) *l*/2 and *D*



Sol. (*a*) For given elliptic trammel, the moving centrode is a circle with radius and centre as *l* and *O*.

30. An electric lift is moving downwards with an acceleration of *g*/3. The vertical force between a passenger in the lift and its floor is equal to

(*a*) 2/3 of the passenger's weight
(*b*) 4/3 of the passenger's weight
(*c*) passenger's weight
(*d*) 4/3 of the passenger's weight.

Sol. (*a*) When lift is moving down with acceleration of *g*/3, then vertical force between a passenger in lift and its floor = 2/3 of passenger's weight.

31. In a circular arc cam with roller follower, the acceleration in any position of the lift would depend only upon

(*a*) total lift, total angle of lift, minimum radius of cam and cam speed.
(*b*) radius of circular arc, cam speed, location of centre of circular arc and roller diameter.
(*c*) weight of cam follower linkage, spring stiffness and cam speed.
(*d*) total lift, centre of gravity of the cam and cam speed.

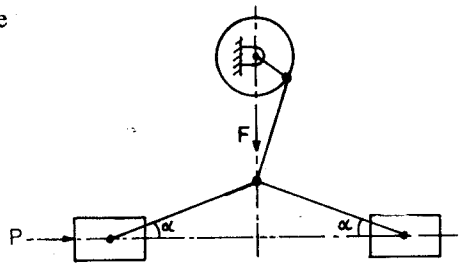
Sol. (*b*) (*b*) is correct answer.

32. The Klein's method of construction for reciprocating engine mechanism.

(*a*) is a simplified version of instantaneous centre method
(*b*) utilises a quadrilateral similar to the diagram of mechanism for reciprocating engine
(*c*) enables determination of Corioli's component.
(*d*) is based on the acceleration diagram.

Sol. (*d*) Klein's method of construction for reciprocating engine mechanism is based on the acceleration diagram.

33. With reference to the mechanism shown in the figure, the relation between F and P is



(*a*) $F = \frac{1}{2} P \cdot \tan \alpha$

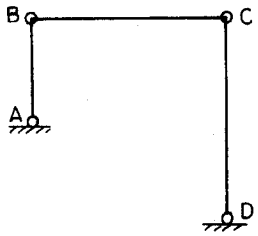
(*b*) $F = P \cdot \tan \alpha$

(*c*) $P = 2F \tan \alpha$

(*d*) $F = 2P \tan \alpha$

Sol. (*b*) $F = P \tan \alpha$.

34. In the given figure, $ABCD$ is a four-bar mechanism. At the instant shown, AB and CD are vertical and BC is horizontal AB is shorter than CD by 30 cm. AB is rotating at 5 radius and CD is rotating at 2 rad/s. The length of AB is



(*a*) 10 cm

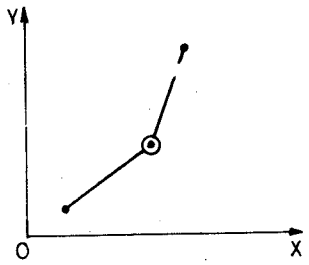
(*b*) 20 cm

(*c*) 30 cm

(*d*) 50 cm.

Sol. (*b*) $5l = 2(l + 30)$, $3l = 60$ and $l = 20$ cm

35. The two-link system, shown in the given figure, is constrained to move with planar motion. It possesses



(*a*) 2-degrees of freedom

(*b*) 3-degrees of freedom

(*c*) 4-degrees of freedom

(*d*) 6-degrees of freedom

Sol. (*a*) Two link system shown in the above figure has 2 degrees of freedom.

36. Two co-axial rotors having moments of inertia I_1, I_2 and angular speeds ω_1 and ω_2 respectively are engaged together. The loss of energy during engagement is equal to

(*a*) $\dfrac{I_1 I_2 (\omega_1 - \omega_2)^2}{2(I_1 + I_2)}$ (*b*) $\dfrac{I_1 I_2 (\omega_1^2 - \omega_2^2)^2}{2 (I_1 - I_2)}$

(*c*) $\dfrac{2I_1 I_2 (\omega_1 - \omega_2)^2}{(I_1 + I_2)}$ (*d*) $\dfrac{I_1 \omega_1^2 - I_2 \omega_2^2}{(I_1 + I_2)}$

Sol. (*d*) Loss of energy during engagement $= (I_1 \omega_1^2 - I_2 \omega_2^2)/(I_1 + I_2)$.

37. A spring controlled governor is found unstable. It can be made stable by

(*a*) increasing the spring stiffness

(*b*) decreasing the spring stiffness

(*c*) increasing the ball weight

(*d*) decreasing the ball weight.

Sol. (*b*) A spring controlled governor can be made stable by decreasing the spring stiffness.

38. If a number of forces act on a rigid body, each force may be replaced by an equal and parallel force acting through a fixed point, together with a couple. For the rigid body to be in equilibrium,

(*a*) the resultant force at the fixed point must be zero

(*b*) the resultant couple on the body must be zero

(*c*) both resultant force and couple must be zero

(*d*) none of the above need be zero.

Sol. (*c*) For rigid body to be in equilibrium, both resultant force and couple must be zero.

39. A rotor which is balanced statically but not dynamically is supported on two bearings L apart, and at high speed of the rotor, dynamic reaction on the left bearing is R. The right side of the bearing is shifted to a new position $2L$ apart from the left bearing. At the same rotor speed, dynamic reaction on the left bearing in the new arrangement will

(*a*) remain same as before (*b*) become equal to $2R$

(*c*) become equal to $R/2$ (*d*) become equal to $R/4$.

Sol. (*b*) (*b*)is correct answer.

40. Consider the following statements regarding a high speed in-line engine with identical reciprocating parts with cranks spaced to give equal firing intervals :

1. All harmonic forces, except those which are multiples of half the number of cylinders, are balanced.
2. Couples are balanced if the engine is symmetrical about a place normal to the axis of the crank shaft.
3. In a four cylinder in-line engine, second and fourth harmonic forces are unbalanced whereas in a six cylinder in-line engine, second, fourth and sixth harmonic forces are unbalanced.

Of these statements

(*a*) 1, 2 and 3 are correct (*b*) 1 and 3 are correct

(*c*) 1 and 2 are correct (*d*) 2 and 3 are correct

Sol. (*a*) Statements 1, 2, and 3 are correct.

41. In the statement, "an eccentric mass rotating at 3000 rpm will create X times more unbalanced force than 50% of the same mass rotating at 300 rpm, 'X' stands for

(*a*) 10 (*b*) 50 (*c*) 100 (*d*) 200

Sol. (*d*) $m \times 3000^2 = X \times m \times 300^2$; $\therefore \quad X = 200$

42. A machine of 100 kg mass has a 20 kg rotor with 0.5 mm eccentricity. The mounting springs have stiffness 85 kN/m, and damping is negligible. If the operating speed is 20π rad/s and the unit is constrained to move vertically, the dynamic amplitude of the machine will be

(*a*) 0.470×10^{-4} m (*b*) 1.000×10^{-4} m (*c*) 1.270×10^{-4} m (*d*) 2.540×10^{-4} m.

Sol. (*a*) $\omega_n = \sqrt{\frac{K}{m}} = \sqrt{\frac{85 \times 1000}{120}} = 26.6, \frac{\omega}{\omega_n} = \frac{20\pi}{26.6} = 2.36$

$$X = \frac{me}{M}\left(\frac{\omega}{\omega_n}\right)^2 \Big/ \left[\left\{1 - \left(\frac{\omega}{\omega_n}\right)^2\right\}^2 + \left(2\frac{\omega}{\omega_n}\right)^2\right] = 0.47 \times 10^{-4} \text{ m}$$

Dynamic amplitude of machine $= 0.470 \times 10^{-4}$ m

43. Match List I (force transmissibility) with List II (frequency ratio) and select the correct answer using the codes given below the Lists :

List I	*List II*
A. 1	1. $\omega/\omega_n > \sqrt{2}$
B. Less than 1	2. $\omega/\omega_n = \sqrt{2}$
C. Greater than 1	3. $\omega/\omega_n \gg \sqrt{2}$
D. Tending to zero	4. $\omega/\omega_n < \sqrt{2}$.

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

Sol. (*b*) Correct matching is A-2, B-1, C-4, D-3.

44. A mass of 1 kg is attached to the end of a spring with a stiffness 0.7 N/mm. The critical damping coefficient of this system is

(*a*) 1.40 Ns/m (*b*) 18.522 Ns/m (*c*) 52.92 Ns/m (*d*) 529.20 Ns/m

Sol. (*c*) For critical damping $\xi = 1 = \frac{c}{2m\omega_n}$, $c = 2 \times 1 \times \sqrt{\frac{K}{m}} = 2\sqrt{\frac{700}{1}} = 2 \times 26.45 = 52.92$ Ns/m

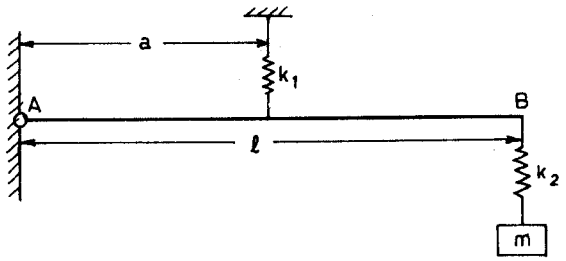
45. A system is shown in the following figure. The bar *AB* is assumed to be rigid and weightless. The natural frequency of vibration of the system is given by

(*a*) $f_n = \frac{1}{2\pi}\sqrt{\frac{k_1 k_2 (a/l)^2}{m[k_2 + (a/l)^2 k_1]}}$

(*b*) $f_n = \frac{1}{2\pi}\sqrt{\frac{k_1 k_2}{m(k_1 + k_2)}}$

(*c*) $f_n = \frac{1}{2\pi}\sqrt{\frac{k_1}{mk_2}}$

(*d*) $f_n = \frac{1}{2\pi}\sqrt{\frac{k_1 + k_2}{mk_1 k_2}}$



Sol. (*a*) Natural frequency of system in given figure is as per (*a*).

46. Two heavy rotating masses are connected by shafts of lengths l_1, l_2 and l_3 and the corresponding diameters are d_1, d_2 and d_3. This system is reduced to a torsionally equivalent system having uniform diameter "d_1" of the shaft. The equivalent length of the shaft is

(*a*) $\frac{l_1 + l_2 + l_3}{3}$ (*b*) $l_1 + l_2\left(\frac{d_1}{d_2}\right)^3 + l_3\left(\frac{d_1}{d_3}\right)^3$

(*c*) $l_1 + l_2\left(\frac{d_1}{d_2}\right)^4 + l_3\left(\frac{d_1}{d_3}\right)^4$ (*d*) $l_1 + l_2 + l_3$

Sol. (*c*) Equivalent length of shaft is $l_1 + l_2\left(\frac{d_1}{d_2}\right)^4 + l_3\left(\frac{d_1}{d_3}\right)^4$

47. A shaft has two heavy rotors mounted on it. The transverse natural frequencies, considering each of the rotor separately, are 100 cycles/sec and 200 cycles/sec respectively. The *lowest* critical speed is

(*a*) 5367 rpm (*b*) 6000 rpm (*c*) 9360 rpm (*d*) 12,000 rpm

Sol. (*b*) Lowest critical speed = 6000 rpm.

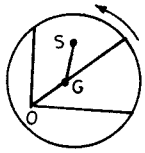
48. A shaft has an attached disc at the centre of its length. The disc has its centre of gravity located at a distance of 2 mm from the axis of the shaft. When the shaft is allowed to vibrate in its natural bow-shaped mode, it has a frequency of vibration of 10 radians/second. When the shaft is rotated at 300 revolutions per minute, it will whirl with a radius of

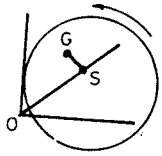
(*a*) 2 mm (*b*) 2.25 mm (*c*) 2.50 mm (*d*) 3.00 mm

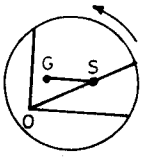
Sol. (*b*) $\omega = 300$ rpm $= 5 \times 2\pi$ cylces/sec $= 10\pi$

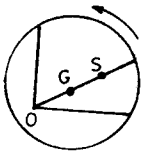
$$\frac{\omega}{\omega_c} = \frac{10\pi}{\omega} = \pi; \quad y = \frac{(\omega/\omega_c)^2 \times e}{1 - (\omega/\omega_c)^2} = \frac{\pi^2 \times 2}{1 - \pi^2} - \frac{9.86 \times 2}{8.86} = 2.25$$

49. Let *S* and *G* be positions of centre of mass and geometric centre of a disc attached to a rotating disc with axis at *O*. Let the system be resisted by viscous damping. Then at the critical speed, the relative positions of *O*, *G* and *S* are given by

(a) 

(b) 

(c) 

(d) 

Sol. (*d*) Figure at (*d*) is correct.

50. Consider the following statements regarding the differential of an automobile :

1. The speed of the crown wheel will always be the mean of the speeds of the two road wheels.
2. The road wheel speeds are independent of the number of teeth on the planets.
3. The difference between the speeds of the road wheels depends on the number of teeth on the planets.
4. The ratio of speeds of the road wheels depends upon the number of teeth on the gear wheels attached to them and on the crown wheel.

Of these statements

(*a*) 1 and 2 are correct (*b*) 3 and 4 are correct (*c*) 1 and 3 are correct (*d*) 2 and 4 are correct.

Sol. (*d*) Statements 2 and 4 are correct.

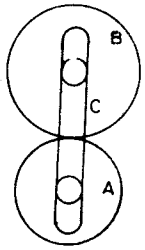
51. A single epicyclic gear train is shown in the given figure. Wheel *A* is stationary. If the number of teeth on *A* and *B* are 120 and 45 respectively, then when *B* rotates about its own axis at 100 rpm, the speed of *C* would be

(*a*) 20 rpm

(*b*) $27\frac{3}{11}$ rpm

(*c*) $19\frac{7}{11}$ rpm

(*d*) 100 rpm.



Sol. (*b*) Speed of $C = 27\frac{3}{11}$ rpm

Directions : The following fifteen items consist of two statements, one labelled the **'Assertion A'** and the other labelled the **'Reason R'**. You are to examine these two statements carefully and decide if the Assertion A and the Reason R are individually true and if so, whether the Reason is a correct explanation of the Assertion. Select your answers to these items using the codes given below and mark your answer sheet accordingly.

Codes :

(*a*) Both A and R are true and R is the correct explanation of A.

(*b*) Both A and R are true but R is not a correct explanation of A.

(*c*) A is true but R is false

(*d*) A is false but R is true

52. Assertion A : Tool wear is expressed in terms of flank wear rather than crater wear.

Reason R : Measurement of flank wear is simple and more accurate.

Sol. (*a*) Tool wear is expressed in flank wear because same is simple and accurate to measure.

53. Assertion A : In a mould, a riser is designed and placed so that the riser will solidify after the casting has solidified.

Reason R : A riser is a reservoir of molten metal which will supply molten metal where a shrinkage cavity would have occurred.

Sol. (*a*) Both A and R are true and R provides correct explanation for A.

54. Assertion A : Machine tool beds are generally made of grey cast iron.

Reason R : Cast iron possesses good self-lubricating properties.

Sol. (*a*) Both A and R are true and R provides correct explanation for A.

55. Assertion A : "Carburising" is done on non-ferrous alloys to increase the surface hardness.

Reason R : "Precipitation hardening" of non-ferrous alloys involves "solution heat treatment" followed by "precipitation heat treatment".

Sol. (*d*) R is true and A is false.

56. Assertion A : Planning and scheduling of job order manufacturing differ from planning and scheduling of mass production manufacturing.

Reason R : In mass production manufacturing, a large variety of products are manufactured in large quantity.

Sol. (*c*) A is true and R is false.

57. Assertion A : In distribution problem, unit cost of production as well as transportation cost are considered.

Reason R : The Vogel approximation method can reduce the number of iterations required to move from the initial assignment to the optimal solution.

Sol. (*b*) Both A and R are true and R is not correct explanation for A.

58. Assertion A : A hollow shaft will transmit a greater torque than a solid shaft of the same weight and same material.

Reason R : The average shear stress in the hollow shaft is smaller than the average shear stress in the solid shaft.

Sol. (*a*) Both A and R are true and R provides right explanation for A.

59. Assertion A : A column subjected to eccentric load will have its stress at centroid independent of the eccentricity.

Reason R : Eccentric loads in columns produce torsion.

Sol. (*c*) A is true and R is false.

60. Assertion A : Uniform-strength bolts are used for resisting impact loads.

Reason R : The area of cross-section of the threaded and unthreaded parts are made equal.

Sol. (*c*) A is true and R is false.

61. Assertion A : In a short centre open-belt drive, an idler pulley is used to maintain the belt tension and to increase the angle of contact on the smaller pulley.

Reason R : An idler pulley is free to rotate on its axis and is put on the slack side of the belt.

Sol. (*a*) Both A and R are true, and R provides correct explanation for A.

62. Assertion A : The effect of keyways on a shaft is to reduce its load carrying capacity and to increase its torsional rigidity.

Reason R : Highly localised stresses occur at or near the corners of keyways.