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(Set-B)

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Branch	**Gen**	**OBC**	**SC**	**ST**	**Branch**	**Gen**	**OBC**	**SC**	**ST**
CE	210-220	205-215	170-180	170-180	**CE**	188	185	143	159
ME	245-255	245-255	210-220	210-220	**ME**	187	187	166	169
EE	225-235	215-225	195-205	195-205	**EE**	221	211	191	172
E&T	235-245	225-235	185-195	185-195	**E&T**	226	221	176	165

Mechanical Engineering Paper Analysis
ESE 2020 Prelims Exam

Sl.	Subjects	Number of Questions
1	Strength of Materials	17
2	Machine Designs	8
3	Industrial Engineering	5
4	Production	5
5	Theory of Machines	12
6	Material Science	11
7	Thermodynamics	4
8	RAC	9
9	HMT	5
10	Power Plant	18
11	IC Engine	6
12	Fluid Mechanics	21
13	Renewable Source of energy	12
14	Mechatronics	12
15	Robotics	9
16	Engineeing Mechanics	2

UPSC ESE/IES Prelims 2020

Mechanical Engineering analysis and expected cutoff by MADE EASY faculties

https://youtu.be/o9snmA7Js2A

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1. The angle through which the Earth must turn to bring the meridian of a point directly in line with the Sun's rays is called

(a) Altitude angle
(b) Hour angle
(c) Solar azimuth angle
(d) Zenith angle

Ans. **(b)**

End of Solution

2. In which type of collector is solar radiation focused into the absorber from the top, rather than from the bottom?

(a) Fresnel lens
(b) Paraboloidal
(c) Concentrating
(d) Compound parabolic

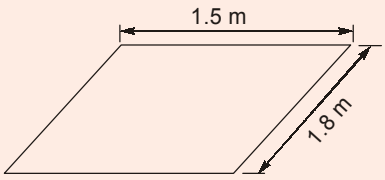
Ans. **(a)**

End of Solution

3. A flat plate collector is 150 cm wide and 180 cm high and is oriented such that it is perpendicular to the sun rays. Its active area is 90% of the panel size. If it is in a location that receives solar insolation of 1000 W/m^2 peak, the peak power delivered to the area of the collector will be

(a) 1.23 kW
(b) 2.43 kW
(c) 4.46 kW
(d) 6.26 kW

Ans. **(b)**



Effective area (A_e) = 0.9 × 1.5 × 1.8 m^2

Incident solar radiation flux (G_s) = 1000 W/m^2

$P_{max} = G_s \times A_e$ = 1000 W/m^2 × 0.9 × 1.5 × 1.8 m^2

P_{max} = 2430 Watt

= 2.43 kW

End of Solution

4. A surface having high absorptance for short wave radiation (less than 2.5 μm) and a low emittance of long-wave radiation (more than 2.5 μm), is called

(a) Absorber
(b) Emitter
(c) Selective
(d) Black

Ans. **(c)**

End of Solution

5. In a solar tower power system, each mirror is mounted on a system called

(a) Regenerator (b) Linear Frensel

(c) Dish (d) Heliostat

Ans. **(d)**

End of Solution

6. The ratio of PV cell's actual maximum power output to its theoretical power output is called

(a) Quantum factor (b) Fill factor

(c) Quantum efficiency (d) PV factor

Ans. **(b)**

$$FF = \frac{P_{max}}{V_{oc} I_{sc}}$$

Theoretical power output = $V_{oc}\ I_{sc}$

End of Solution

7. With respect to the wind turbine blades, TSR means

(a) Tip Swift Ratio (b) Tip Sharp Ratio

(c) Tip Speed Ratio (d) Tip Swing Ratio

Ans. **(c)**

TSR = Tip Speed Ratio

End of Solution

8. For a wind turbine 10 m long running at 20 rpm in 12.9 kmph wind, the TSR will be nearly

(a) 3.6 (b) 5.8

(c) 7.6 (d) 9.8

Ans. **(b)**

$$TSR = \frac{\text{Tip Speed}(R\omega)}{\text{Wind velocity}(V_o)}$$

$$R = 10 \text{ m}$$

$$\omega = \frac{2\times\pi\times 20}{60} \text{ rad/sec}$$

$$V_o = 12.9 \times \frac{5}{18} \text{ m/sec}$$

$$TSR = \frac{10\times\frac{2\times\pi\times 20}{60}}{12.9\times\frac{5}{18}}$$

$$TSR = 5.84$$

End of Solution

9. Which one of the following is an enclosure or housing for the generator, gear box and any other parts of the wind turbine that are on the top of the tower?

(a) Turbine blade
(b) Nacelle
(c) Turbine head
(d) Gear box

Ans. (b)

End of Solution

10. The force required for producing tides in the ocean is

(a) 70% due to Moon and 30% due to Sun
(b) 30% due to Moon and 70% due to Sun
(c) 45% due to Moon and 55% due to Sun
(d) 55% due to Moon and 45% due to Sun

Ans. (a)

End of Solution

11. Which of the following are related to the Proton Exchange Membrane Fuel Cell (PEMFC) ?

1. Polymer electrolyte
2. Hydrogen fuel and oxygen
3. Pure water and small amount of electricity
4. Nitrogen gas

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

Ans. (c)

End of Solution

12. Which of the following are the essential functions of fuel cells?'

1. The charging (or electrolyser) function in which the chemical AB is decomposed to A and B.
2. The storage function in which A and B are held apart. .
3. The charge function in which A and B are charged with the simultaneous generation of electricity.

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

Ans. (b)

End of Solution

13. The position of centroid can be determined by inspection, if an area has

(a) Single axis of symmetry
(b) Two axes of symmetry
(c) An irregular shape
(d) Centre axes of symmetry

Ans. (b)

End of Solution

14. Which of the following statements of D'Alembert's principle are correct?

1. The net external force F actually acting on the body and the inertia force F_I together keep the body in a state of fictitious equilibrium.
2. The equation of motion may be written as F+ (– ma) = 0 and the fictitious force (– ma) is called an inertia force.
3. It tends to give solution of a static problem an appearance akin to that of a dynamic problem.

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

Ans. **(b)**

End of Solution

15. The linear relationship between stress and strain for a bar in simple tension or compression is expressed with standard notations by the equation

(a) $\sigma = E\varepsilon$
(b) $\sigma = E\nu$
(c) $\sigma = G\nu$
(d) $\sigma = G\varepsilon$

Ans. **(a)**

End of Solution

16. A punch is used for making holes in steel plates with thickness 8 mm. If the punch diameter is 20 mm and force required for creating a hole is 110 kN, the average shear stress in the plate will be nearly

(a) 139 MPa
(b) 219 MPa
(c) 336 MPa
(d) 416 MPa

Ans. **(b)**

$t = 8$ mm
$d = 20$ mm
$F = 110$ kN
$F = K'(\pi dt)$

$$K' = \frac{110\times1000}{8\times20\times\pi} = \frac{5500}{8\pi} = 218.94 \simeq 219 \text{ MPa}$$

End of Solution

17. A rod of length 2 m and diameter 50 mm is elongated by 5 mm when an axial force of 400 kN is applied. The modulus of elasticity of the material of the rod will be nearly

(a) 66 GPa
(b) 72 GPa
(c) 82 GPa
(d) 96 GPa

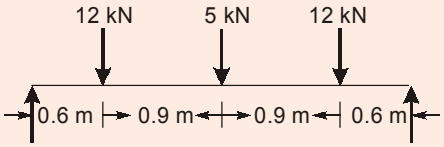
Ans. **(c)**

$$\text{Axial elongation, } \Delta = \frac{PL}{AE}$$

$$E = \frac{PL}{A\Delta} = \frac{400\times10^3\times2\times10^3}{\frac{\pi}{4}(50)^2\times5} = 81.5 \text{ GPa}$$

End of Solution

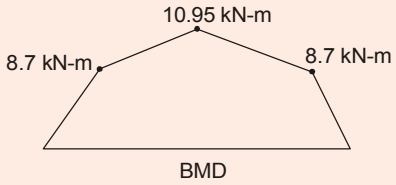
18. A beam of span 3 m and width 90 mm is loaded as shown in the figure. If the allowable bending stress is 12 MPa, the minimum depth required for the beam will be



(a) 218 mm (b) 246 mm
(c) 318 mm (d) 346 mm

Ans. **(b)**

Max B.M. at mid section $M_{max} = 14.5 \times 1.5 - 12 \times 0.9 = 10.95$ kNm



Now, $$\sigma_{max} = \frac{M_{max}}{Z} = \frac{M_{max}}{\frac{bd^2}{6}}$$

$$\sigma_{max} = \frac{6M_{max}}{bd^2}$$

$\therefore$ $$d = \sqrt{\frac{6M_{max}}{b \cdot \sigma_{max}}} = \sqrt{\frac{6 \times 10.95 \times 10^6}{90 \times 12}} = 246.64 \text{ mm}$$

End of Solution

19. A vertical hollow aluminium tube 2.5 m high fixed at the lower end, must support a lateral load of 12 kN at its upper end. If the wall thickness is $\frac{1}{8}$ th of the outer diameter and the allowable bending stress is 50 MPa, the inner diameter will be nearly

(a) 186 mm (b) 176 mm
(c) 166 mm (d) 156 mm

Ans. **(d)**

$$t = \frac{d_o}{8}$$

$$d_i = d_o - 2t = d_o - \frac{d_o}{4} = \frac{3d_o}{4}$$

$$\sigma_{max} = \frac{M}{I} y_{max} = \frac{M}{\frac{\pi}{64}\left(d_o^4 - d_i^4\right)} \cdot \frac{d_o}{2} = \frac{32M}{\pi d_o^3 \left(1 - \left(\frac{d_i}{d_o}\right)^4\right)}$$

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$$d_o = \left[\frac{32M}{\pi\sigma_{max}\left(1-\left(\frac{d_i}{d_o}\right)^4\right)}\right]^{1/3} = \left\{\frac{32\times12\times10^3\times2500}{\pi\times50\left[1-\left(\frac{3}{4}\right)^4\right]}\right\}^{1/3}$$

$= 207.58$ mm

$\therefore$ $d_i = 155.68$ mm

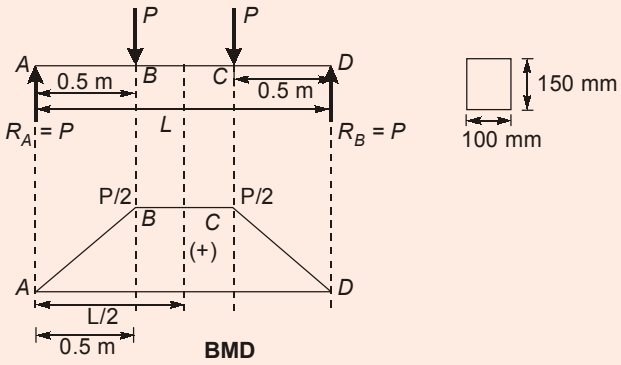
End of Solution

20. A wooden beam AB supporting two concentrated loads P has a rectangular cross-section of width = 100 mm and height = 150 mm. The distance from each end of the beam to the nearest load is 0.5 m. If the allowable stress in bending is 11 MPa and the beam weight is negligible, the maximum permissible load will be nearly

(a) 5.8 kN (b) 6.6 kN

(c) 7.4 kN (d) 8.2 kN

Ans. **(d)**



$M_{max} = 0.5P$

Now $\sigma_{max} = \frac{M_{max}}{Z} = \frac{0.5P}{\frac{bd^2}{6}} = \frac{3P}{bd^2}$

$$P = \sigma_{max}\frac{bd^2}{3} = \frac{11\times10^6\times0.1\times0.15^2}{3} = 8.25 \text{ kN}$$

End of Solution

21. Which of the following statements regarding thin and thick cylinders, subjected to internal pressure only, is/are correct?

1. A cylinder is considered thin when the ratio of its inner diameter to the wall thickness is less than 15.
2. In thick cylinders, tangential stress has highest magnitude at the inner surface of the cylinder and gradually decreases towards the outer surface.

(a) 1 only (b) 2 only

(c) Both 1 and 2 (d) Neither 1 nor 2

Ans. **(d)**

End of Solution

22. A cylindrical storage tank has an inner diameter of 600 mm and a wall thickness of 18 mm. The transverse and longitudinal strains induced are 255 × 10^{-6} mm/mm and 60 × 10^{-6} mm/mm, and if G is 77 GPa, the gauge pressure inside the tank will be

(a) 2.4 MPa (b) 2.8 MPa

(c) 3.2 MPa (d) 3.6 MPa

Ans. (d)

$$\varepsilon_h = \frac{pD}{4tE}(2-\mu)$$

$$\varepsilon_L = \frac{pD}{4tE}(1-2\mu)$$

$$\therefore \quad \frac{\varepsilon_h}{\varepsilon_L} = \frac{2-\mu}{1-2\mu}$$

$$\frac{255}{60} = \frac{2-\mu}{1-2\mu}$$

$$\therefore \quad \mu = 0.3$$

Now $E = 2G(1 + \mu) = 2 \times 77\ (1 + 0.3) = 200.2$ GPa

Now $$\varepsilon_h = \frac{pD}{4tE}(2-\mu)$$

$$p = \varepsilon_h \frac{4tE}{D(2-\mu)}$$

$$= \frac{255\times10^{-6}\times4\times18\times200.2\times10^{3}}{600\times1.7} = 3.6 \text{ MPa}$$

End of Solution

23. A compressed air spherical tank having an inner diameter of 450 mm and a wall thickness of 7 mm is formed by welding. If the allowable shear stress is 40 MPa, the maximum permissible air pressure in the tank will be nearly

(a) 3 MPa (b) 5 MPa

(c) 7 MPa (d) 9 MPa

Ans. (b)

Maximum shear stress, $\tau_{max} = \frac{PD}{8t}$

$$40 = \frac{P\times450}{8\times7}$$

$$P = 5 \text{ MPa}$$

End of Solution

24. A solid bar of circular cross-section having a diameter of 40 mm and length of 1.3 m is subjected to torque of 340 N-m. If the shear modulus of elasticity is 80 GPa, the angle of twist between the ends will be

(a) 1.26° (b) 1.32°
(c) 1.38° (d) 1.44°

Ans. **(a)**

$$\text{Angle of twist, } \theta = \frac{T.L.}{G.J}$$

$$= \frac{340\times10^3\times1.3\times10^3}{80\times10^3\times\frac{\pi}{32}(40)^4} = 0.02199 \text{ rad} = 1.26°$$

End of Solution

25. Which one of the following statements regarding screw dislocation is correct?

(a) It lies parallel to its Burgers vector.
(b) It moves in the direction parallel to its Burgers vector.
(c) It initially requires very less force to move
(d) It moves very fast as compared to edge dislocation

Ans. **(a)**

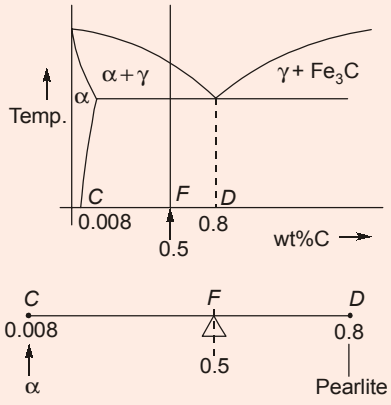
In a screw dislocation, the dislocation lies in a direction parallel to Burger's vector.

End of Solution

26. The percentage of pearlite in a slowly cooled melt of 0.5% of carbon steel is

(a) 48.5% (b) 52.5%
(c) 58.5% (d) 62.5%

Ans. **(d)**



By lever rule:

$$wt\% \text{ of pearlite, } m_p = \frac{0.5-0.008}{0.8-0.008}\times100 = 62.5\%$$

End of Solution

27. In the study of phase diagrams, the rule which helps to calculate the relative proportions of liquid and solid material present in the mixture at any given temperature is known as

(a) Hume-Rothery rule (b) Lever rule
(c) Gibb's phase rule (d) Empirical rule

Ans. **(b)**

Lever rule is used to study the relative proportion of two phases present in an alloy, at any given temperature.

End of Solution

28. The phenomenon that artificially increases the dielectric constant of plastics containing filler is known as

(a) Gamma polarization (b) Interfacial polarization
(c) Post-forming drawing (d) Reinforcement drawing

Ans. **(b)**

Interfacial polarization is caused by the presence of impurities/fillers. This phenomenon increases dielectric constant.

End of Solution

29. The addition of alloying element nickel to cast iron will primarily improve

(a) Wear resistance (b) Toughness
(c) Carbide formation (d) Machinability

Ans. **(b)**

Nickel promotes formation of small discontinuous carbides and enhance toughness.

End of Solution

30. A unidirectional fibre-epoxy composite contains 65% by volume fibre and 35% epoxy resin. If the relative density of the fibre is 1.48 and of the resin is 1.2, the percentage weight of fibre will be nearly

(a) 70% (b) 75%
(c) 80% (d) 85%

Ans. **(a)**

We know,
$$V_f = \frac{\frac{m_f}{\rho_f}}{\frac{m_f}{\rho_f} + \frac{m_e}{\rho_e}} \quad \ldots(1)$$

$$V_e = \frac{\frac{m_e}{\rho_e}}{\frac{m_f}{\rho_f} + \frac{m_e}{\rho_e}} \quad \ldots(2)$$

Divide,
$$\frac{V_f}{V_e} = \frac{m_f / \rho_f}{\frac{m_e}{\rho_e}}$$

$$\Rightarrow \quad \frac{0.65}{0.35} = \frac{m_f}{m_e} \times \frac{1.2}{1.48}$$

$$\frac{m_f}{m_e} = 2.29$$

Also $m_f + m_e = 1$

Solving the above two relations, we get, $m_f = 0.7$ or 70%

End of Solution

31. Which of the following are the advantages of Nano-composite materials?

1. Decreased thermal expansion coefficients
2. Higher residual stress
3. Reduced gas permeability
4. Increased solvent resistance

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

Ans. **(b)**

Nano-composites based on Carbon -nanotubes have been used to enhance a wide range of properties, giving rise to functional materials. They have enhanced die-electric properties, thermal resistance, stiffness, strength and wear resistance. Nano-composites will show improved solvent resistance and reduced gas permeability.

End of Solution

32. A rod of copper originally 305 mm long is pulled in tension with a stress of 276 MPa. If the modulus of elasticity is 110 GPa and the deformation is entirely elastic, the resultant elongation will be nearly

(a) 1.0 mm (b) 0.8 mm
(c) 0.6 mm (d) 0.4 mm

Ans. **(b)**

$$\Delta = \frac{PL}{AE} = \frac{\sigma L}{E} = \frac{276 \times 305}{110 \times 10^3} = 0.765 \text{ mm} \simeq 0.8 \text{ mm}$$

End of Solution

33. A 1.25 cm diameter steel bar is subjected to a load of 2500 kg. The stress induced in the bar will be

(a) 200 MPa (b) 210 MPa
(c) 220 MPa (d) 230 MPa

Ans. **(a)**

$$\text{Axial stress, } \sigma = \frac{P}{A} = \frac{2500 \times 9.81}{\frac{\pi}{4}(12.5)^2} = 200 \text{ MPa}$$

End of Solution

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34. The maximum energy which can be stored in a body up to the elastic limit is called
(a) Proof resilience
(b) Modulus of resilience
(c) Impact toughness
(d) Endurance strength

Ans. **(a)**
The maximum energy which can be stored in a body upto elastic limit, is called proof resilience.

End of Solution

35. A cast iron bed plate for a pump has a crack length of 100 μm. If the Young's modulus of cast iron is 210 GN/m^2 and the specific surface energy is 10 J/m^2, the fracture strength required will be nearly
(a) 1.0×10^8 N/m^2
(b) 1.2×10^8 N/m^2
(c) 1.4×10^8 N/m^2
(d) 1.6×10^8 N/m^2

Ans. **(d)**
Crack length = 2c = 100 μm
$E = 210$ GN/m^2 $= 210 \times 10^9$ N/m^2
Surface energy, $\gamma = 10$ J/m^2
According to Griffith's theory of brittle fracture,

$$\text{Fracture strength, } \sigma = \left(\frac{2E\gamma}{\pi c}\right)^{1/2} = \left[\frac{2\times(210\times10^9)\times10}{\pi\times50\times10^{-6}\,\text{m}}\right]^{1/2} = 1.6 \times 10^8 \text{ N/m}^2$$

End of Solution

36. A 13 mm diameter tensile specimen has 50 mm gauge length. If the load corresponding to the 0.2% offset is 6800 kg, the yield stress will be nearly
(a) 31 kg/mm^2
(b) 43 kg/mm^2
(c) 51 kg/mm^2
(d) 63 kg/mm^2

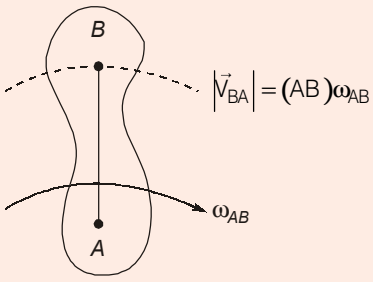
Ans. **(c)**

$$\text{Yield stress, } \sigma = \frac{6800}{\frac{\pi}{4}\times(13)^2} = 51.25 \text{ kg/mm}^2$$

End of Solution

37. The magnitude of the velocity of any point on the kinematic link relative to the other point on the same kinematic link is the product of
(a) A square root of an angular velocity of the link and the distance between the two points under consideration
(b) An angular velocity of the link and the square of distance between the two points under consideration
(c) A square of an angular velocity of the link and the distance between the two points under consideration
(d) An angular velocity of the link and the distance between the two points under consideration

Ans. (d)



End of Solution

38. In a mechanism, the number of Instantaneous centres (I-centres) N is

(a) $\frac{n(n-1)}{2}$ (b) $\frac{n(2n-1)}{2}$

(c) $\frac{2n(n-1)}{3}$ (d) $\frac{n(2n-1)}{3}$

where: n = Number of links

Ans. (a)

I-centre is defined for the relative motion. For relative motion two links are involved. Therefore two links in combination will give the one I-centre.

Number of IC = Number of relative motions

If n is the number of links.

Number of IC = n_{c2}

$$= \frac{n(n-1)}{2}$$

End of Solution

39. In cycloidal motion of cam follower, the maximum acceleration of follower motion f_{max} at $\theta = \frac{\varphi}{4}$ is

(a) $\frac{h\pi\omega^2}{2\varphi^2}$ (b) $\frac{3h\pi\omega^2}{2\varphi^2}$

(c) $\frac{2h\pi\omega^2}{\varphi^2}$ (d) $\frac{3h\pi\omega^2}{\varphi^2}$

where:

h = Maximum follower displacement

ω = Angular velocity of cam

φ = Angle for the maximum follower displacement for cam rotation

Ans. **(c)**

In cycloidal motion

Displacement of follower.

$$x = h\left[\frac{\theta}{\theta_0} - \frac{1}{2\pi}\sin\left(\frac{2\pi\theta}{\theta_0}\right)\right]$$

$$v = \frac{dx}{d\theta}\cdot\frac{d\theta_0}{dt}$$

$$= \omega h\left[\frac{1}{\theta_0} - \frac{1}{2\pi}\cos\left(\frac{2\pi\theta}{\theta_0}\right)\frac{2\pi}{\theta_0}\right]$$

$$= \frac{\omega h}{\theta_0}\left[1 - \cos\left(\frac{2\pi\theta}{\theta_0}\right)\right]$$

$$a = \frac{dV}{d\theta}\cdot\frac{d\theta}{dt} = \frac{\omega^2\cdot h}{\theta_0}\sin\left(\frac{2\pi\theta}{\theta_0}\right)\cdot\frac{2\pi}{\theta_0}$$

$$= \frac{2\pi\omega^2\cdot h}{\theta_0^2}\sin\left(\frac{2\pi\theta}{\theta_0}\right)$$

At $\theta = \left(\frac{\phi}{4}\right) = \left(\frac{\theta_0}{4}\right)$ (Here $\theta_0 = \phi$)

$$(a)_{\text{at } \theta = \phi/4} = \frac{2\pi\omega^2\cdot h}{\phi^2}$$

End of Solution

40. A shaft of span 1 m and diameter 25 mm is simply supported at the ends. It carries a 1.5 kN concentrated load at mid-span. If E is 200 GPa, its fundamental frequency will be nearly

(a) 3.5 Hz (b) 4.2 Hz

(c) 4.8 Hz (d) 5.5 Hz

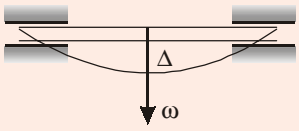
Ans. **(d)**

l = 1 m

d = 25 mm = 0.025 meters

W = 1.5 kN = 1500 N

E = 200 GPa = 200 × 10^9 Pa



Static deflection

$$\Delta_{static} = \frac{Wl^3}{48EI} \qquad \text{(Simply supported)}$$

$$= \frac{1500\times(1)^3}{48\times200\times10^9\times\frac{\pi}{64}(0.025)^4}$$

$$= \frac{64\times1500}{48\times2\times10^{11}\times\pi\times(0.025)^4} = 8.1487 \times 10^{-3} \text{ meters}$$

$$\omega_n = \sqrt{\frac{g}{\Delta_{static}}} = \sqrt{\frac{9.81}{8.1487\times10^{-3}}}$$

$$\omega_n = 34.6968 \text{ rad/s}$$

$$f_n = \frac{\omega_n}{2\pi} = \frac{34.6968}{2\pi} = 5.522 \text{ Hz}$$

End of Solution

41. A vibrating system consists of mass of 50 kg, a spring with a stiffness of 30 kN/m and a damper. If damping is 20% of the critical value, the natural frequency of damped vibrations will be

(a) 16 rad/s (b) 20 rad/s
(c) 24 rad/s (d) 28 rad/s

Ans. (c)

$m = 50$ kg

$s = 30$ kN/m $= 30000$ N/m

$\xi = 0.2$

(Critical, $\xi_{CR} = 1$, $\xi = (0.2)\xi_{CR} = 0.2$)

$$\omega_n = \sqrt{\frac{30000}{50}} = \sqrt{600} = 24.1948 \text{ rad/s}$$

$$\omega_d = \sqrt{1-\xi^2}\cdot\omega_n = \sqrt{1-0.04}\times24.4948 = 24.4948\times\sqrt{0.96}$$

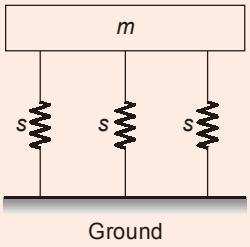
$$\omega_d = 23.999 \text{ rad/s} = 24 \text{ rad/s}$$

End of Solution

42. A refrigerator unit having a mass of 35 kg is to be supported on three springs, each having spring stiffness s. The unit operates at 480 rpm. If only 10% of the shaking force is allowed to transmit to the supporting structure, the value of stiffness will be nearly

(a) 2.7 N/mm (b) 3.2 N/mm
(c) 3.7 N/mm (d) 4.2 N/mm

Ans. (a)



$m = 35$ kg

Total stiffness, $s_{equi} = 3s$

$N = 480$ rpm

$$\omega = \frac{2\pi \times 480}{60} = 50.2654 \text{ rad/s}$$

$$\omega_n = \sqrt{\frac{s_{equi}}{m}} = \sqrt{\frac{3s}{35}} = \sqrt{\frac{3s}{35}} \text{ rad/s}$$

Here $\xi = 0$ (No damping)

$F_T = (10\% \text{ of } F_o)$

$= (0.1)F_o$

$$\frac{F_T}{F_o} = 0.1 = \epsilon \Rightarrow \text{Transmissibility}$$

$$\epsilon = \frac{\sqrt{1+\left(\frac{2\xi\omega}{\omega_n}\right)^2}}{\sqrt{\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right)^2+\left(\frac{2\xi\omega}{\omega_n}\right)^2}} = \frac{1}{\left|1-\left(\frac{\omega}{\omega_n}\right)^2\right|}$$

$$0.1 = \frac{1}{\pm\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right)}$$

$$\pm\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right) = \frac{1}{0.1} = 10$$

Taking (+ve) sign

$$1-\left(\frac{\omega}{\omega_n}\right)^2 = 10$$

$$\left(\frac{\omega}{\omega_n}\right)^2 = 1 - 10 = -9 \qquad \text{(Not possible)}$$

Taking (–ve)sign

$$-\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right) = 10$$

$$-1+\left(\frac{\omega}{\omega_n}\right)^2 = 10$$

$$\left(\frac{\omega}{\omega_n}\right)^2 = 11$$

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$$\Rightarrow \quad \frac{\omega}{\omega_n} = 3.3166$$

$$\frac{50.2654}{\omega_n} = 3.3166$$

$$\Rightarrow \quad \omega_n = 15.1557 \text{ rad/s}$$

$$15.1557 = \sqrt{\frac{3s}{35}}$$

$$\Rightarrow \quad s = 2679.778 \text{ N/m} = 2.679 \text{ N/mm}$$
$$= 2.7 \text{ N/mm}$$

End of Solution

43. In which one of the following tooth profiles, does the pressure angle remain constant throughout the engagement of teeth?

(a) Cycloidal (b) Involute
(c) Conjugate (d) Epicycloid

Ans. **(b)**

In involute profile tooth, because of the involute property to be satisfied, pressure angle does not change with point of contact position.

End of Solution

44. If the axes of the first and last wheels of a compound gear coincide, it is called

(a) Simple gear train (b) Compound gear train
(c) Epicyclic gear train (d) Reverted gear train

Ans. **(d)**

Reverted gear train is that compound gear train, which is used to connect co-axial shafts.

End of Solution

45. In a reciprocating engine, the force along the connecting rod F_Q is

(a) $\dfrac{F_P}{\sqrt{n^2 - \sin^2\theta}}$ (b) $\dfrac{F_P}{2\sqrt{n^2 - \sin^2\theta}}$

(c) $\dfrac{nF_P}{2\sqrt{n^2 - \sin^2\theta}}$ (d) $\dfrac{nF_P}{\sqrt{n^2 - \sin^2\theta}}$

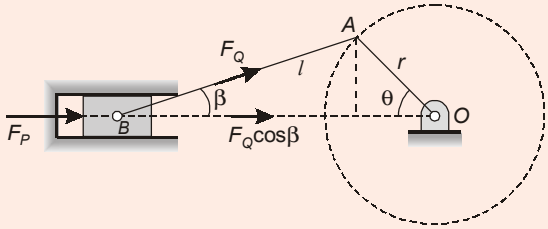
Where,

F_P = Force on piston

$n = \dfrac{L}{r}$

θ = angle for crank from IDC

Ans. (d)



$$\sin\beta = \frac{\sin\theta}{n}$$

Here, $$\cos\beta = \sqrt{1-\frac{\sin^2\theta}{n^2}} = \frac{\sqrt{n^2-\sin^2\theta}}{n}$$

$$F_p = F_Q\cos\beta$$

$$F_Q = \frac{F_p}{\cos\beta} = \frac{F_p}{\frac{\sqrt{n^2-\sin^2\theta}}{n}} = \frac{nF_p}{\sqrt{n^2-\sin^2\theta}}$$

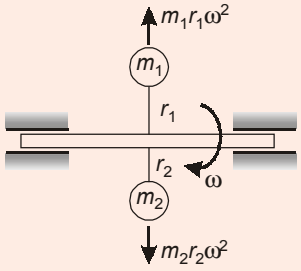
End of Solution

46. A mass m_1 attached to a shaft at radius r_1 rotating with angular velocity ω rad/s, can be balanced by another single mass m_2 which is attached to the opposite side of the shaft at radius r_2, in the same plane, if

(a) $m_1r_2 = m_2r_1$ (b) $m_1r_1 = m_2r_2$

(c) $m_1r_1\omega_1 = m_2r_2\omega_2$ (d) $m_1r_2\omega_1 = m_2r_1\omega_2$

Ans. (b)



In same plane, static balancing

$$\Rightarrow \quad \Sigma\vec{F} = 0$$

$$\Rightarrow \quad m_1r_1\omega^2 = m_2r_2\omega^2$$

$$m_1r_1 = m_2r_2$$

End of Solution

47. For a single cylinder reciprocating engine speed is 500 rpm, stroke is 150 mm, mass of reciprocating parts is 21 kg; mass of revolving parts is 15 kg at crank radius. If two-thirds of reciprocating masses and all the revolving masses are balanced, the mass at a radius of 150 mm will be

(a) 7.5 kg (b) 10.5 kg
(c) 12.5 kg (d) 14.5 kg

Ans. (d)

$$N = 500 \text{ rpm}$$

$$\omega = \frac{2\pi \times 500}{60} = 52.3598 \text{ rad/s}$$

$$r = \frac{150}{2} \text{mm} = 75 \text{ mm} = 0.075 \text{ meter}$$

$$m_{reci} = 21 \text{ kg}$$
$$m_{rot} = 15 \text{ kg}$$
$$b = 150 \text{ mm} = 0.150 \text{ meter}$$
$$B = ?$$

$$\text{Mass to be balanced} = \text{Rotating} + \frac{2}{3}\text{Reciprocating}$$

$$= \left(15 + \frac{2}{3} \times 21\right) = 15 + 14 = 29 \text{ kg}$$

Total mass to be balanced

$$m = 29 \text{ kg}$$
$$m r \omega^2 = B \cdot b \cdot \omega^2$$
$$29 \times 0.075 = B \times 0.150$$

$$B = \frac{29 \times 0.075}{0.150} \text{ kg}$$

$$B = 14.5 \text{ kg}$$

End of Solution

48. If the axes of the rolling of the ship and of the stabilizing rotor are parallel, it will result in

(a) A higher bow and lower stern (b) A lower bow and higher stern
(c) Turning towards left (d) No gyroscopic effect

Ans. (d)

If rotor rotating axis i.e. the axis of spin and rolling axis are parallel, then during rolling there will not be any precession i.e. the direction of spin will not be changing during rolling of ship.

Therefore angular velocity of precession

$$\omega_p = 0$$

$$\Rightarrow \quad C = I.\ \omega.\omega_p = 0$$

Therefore, ship will not experience any gyroscopic effect during rolling.

End of Solution

49. Coaxing is a process of_____.
(a) Improving the fatigue properties, attained by under-stressing and then raising the stress in small increments
(b) Decreasing the hardness by full annealing
(c) Increasing the uniaxial tensile strength by heating above recrystallization temperature and quenching in oil media
(d) Maintaining the ductility of the material by chemical treatment

Ans. **(a)**

End of Solution

50. According to the distortion-energy theory, the yield strength in shear is
(a) 0.277 times the yield stress
(b) 0.377 times the maximum' shear stress
(c) 0.477 times the yield strength in tension
(d) 0.577 times the yield strength in tension

Ans. **(d)**
According to distortion energy theory,

$$\tau_y = \frac{\sigma_y}{\sqrt{3}} = 0.577\ \sigma_y$$

End of Solution

51. For the prediction of ductile yielding, the theory of failure utilized is
(a) Maximum strain energy theory
(b) Distortion energy theory
(c) Maximum normal strain theory
(d) Mohr theory

Ans. **(b)**
For ductile material MDET result is best.

End of Solution

52. A steel specimen is subjected to the following principal stresses : 120 MPa tensile, 60 MPa tensile and 30 MPa compressive. If the proportionality limit for the steel specimen is 250 MPa; the factor of safety as per maximum shear stress theory will be nearly
(a) 1.3 (b) 1.7
(c) 2.3 (d) 2.7

Ans. **(b)**

$$\tau_{max} = \text{max of}\left[\left|\frac{\sigma_1-\sigma_2}{2}\right|, \left|\frac{\sigma_2-\sigma_3}{2}\right|, \left|\frac{\sigma_2-\sigma_1}{2}\right|\right]$$

$$= \text{max of}\left[\left|\frac{120-60}{2}\right|, \left|\frac{60+30}{2}\right|, \left|\frac{120+30}{2}\right|\right]$$

$$\tau_{max} = 75 \text{ MPa}$$
$$S_{yt} = 250 \text{ MPa}$$
$$S_{ys} = 0.5S_{yt} = 125 \text{ MPa}$$
$$\tau_{max} = \frac{S_{yt}}{N}$$
$$N = \frac{125}{75} = 1.66 \approx 1.7$$

End of Solution

53. For which one of the following loading conditions is the standard endurance strength multiplied by a load factor, $K_e = 0.9$?
(a) Reversed beam bending loads
(b) Reversed axial load with no bending
(c) Reversed axial loads with intermediate bending
(d) Reversed torsion loads

Ans. **(c)**
For bending complete reversed, $k_c = 1$
For axial complete reversed, $k_c = 0.74$
Hence, (c), $k_c \approx 0.9$
For mix bending and axial.

End of Solution

54. A 120 mm wide uniform plate is to be subjected to a tensile load that has a maximum value of 250 kN and a minimum value of 100 kN. The properties of the plate material are : endurance limit stress is 225 MPa, yield point stress is 300 MPa. If the factor of safety based on yield point is 1.5, the thickness of the plate will be nearly
(a) 12 mm (b) 14 mm
(c) 16 mm (d) 18 mm

Ans. **(a)**

$$\sigma_{max} = \frac{250\times10^3}{120\times t}, \qquad \sigma_{min} = \frac{100\times10^3}{120\times t}$$
$$\sigma_{mean} = \frac{175\times10^3}{120\times t}, \qquad \sigma_a = \frac{75\times10^3}{120\times t}$$
$$\frac{\sigma_m}{S_{yt}} + \frac{\sigma_a}{\sigma_c} = \frac{1}{N}$$
$$\frac{175\times10^3}{120\times t\times300} + \frac{75}{120\times t\times225} = \frac{1}{1.5}$$
$$\frac{4.861}{t} + \frac{2.77}{t} = \frac{1}{1.5}$$
$$t = 11.45 \approx 12 \text{ mm}$$

End of Solution

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55. A steel connecting rod having S_{ut} = 1000 MN/m^2, S_{yt} = 900 MN/m^2 is subjected to a completely reversed axial load of 50 kN. By neglecting any column action, if the values of k_e = 0.85, k_b = 0.9, k_a = 0.82, k_t = 1.5, q = 0.6 and N = 2, the diameter of the rod will be nearly

(a) 20 mm (b) 23 mm
(c) 26 mm (d) 29 mm

Ans. (b)

$$\frac{k_f - 1}{k_t - 1} = q$$

$$\frac{k_f - 1}{1.5 - 1} = 0.6$$

$$k_f = 1.3$$

$$k_d = \frac{1}{k_f} = 0.769$$

$$\sigma_e^* = \frac{S_{ut}}{2} = 500$$

$$\sigma_e = k_a \times k_b \times k_c \times k_d \times k_e \ldots\ldots \sigma_e^*$$
$$\sigma_e = 0.82 \times 0.9 \times 0.85 \times 0.769 \times 500$$
$$= 241.19 \text{ MPa}$$

Strength criterion, Soderberg equation, Goodman equation will give same result for completely reversed fatigue loading. Hence, by using strength criterion,

$$\sigma_{max} \le \sigma_{per}$$

$$\sigma_{max} \le \left[\frac{\sigma_e}{N} = \frac{\sigma_e^* k_a k_b k_c k_d}{N}\right]$$

$$\frac{50000}{\frac{\pi}{4}d^2} \le \frac{241.19}{2}$$

$$d \ge 22.97$$

$$d = 23 \text{ mm}$$

End of Solution

56. During crushing or bearing failure of riveted joints.

(a) The holes in the plates become oval shaped and joints become loose
(b) There is tearing of the plate at an edge
(c) The plates will crack in radial directions and joints fail
(d) The rivet heads will shear out by applied stress

Ans. **(a)**

Crushing strength of plate/rivet crushing failure of the plate/rivet. This type of failure occurs when the compressive stress between the shank of the rivet and the plate exceeds the yield stress in compression. The failure results in elongating the rivet hole in the plate and loosening of the joint.

End of Solution

57. The double riveted joint with two cover plates for boiler shell is 1.5 m in diameter subjected to steam pressure of 1 MPa. If the joint efficiency *ts* 75%, allowable tensile stress in the plate is 83 MN/m^2, compressive stress is 138 MN/m^2 and shear stress in the rivet is 55 MN/m^2, the diameter of rivet hole will be nearly

(a) 8 mm (b) 22 mm

(c) 36 mm (d) 52 mm

Ans. **(b)**

$$t = \frac{PD}{2\sigma_{per}\eta} + CA = \frac{1\times 1.5}{2\times \sigma_{per}} + CA$$

$$t = \frac{1\times 1.5}{2\times 83\times 0.75} + 2 = 14\,\text{mm} \geq 8\,\text{mm}$$

Hence by Unwin's formula

$$d = 6\times\sqrt{t} = 21\text{mm}$$

$$d_h = 22\ \text{mm}$$

End of Solution

58. A bearing supports a radial load of 7000 N and a thrust load of 2100 N. The desired life of the ball bearing is 160 × 10^6 revolutions at 300 rpm. If the load is uniform and steady, service factor is 1, radial factor is 0.65, thrust factor is 3.5, k = 3 and rotational factor is 1, the basic dynamic load rating of a bearing will be nearly

(a) 65 kN (b) 75 kN

(c) 85 kN (d) 95 kN

Ans. **(a)**

$$F_r = 7000\ \text{N}$$

$$F_a = 2100\ \text{N}$$

$$\text{Pe} = s[XV\,F_r + YF_a] = 1\,[0.65 \times 1 \times 7000 + 3.5 \times 2100]$$

$$= 11900$$

$$L_{90} = \left[\frac{C}{Pe}\right]^k$$

$$160 = \left[\frac{C}{11900}\right]^3 \Rightarrow C = 64603\,\text{kN}$$

End of Solution

59. A solid cast iron disk, 1 m in diameter and 0.2 m thick, is used as a flywheel. It is rotating at 350 rpm. It is brought to rest in 1.5 sec by means of a brake. If the mass density of cast iron is 7200 kg/m^3, the torque exerted by the brake will be nearly

(a) 3.5 kNm (b) 4.5 kNm
(c) 5.3 kNm (d) 6.3 kNm

Ans. **(a)**

$$m = \rho v = \rho\frac{\pi}{4}D^2 \times t = 7200 \times \frac{\pi}{4} \times (1)^2 \times 0.2$$

$$m = 1.13094 \text{ kg-m}^2$$

$$I = \frac{mR^2}{2} = 0.1413 \text{ kg–m}^2$$

$$T_{braking} = I \times \alpha$$

$$\omega_f = \omega_i + \alpha t$$

$$0 = \frac{2\pi N_i}{60} + \alpha t$$

$$\alpha = \frac{2\pi \times 350}{60 \times 1.5} = -24.43 \text{ rad/s}^2$$

$$T = 3.45 \text{ N-m}$$

End of Solution

60. The torque transmitting capacity of friction clutches can be increased by

(a) Use of friction material with a lower coefficient of friction
(b) Decreasing the mean radius of the friction disk
(c) Increasing the mean radius of the friction disk.
(d) Decreasing the plate pressure

Ans. **(c)**

$$T_f \uparrow = \mu W R_{eff} \uparrow$$

End of Solution

61. A stone weighs 400 N in air and when immersed in water it weighs 225 N. If the specific weight of water is 9810 N/m^3, the relative density of the stone will be nearly

(a) 5.9 (b) 4.7
(c) 3.5 (d) 2.3

Ans. **(d)**

$$W_{real} = 400\ N = mg = \rho_{body} \times g \times V_{body} \quad \text{... (i)}$$

$$W_{apparent} = 225 \text{ N}$$

$$W_{apparent} = W_{real} - \text{Buoyant force}$$

So, $$\text{Buoyant force} = 400 - 225 = \rho_{fluid} \times g \times V_{fd} \quad \text{... (ii)}$$

By (i) and (ii)

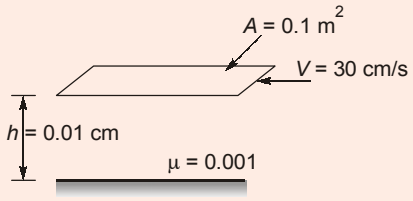
$$\frac{\rho_{body} \times g \times V_{body}}{\rho_{fluid} \times g \times V_{fluid}} = \frac{400}{175} \qquad [V_{fluid} = V_{body},\ S_{body} = 2.28 \approx 2.3]$$

End of Solution

62. A flat plate 0.1 m^2 area is pulled at 30 cm/s relative to another plate located at a distance of 0.01 cm from it, the fluid separating them being water with viscosity of 0.001 Ns/m^2, The power required to maintain velocity will be

(a) 0.05 W (b) 0.07 W
(c) 0.09 W (d) 0.11 W

Ans. (c)



$$\text{Power} = F \times V = \tau AV = \mu \frac{V}{h} \times AV = 0.001 \frac{0.3}{0.01 \times 10^{-2}} \times 0.1 \times 0.3$$

$$= 0.09 \text{ W}$$

End of Solution

63. When the pressure of liquid is increased from 3 MN/m^2 to 6 MN/m^2, its volume is decreased by 0.1%. The bulk modulus of elasticity of the liquid will be

(a) 3×10^{12} N/m^2 (b) 3×10^{9} N/m^2
(c) 3×10^{8} N/m^2 (d) 3×10^{4} N/m^2

Ans. (b)

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

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

$$K = \frac{dp}{\left(-\frac{dV}{V}\right)} = \frac{(6-3)}{(0.001)} = 3 \times 10^9 \text{ N/m}^2$$

End of Solution

64. A curve that is everywhere tangent to the instantaneous local velocity vector, is

(a) Streak line (b) Path line
(c) Normal line (d) Streamline

Ans. (d)

Tangent to streamline defines velocity vector.

End of Solution

65. A 120 mm diameter jet of water is discharging from a nozzle into the air at a velocity of 40 m/s. The power in the jet with respect to a datum at the jet will be

(a) 380 kW (b) 360 kW
(c) 340 kW (d) 320 kW

Ans. **(b)**

$d = 120$ mm

$V = 40$ m/s

$$\text{Power} = \frac{1}{2}\dot{m}V_1^2 = \frac{1}{2}\rho a V_1^3$$

$$= \frac{1}{2}\times 1000 \times \left(\frac{\pi}{4}\times 0.12^2\right)\times 40^3$$

Power = 360 kW

End of Solution

66. Which of the following applications regarding Navier-Stokes equations are correct ?

1. Laminar unidirectional flow between stationary parallel plates.
2. Laminar unidirectional flow between parallel plates having no relative motion.
3. Laminar flow in circuit pipes.
4. Laminar flow between concentric rotating cylinders.

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

Ans. **(a)**

End of Solution

67. A crude oil having a specific gravity of 0.9 flows through a pipe of diameter 0.15 m at the rate of 8 lps. If the value of μ is 0.3 Ns/m^2, the Reynolds number will be nearly

(a) 295 (b) 235
(c) 205 (d) 165

Ans. **(c)**

$$\text{Re} = \frac{\rho VD}{\mu} = \frac{\rho QD}{\mu\frac{\pi}{4}D^2} = \frac{\rho Q\times 4}{\mu\pi D}$$

$$= \frac{900\times 8\times 10^{-3}\times 4}{0.3\times\pi\times 0.15} = 203.7 = 205$$

End of Solution

68. Two pipes of lengths 2500 m each and diameters 80 cm and 60 cm respectively, are connected in parallel. The coefficient of friction for each pipe is 0.006 and the total flow is 250 litres/s. The rates of flow in the pipes are nearly

(a) 0.17 m^3/s and 0.1 m^3/s (b) 0.23 m^3/s and 0.1 m^3/s
(c) 0.17 m^3/s and 0.4 m^3/s (d) 0.23 m^3/s and 0.4 m^3/s

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Ans. **(a)**

$$Q = Q_1 + Q_2$$
$$Q_1 + Q_2 = 0.25 \text{ m}^3/\text{s} \quad \text{... (i)}$$

For parallel connection $h_{f1} = h_{f2}$

$$\frac{fL_1Q_1^2}{12.1 \times d_1^5} = \frac{fL_2Q_2^2}{12.1 \times d_2^5} \quad [\because L_1 = L_2]$$

$$\frac{Q_1^2}{0.8^5} = \frac{Q_2^2}{0.6^5}$$

$$\frac{Q_1}{Q_2} = \left(\frac{0.8}{0.6}\right)^{5/2} = 2.05$$

$$Q_1 = 2.05\, Q_2 \quad \text{... (ii)}$$

By (i) and (ii),

$$2.05Q_2 + Q_2 = 0.25,\ Q_2 = 0.0814 \text{ m}^3/\text{s}$$
$$Q_1 = 0.25 - 0.082 = 0.168 \text{ m}^3/\text{s}$$

End of Solution

69. A fluid of mass density 1790 kg/m^3 and viscosity 2.1 Ns/m^2 flows at a velocity of 3 m/s in a 6 cm diameter pipe. The head loss over a length of 12 m pipe will be nearly

(a) 62.0 m (b) 54.0 m
(c) 46.5 m (d) 38.5 m

Ans. **(d)**

$$\text{Re} = \frac{\rho VD}{\mu} = \frac{1790 \times 3 \times 0.06}{2.1} = 153.42 < 2300 \text{ Laminar}$$

$$h_f = \frac{32\mu VL}{\omega d^2} = \frac{32 \times 2.1 \times 3 \times 12}{1790 \times 9.81 \times 0.06^2} = 38.26 \text{ m}$$

End of Solution

70. Which of the following characteristics regarding fluid kinematics is/are correct?

1. Streamline represents an imaginary curve in the flow field so that the tangent to the curve at any point represents the direction of instantaneous velocity at that point.
2. Path lines, streamlines and streak lines are identical in steady flow.

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

Ans. **(c)**

End of Solution

71. To maintain 0.08 m^3/s flow of petrol with a specific gravity of 0.7, through a steel pipe of 0.3 m diameter and 800 m length, with coefficient of friction of 0.0025 in the Darcy relation, the power required will be nearly

(a) 0.6 kW (b) 1.0 kW
(c) 2.6 kW (d) 3.0 kW

Ans. (b)

$$h_f = \frac{4f'LQ^2}{12.1\times d^5} = \frac{4\times 0.0025\times 800\times 0.08^2}{12.1\times 0.3^5} = 1.741\text{m}$$

$$\text{Power} = \rho g Q h_f = 700 \times 9.81 \times 0.08 \times 1.741$$
$$= 956.43 = 1 \text{ kW}$$

Alternate solution:

$Q = 0.08 \text{ m}^3/\text{sec}$
$s = 0.7$
$d = 0.3$ m
$L = 800$ m
$f' = 0.0025$

$$\text{Power} = wp = \rho g Q H_m$$

$$H_m = h_f = \text{Head loss in pipe} = \left.\frac{fLV^2}{2gD}\right|_{\text{pipe}}$$

$$Q_{\text{pump}} = Q_{\text{pipe}}$$

$$0.08 = \frac{\pi}{4}d^2 \cdot V_{\text{pipe}} = \frac{\pi}{4}\times 0.^3 \times V_{\text{pipe}}$$

$$V_{\text{pipe}} = 1.13 \text{ m/s}$$

$$h_f = \left.\frac{(4\times 0.0025)\times 800\times 1.13^2}{2\times 9.81\times 0.3}\right|_{\text{pipe}} = 1.74 \text{ m}$$

$$WP = (1000 \times 0.7) \times 9.81 \times 0.08 \times 1.74 = 1 \text{ kW}$$

End of Solution

72. The diameter of a nozzle d for maximum transmission of power through it, is

(a) $\left[\frac{D^5}{8fL}\right]^{1/4}$ (b) $\left[\frac{D^5}{8fL}\right]^{1/2}$

(c) $\left[\frac{8D^5}{fL}\right]^{1/4}$ (d) $\left[\frac{8D^5}{fL}\right]^{1/2}$

Where:
D = Diameter of pipe
f = Coefficient of friction
L = Length of pipe

Ans. (a)

Available head at nozzle= Dynamic head at exit of nozzle

$$H - h_f = \frac{V^2}{2g}$$

For maximum power, $H = 3h_f$

$$3h_f - h_f = \frac{V^2}{2g}$$

$$2h_f = \frac{V^2}{2g}$$

$$\frac{2\times\left(4\times fLQ^2\right)}{12.1\times D^5} = \frac{Q^2}{2\times 9.81\times\frac{\pi^2}{16}\times\left(d_n^2\right)^2}$$

$$\frac{8fL}{12.1\times D^5} = \frac{1}{12.1d_n^4}$$

$$d_n = \left[\frac{D^5}{8fL}\right]^{1/4}$$

End of Solution

73. A piston-cylinder device with air at an initial temperature of 30°C undergoes an expansion process for which pressure and volume are related as given below:

p(kPa)	100	37.9	14.4
$V(m^3)$	0.1	0.2	0.4

The work done by the system for n = 1.4 will be

(a) 4.8 kJ (b) 6.8 kJ

(c) 8.4 kJ (d) 10.6 kJ

Ans. (d)

$$T_1 = 303$$

$$W = \frac{P_1V_1 - P_2V_2}{n-1} = \frac{100\times 0.1 - 14.4\times 0.4}{1.4-1} = 10.6\,\text{kJ}$$

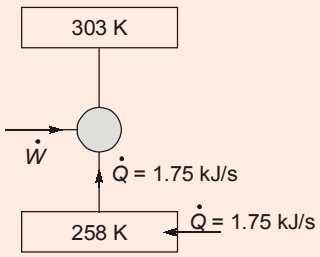
End of Solution

74. A domestic food freezer maintains a temperature of –15°C. The ambient air temperature is 30°C. If heat leaks into the freezer at the continuous rate of 1.75 kJ/s, the least power necessary to pump this heat out continuously will be nearly

(a) 0.1 kW (b) 0.2 kW

(c) 0.3 kW (d) 0.4 kW

Ans. (c)



$$COP_{max} = \frac{T_L}{T_H - T_L} = \frac{258}{303 - 258} = 5.733$$

Also, $$COP_{max} = \frac{\dot{Q}}{\dot{W}} = \frac{1.75}{\dot{W}}$$

$\therefore$ $$\dot{W}_{min} = 0.305 \text{ kW}$$

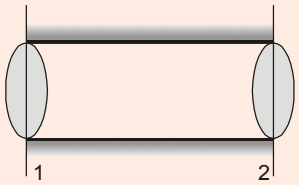
End of Solution

75. An ideal gas is flowing through an insulated pipe at the rate of 3 kg/s. There is a 10% pressure drop from an inlet to exit of the pipe. The values of R = 0.287 kJ/kg.K and T_o = 300 K. The rate of energy loss for the pressure drop due to friction, will be nearly

(a) 34 kW (b) 30 kW

(c) 26 kW (d) 22 kW

Ans. **(c)**



$\dot{m}$ = 3 kg/s

$P_2 = 0.9P_1$

T_o = 300 K

Applying SFEE

$$h_1 + \frac{C_1^2}{2} + gz_1 + q = h_2 + \frac{C_2^2}{2} + gz_2 + w_{cv} \qquad [q = 0,\ w_{cv} = 0]$$

Neglecting change in KE and PE

$\therefore$ $h_1 = h_2$

$C_pT_1 = C_pT_2$

$T_1 = T_2$

$\therefore$ $I = T_o \times (\Delta S)$

$$= 300 \times \dot{m}\left[c_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}\right] \qquad [T_2 = T_1]$$

$$I = 300 \times 3 \times (-0.287)\ln\frac{0.9P_1}{P_1}$$

$= 300 \times 3 \times (-0.287)\ln(1 - 0.1)$

$\dot{I} = 300 \times 3 \times (-0.287) \times (-0.1)$

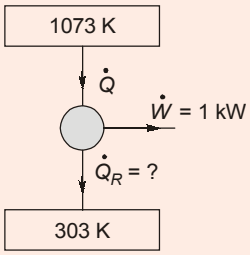
$= 25.83$ kW $\qquad [\ln(1 - x) \approx (-x)]$

End of Solution

76. A cyclic heat engine operates between a source temperature of 800°C and a sink temperature of 30°C. The .least rate of heat rejection per kW net output of engine will be nearly

(a) 0.2 kW (b) 0.4 kW
(c) 0.6 kW (d) 0.8 kW

Ans. (b)



For least $\dot{Q}_R$ efficiency should be maximum

$$\therefore \quad \eta_{max} = \frac{\dot{W}}{\dot{Q}}$$

$$1-\frac{303}{1073} = \frac{1}{\dot{W}+\dot{Q}_R} = \frac{1}{1+\dot{Q}_R}$$

$$0.7176 = \frac{1}{1+\dot{Q}_R}$$

$$1+\dot{Q}_R = 1.393$$

$$\dot{Q}_R = 0.393 \text{ kW}$$

End of Solution

77. A fictitious pressure that, if it acted on the piston during the entire power stroke, would produce the same amount of net work as that produced during the actual cycle is called

(a) Quasi equivalent pressure (b) Mean equivalent pressure
(c) Mean effective pressure (d) Quasi static pressure

Ans. (c)

End of Solution

78. An ideal cycle based on the concept of combination of two heat transfer processes, one at constant volume and the other at constant pressure, is called

(a) Otto cycle (b) Dual cycle
(c) Diesel cycle (d) Carnot cycle

Ans. (b)

End of Solution

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79. The ideal thermodynamic cycle for the development of gas-turbine engine is
(a) Otto (b) Stirling
(c) Ericsson (d) Brayton

Ans. **(d)**
Brayton cycle is the ideal gas turbine cycle.

End of Solution

80. If the pressure at exhaust from the turbine is the saturation pressure corresponding to the temperature desired in the process heater, such a turbine is called
(a) Condensing turbine (b) Extraction turbine
(c) Pass out turbine (d) Back pressure turbine

Ans. **(d)**

End of Solution

81. The purpose of providing fins on heat transfer surface is to increase
(a) Temperature gradient so as to enhance heat transfer by convection
(b) Effective surface area to promote rate of heat transfer by convection
(c) Turbulence in flow for enhancing heat transfer by convection
(d) Pressure drop of the fluid

Ans. **(b)**
Since providing fins can increase the area of contact between solid and fluid surface.

End of Solution

82. For fully developed laminar pipe flow, the average velocity is
(a) One-half of the maximum velocity
(b) One-third of the maximum velocity
(c) One-fourth of the maximum velocity
(d) Two-third of the maximum velocity

Ans. **(a)**

End of Solution

83. The overall heat transfer coefficient due to convection and radiation for a steam maintained at 200°C running in a large room at 30°C is 17.95 W/m^2K. If the emissivity of the pipe surface is 0.8; the value of $\sigma = 5.67 \times 10^{-8}$ W/m^2K^4; the heat transfer coefficient due to radiation will be nearly
(a) 17 W/m^2K (b) 14 W/m^2K
(c) 11 W/m^2K (d) 8 W/m^2K

Ans. **(c)**
Heat lost by pipe due to radiation to the room air

$$= \sigma A_{pipe} \in_{pipe} \left(T_{pipe}^4 - T_{room}^4\right)$$

$$= h_{radiation} \times A_{pipe} \times (T_{pipe} - T_{room})$$

$\therefore$ Heat transfer coefficient due to radiation

$$h_{radiation} = \frac{\sigma \times \epsilon_{pipe} \left(T_{pipe}^4 - T_{room}^4\right)}{T_{pipe} - T_{room}}$$

$$= \frac{5.67 \times 10^{-8} \times 0.8\left[(200+273)^4 - (30+273)^4\right]}{(200-30)}$$

$$= 11.1067 \text{ W/m}^2\text{K}$$

End of Solution

84. Large heat transfer coefficients for vapour condensation can be achieved by promoting

(a) Film condensation (b) Dropwise condensation
(c) Cloud condensation (d) Dew condensation

Ans. **(b)**

Since dropwise condensation offers lesser thermal resistance during phase change thus can enhance heat transfer rate between vapour and solid surface.

End of Solution

85. Which one of the following valves is provided for starting the engine manually, during cold weather conditions?

(a) Starting jet valve (b) Compensating jet valve
(c) Choke valve (d) Auxiliary air valve

Ans. **(c)**

End of Solution

86. A 4-cylinder, 4-stroke single acting petrol engine consumes 6 kg of fuel per minute at 800 rpm when the air-fuel ratio of the mixture supplied is 9 : 1. The temperature is 650 K and pressure is 12.5 bar at the end of compression stroke. Take R = 300 Nm/kg.K, diameter of cylinder as 8 cm, stroke of cylinder as 10 cm. The compression ratio will be nearly

(a) 6.2 (b) 5.7
(c) 5.2 (d) 4.6

Ans. **(*)**

Due to the unavailability of sufficient data or either because of data mismatch, no option is matching correctly.

End of Solution

87. Ice is formed at 0°C from water at 20°C. The temperature of the brine is –8°C. The refrigeration cycle used is perfect reversed Carnot cycle. Latent heat of ice = 335 kJ/kg, and c_{pw} = 4.18. The ice formed per kWh will

(a) 81.4 kg (b) 76.4 kg
(c) 71.8 kg (d) 68.8 kg

Ans. (a)

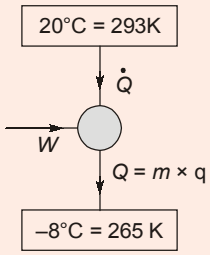
$$20^\circ C_{(w)} \rightarrow 0^\circ C_{(w)} \rightarrow 0^\circ C_{(ice)}$$

$$q = m\left\{C_w \times 20 + L.H.\right\}$$

$m = 1$ kg, $C_w = 4.18$, L.H. $= 335$ kJ/kg

$q = 418.6$ kJ/kg

1 kWh $= 3600$ kJ



$$COP_{max} = \frac{Q}{W}$$

but $$COP_{max} = \frac{T_L}{T_H - T_L} = \frac{265}{293 - 265} = 9.464$$

$$\therefore \quad 9.464 = \frac{Q}{W} = \frac{m \times q}{3600}$$

$$\therefore \quad m = 81.39 \text{ kg}$$

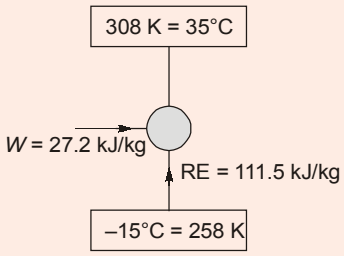
End of Solution

88. A Freon 12 simple saturation cycle operates at temperatures of 35°C and –15°C for the condenser and evaporator. If the refrigeration effect produced by the cycle is 111.5 kJ/kg and the work required by the compressor is 27.2 kJ/kg, the value of COP will be nearly

(a) 4.1 (b) 3.6

(c) 3.1 (d) 2.6

Ans. (a)



$$COP = \frac{RE}{W} = \frac{111.5}{27.2} = 4.099$$

End of Solution

89. A cold storage is to be maintained at - 5°C while the surroundings are at 35°C. The heat leakage from the surroundings into the cold storage is estimated to be 29 kW. The actual COP of the refrigeration plant used is one-third of an ideal plant working between the same temperatures. The power required to drive the plant will be

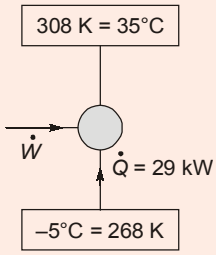
(a) 10 kW (b) 11 kW

(c) 12 kW (d) 13 kW

Ans. **(d)**

$$COP_{actual} = \frac{1}{3}COP_{max}$$

$$= \frac{1}{3}\left[\frac{268}{308-268}\right] = 2.233$$



But $COP_{actual} = \frac{\dot{Q}}{\dot{W}}$

$\therefore$ $\dot{W} = 12.98$ kW

End of Solution

90. A single acting two-stage air compressor deals with 4 m^3/min of air at 1.013 bar and 15°C with a speed of 250 rpm. The delivery pressure is 80 bar. If the inter cooling is complete, the intermittent pressure after first stage will be

(a) 9 bar (b) 8 bar

(c) 7 bar (d) 6 bar

Ans. **(a)**

For two stage air compressor

$$P_i = \sqrt{P_1 P_2} = \sqrt{80} = 9 \text{ bar}$$

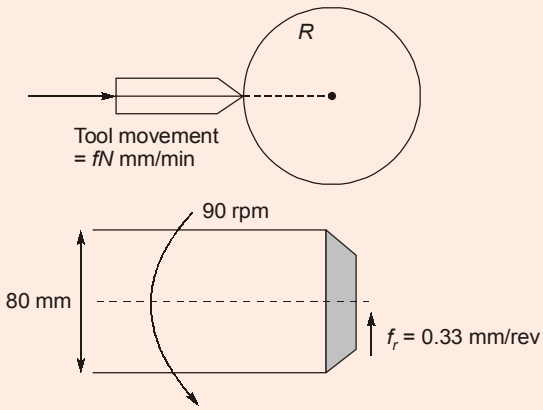
End of Solution

91. The time taken to face a workpiece of 80 mm diameter for the spindle speed of 90 rpm and cross feed of 0.3 mm/rev will be

(a) 4.12 min (b) 3.24 min

(c) 2.36 min (d) 1.48 min

Ans. **(d)**



Machining time (t_m) in facing operation $= \frac{R}{fN} = \frac{D/2}{f_r N} = \frac{40 \text{ mm}}{0.3 \frac{\text{mm}}{\text{rev}} \times 90 \frac{\text{rev}}{\text{min}}} = 1.48 \text{ min}$

End of Solution

92. A feed f for the lathe operation is

(a) $\frac{N}{L \times T_m}$ mm/rev (b) $\frac{L}{N \times T_m}$ mm/rev

(c) $\frac{T_m}{N \times L}$ mm/rev (d) $\frac{T_m \times L}{N}$ mm/rev

Where,

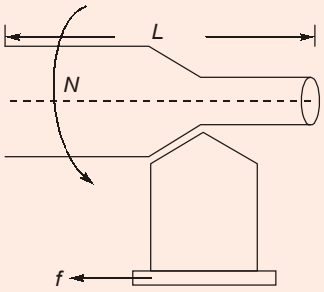
T_m = Machining time in min; N = Speed in rpm; L = Length of cut in mm

Ans. **(b)**

In lathe, operation like turning has matching time which is given as,

$$t_m = \frac{L}{fN}$$

$$f = \frac{L}{N \times t_m}$$



For example, if $f = 0.2$ mm/rev

$N = 50$ rpm

$L = 200$ mm

$$t_m = \frac{200}{0.2 \times 50} = 20 \text{ min}$$

End of Solution

93. The main advantage of the radial drilling machine is that

(a) It is very compatible and handy for machining

(b) It is accurate, economical, portable and least time consuming while machining

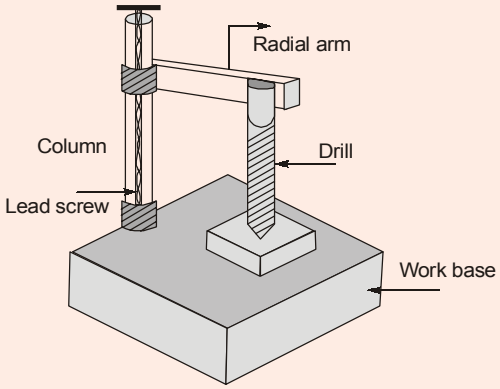
(c) Heavy workpieces can be machined in any position without moving them

(d) Small workpieces can be machined and it can be used for mass production as well

Ans. **(c)**

The main advantage of the radial drilling machine is that the drilling can be carried out on heavy workpiece in any position without moving them. This type of drilling machine is used in tool rooms and in large scale die manufacturing units.

Radial drilling machine is specially designed and manufactured for large and heavy work items. A quality radial drilling machine is basically designed to perform the drilling action on any specified place and position without moving the large and heavy workpiece.



End of Solution

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94. For the purpose of sampling inspection, the maximum percent defective that can be considered satisfactory as a process average is
(a) Rejectable Quality Level (RQL)
(b) Acceptable Quality Level (AQL)
(c) Average Outgoing Quality Limit (AOQL)
(d) Lot Tolerance Percent Defective (LTPD)

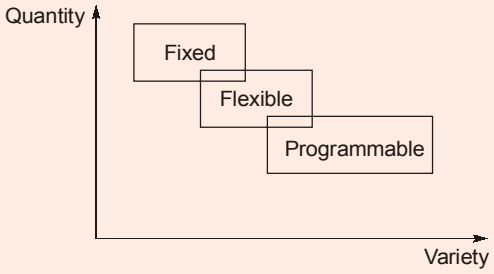
Ans. **(b)**

End of Solution

95. Hard automation is also called
(a) Selective automation
(b) Total automation
(c) Group technology
(d) Fixed position automation

Ans. **(d)**

Hard automation is also known as fixed automation that involves large quantity production but at low production volume.



End of Solution

96. The method of CNC programming which enables the programmer to describe part geometry using variables is
(a) Computer assisted part programming
(b) Computer aided drafting programming
(c) Conversational programming
(d) Parametric programming

Ans. **(d)**

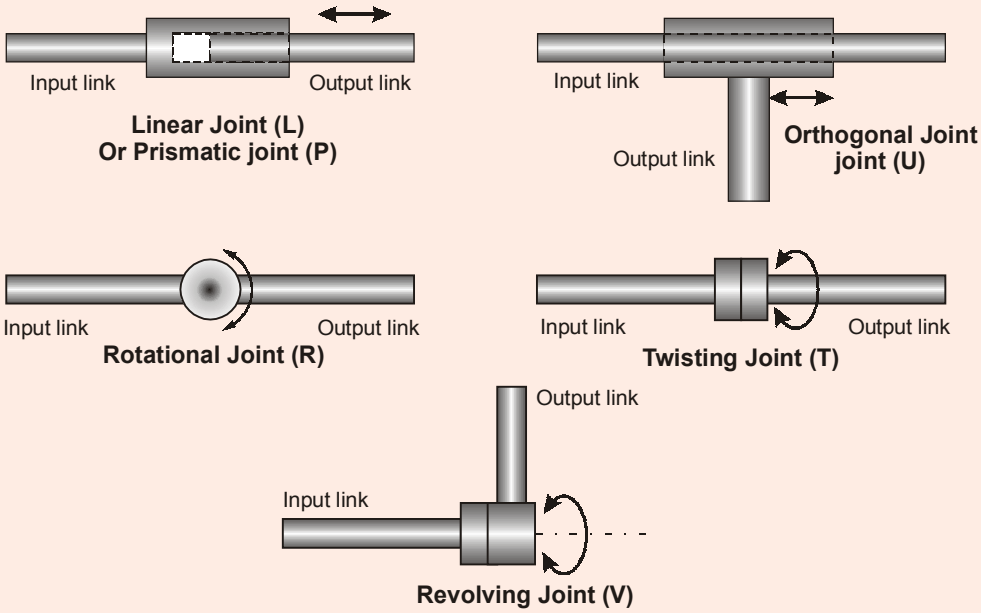
End of Solution

97. Revolving joint of the robot is referred to as

(a) L joint (b) O joint

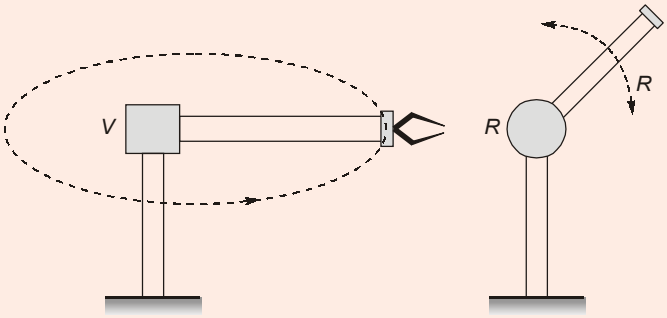
(c) T joint (d) V joint

Ans. (d)



Robot notations for various joints are

L - Linear, O - Orthogonal, R - Rotating, V - Revolving, T - Twisting



End of Solution

98. Repairing of a machine consists of 5 steps that must be performed sequentially. Time taken to perform each of the 5 steps is found to have an exponential distribution with a mean of 5 minutes and is independent of other steps. If these machines break down in Poisson distribution at an average rate of 2/hour and if there is only one repairman, the average idle time for each machine that has broken down will be

(a) 120 minutes (b) 110 minutes

(c) 100 minutes (d) 90 minutes

Ans. **(a)**

$$\lambda = 2 \text{ mc/hr}$$

$$\frac{1}{\mu} = 25 \text{ min/mc}$$

$$\mu = \frac{60}{25} \text{ mc/hr} = 2.4 \text{ mc/hr}$$

$$\rho = \frac{\lambda}{\mu} = \frac{2}{2.4} = 0.833$$

$$W_s = \frac{L_s}{\lambda}$$

$$L_s = \frac{\rho}{1-\rho} = \frac{0.8333}{1-0.8333} = 5 \text{ mc}$$

$$W_s = \frac{L_s}{\lambda} = \frac{5}{2} = 2.5 \text{ hr/mc} = 150 \text{ min}$$

Idle time means in the queue:

$$W_q = W_s - \frac{1}{\mu} = 150 - 25 = 125 \text{ min}$$

End of Solution

99. A portion of the total float within which an activity can be delayed for start without affecting the floats of preceding activities is called

(a) Safety float
(b) Free float
(c) Independent float
(d) Interfering float

Ans. **(c)**

End of Solution

100. An oil engine manufacturer purchases lubricant cans at the rate of ₹42 per piece from a vendor. The requirement of these lubricant cans is 1800 per year. If the cost per placement of an order is ₹16 and inventory carrying charges per rupee per year is 20 paise, the order quantity per order will be

(a) 91 cans
(b) 83 cans
(c) 75 cans
(d) 67 cans

Ans. **(b)**

$$Q^* = \sqrt{\frac{2 \times 1800 \times 16}{42 \times 0.2}} = 82.8 \approx 83 \text{ cans}$$

End of Solution

101. Consider the following data regarding the acceptance sampling process:
$N = 10000$, $n = 89$, $c = 2$, $P = 0.01$, and $P_a = 0.9397$
The Average Total Inspection (ATI) will be

(a) 795
(b) 687
(c) 595
(d) 487

Ans. **(b)**

$$ATI = n + (1 - P_a)(N - n) = 89 + (1 - 0.9397)(10000 - 89)$$
$$= 686.63 \approx 687$$

End of Solution

102. The Non-Destructive Inspection (NDI) technique employed during inspection for castings of tubes and pipes to check the overall strength of a casting in resistance to bursting under hydraulic pressure is

(a) Radiographic inspection
(b) Magnetic particle inspection
(c) Fluorescent penetrant
(d) Pressure testing

Ans. **(d)**

Non-Destructive Inspection (NDI): Pressure test is a non-destructive testing performed to identify any leakages, to know the strength of hollow objects and piping equipment produced by casting and welding before the actual application.

End of Solution

103. Consider the situation where a microprocessor gives an output of an 8-bit word. This is fed through an 8-bit digital-to-analogue converter to a control valve. The control valve requires 6.0 V being fully open. If the fully open state is indicated by 11111111, the output to the valve for a change of 1-bit will be

(a) 0.061 V
(b) 0.042 V
(c) 0.023 V
(d) 0.014 V

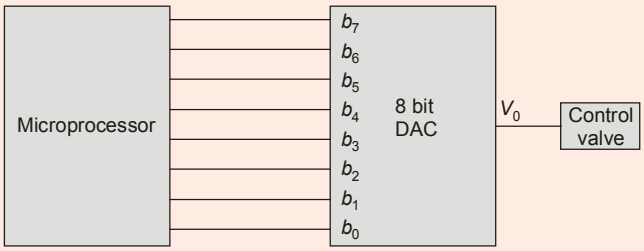
Ans. **(c)**

0 - 255 → 00 H - FF H i.e. 256 levels

$\rightarrow \underbrace{1111}_{F}\ \underbrace{1111}_{F} \rightarrow 6\ V \approx (255)$ in decimals

$\therefore \frac{6\,V}{256} \rightarrow 0.023$ V will be for '1' bit change

Alternate Solution:



From the data of the question, we can understand that control valve fully opens if 60 V is given to it.

For, 8 bit digital to analog converter '11111111' is 256th combination

So, the voltage generated for each combination is nothing but resolution of digital to analog converter.

$$\text{Resolution} = \frac{6\ V}{2^8} = 0.023\ V$$

End of Solution

104. Which of the following factors are to be considered while selecting a microcontroller?
1. Memory requirements
2. Processing speed required
3. Number of input/output pins

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

Ans. **(d)**

End of Solution

105. Which of the following statements regarding interface circuit are correct?
1. Electrical buffering is needed when the peripheral operates at a different voltage or current to that on the microprocessor bus system or there are different ground references.
2. Timing control is needed when the data transfer rates of the peripheral and the microprocessor are different.
3. Changing the number of lines is needed when the codes used by the peripherals differ from those used by the microprocessor.

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

Ans. **(a)**

Codes of microprocessor and peripherals don't depend on interface.

End of Solution

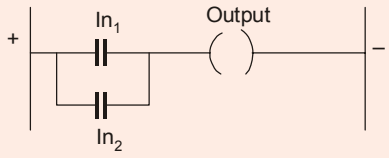
106. Alternative paths provided by vertical paths from the main rung of a ladder diagram, that is, paths in parallel, represent

(a) Logical AND operations (b) Logical OR operations
(c) Logical NOT operations (d) Logical NOR operations

Ans. **(b)**

Since output is '1' if one of the input is '1'.

A	*B*	Output
0	0	0
0	1	1
1	0	1
1	1	1



End of Solution

107. The resolution of an encoder with 10 tracks will be nearly

(a) 0.15° (b) 0.25°
(c) 0.35° (d) 0.45°

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Ans. **(c)**

If the encoder has 'N' tracks then the resolution $= \frac{360°}{2^N}$

In the given data $N = 10$

So, Resolution $= \frac{360°}{2^{10}} = 0.35°$

End of Solution

108. Which of the following features is/are relevant to variable reluctance stepper motors?
1. Smaller rotor mass; more responsive
2. Step size is small
3. More sluggish

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

Ans. **(a)**

As the rotor is made up of soft-iron in case of variable reluctance motor, it has small rotor mass, hence it is quick in response.

End of Solution

109. Which of the following statements regarding hydraulic pumps are correct ?
1. The gear pump consists of two close-meshing gear wheels which rotate in opposite directions.
2. In vane pump, as the rotor rotates, the vanes follow the contours of the casing.
3. The leakage is more in vane pump compared to gear pump.

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

Ans. **(b)**

The volumetric efficiency of vane pump (upto 95%) is higher compared to gear pump.

End of Solution

110. The selection of the right controller for the application depends on
1. The degree of control required by the application.
2. The individual characteristics of the plants.
3. The desirable performance level including required response, steady-state deviation and stability.

Which of the above statements are correct ?

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

Ans. **(d)**

End of Solution

111. Consider a system described by

$$\dot{x} = Ax + Bu$$
$$y = Cx + Du$$

The system is completely output controllable if and only if

(a) The matrix $[CB : CBA : CB^2A : \cdots : CB^{n-1}A : D]$ is of rank n

(b) The matrix $[CB : CAB : CA^2B : \cdots : CA^{n-1}B : D]$ is of rank m

(c) The matrix $[BC : BAC : BA^2C : \cdots : BA^{n-1}C : D]$ is of rank m

(d) The matrix $[BC : ABC : CA^2B : \cdots : CB^{n-1}A : D]$ is of rank n

where:

x = State vector (n-vector) ; u = Control vector (r-vector)
y = Output vector (m-vector); A = n × n matrix
B = n × r matrix; C = m × n matrix
D = m × r matrix

Ans. (*) (No option is matching)

End of Solution

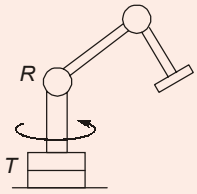
112. Which one of the following symbols is used as the notation for designating arm and body of a robot with jointed arm configuration?

(a) TRL (b) TLL, LTL, LVL
(c) LLL (d) TRR, VVR

Ans. (d)

Robot with jointed arm configuration for 3 DOF-robot carries all its joints as revolute. It can be TRR, VRR and other combinations of *T*, *R* and *V*.

For e.g., TRR configuration consists of a vertical column, that swivels about the base using a *T* joint. At the top of the column is a shoulder joint (*R* joint), output to an elbow joint (*R*-joint)



Wrist Configuration	Symbol
Two-axis wrist	: RT
Three-axis wrist	: TRT

ROBOT configuration (arm and Body)	Symbol
Cartesian	LLL
Cylindrical	TLL, LTL, LVL
Polar	TRL
Revolute or Jointed arm	TRR, VVR

End of Solution

113. A compliant motion control of robots can be understood by the problem of controlling of
(a) Position and velocity of joints
(b) Position and acceleration of the end-effector
(c) Manipulator motion and its force interactions with the environment
(d) Joint velocities of given end-effector velocity

Ans. **(c)**
The role of compliant motion is to control a robot manipulator in contact with its environment. By accommodating with the interaction force, the manipulator can be used to accomplish tasks that involve constrained motions.
In this method, the compliance is formulated as function of interaction force.

End of Solution

114. For the vector $v = 25i + 10j + 20k$, perform a translation by a distance of 8 in the x-direction, 5 in the y-direction and 0 in the z-direction. The translated vector Hv will be

(a) $\begin{bmatrix} 1 \\ 20 \\ 33 \\ 15 \end{bmatrix}$ (b) $\begin{bmatrix} 33 \\ 15 \\ 20 \\ 1 \end{bmatrix}$

(c) $\begin{bmatrix} 15 \\ 33 \\ 1 \\ 20 \end{bmatrix}$ (d) $\begin{bmatrix} 1 \\ 15 \\ 20 \\ 33 \end{bmatrix}$

Ans. **(b)**
$\vec{V} = 25i + 10j + 20k$ is translated by 8 units along x, 5 units along y, 0 units along z
Translated frame,

$$\begin{bmatrix} 1 & 0 & 0 & 8 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 25 \\ 10 \\ 20 \\ 1 \end{bmatrix} = \begin{bmatrix} 33 \\ 15 \\ 20 \\ 1 \end{bmatrix}$$

End of Solution

Directions: Each of the next six (6) items consist of two statements, one labelled as 'Statement (I)' and the other as 'Statement (II)'. You are to examine these two statements carefully and select the answers to these items using the code given below:

Code:
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

115. **Statement (I):** The greater the chemical affinity of two metals, the more restricted is their solid solubility and greater is the tendency of formation of compound.
Statement (II): Wider the separation of elements in the periodic table, greater is their chemical affinity.

Ans. **(a)**
The greater the chemical affinity of two metals, the more restricted will be their solubility. Wider the separation of elements in the periodic table, greater is their chemical affinity.

End of Solution

116. **Statement (I):** The size of a memory unit is specified in terms of the number of storage locations available; 1 K is 2^{10} = 1024 locations and thus a 4 K memory has 4096 locations.
Statement (II): Erasable and programmable ROM (EPROM) is a form of memory unit used for ROMs that can be programmed and their contents altered.

Ans. **(b)**
M/M (or) memory size can't be compared with types of memory.

End of Solution

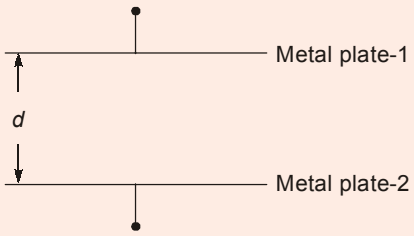
117. **Statement (I):** Microprocessors which have memory and various input/output arrangements, all on the same chip, are called microcontrollers.
Statement (II): The microcontroller is the integration of a microprocessor with RAM, ROM, EPROM, EEPROM and I/O interfaces, and other peripherals such as timers, on a single chip.

Ans. **(a)**
Microcontroller contains, everything on-chip. i.e., microprocessor, interfaces, memory, Timers/counters.

End of Solution

118. **Statement (I):** Capacitive proximity sensor can only be used for the detection of metal objects and is best with ferrous metals.
Statement (II): One form of capacitive proximity sensor consists of a single capacitor plate probe with the other plate being formed by the object, which has to be metallic and earthed.

Ans. **(a)**
Capacitor is made of two-metal plates, which are seprated by small gap in between them as shown below.



If one of metal plates is displaced by keeping other plate at fixed position, then the capacitance of capacitor will change. As a result voltage across the capacitor changes. Hence it can work like "proximity sensor".

In metal-object detection capacitive probe forms one-plate of the capacitor and metal object acts like other plate.

End of Solution

119. **Statement (I):** SCARA configuration provides substantial rigidity for the robot in the vertical direction, but compliance in the horizontal plane.

Statement (II): A special version of the Cartesian coordinate robot is the SCARA, which has a very high lift capacity as it is designed for high rigidity.

Ans. **(c)**

SCARA configuration provides high stiffness to the arm in the vertical direction and high compliance in the horizontal plane.

SCARA robot has two parallel revolute joints to provide compliance in a selected plane, and may be considered a special case of a cylindrical robot.

Statement I is correct and statement II is wrong.

End of Solution

120. **Statement (I):** The stepper motor is a device that produces rotation through equal angles, the so-called steps, for each digital pulse supplied to its input.

Statement (II): Stepper motors can be used to give controlled rotational steps but cannot give continuous rotation, as a result their applications are limited to step angles only.

Ans. **(b)**

End of Solution

121. The ideal gas-refrigeration cycle is the same as the

(a) Brayton cycle
(b) Reversed Brayton cycle
(c) Vapour compression refrigeration cycle
(d) Vapour absorption refrigeration cycle

Ans. **(b)**

End of Solution

122. If the atmospheric conditions are 20°C, 1.013 bar and specific humidity of 0.0095 kg/kg of dry air, the partial pressure of vapour will be nearly

(a) 0.076 bar (b) 0.056 bar
(c) 0.036 bar (d) 0.016 bar

Ans. **(d)**

$$\text{DBT} = 20^\circ\text{C} = 293\ \text{K}$$

$$P_t = 1.013\ \text{bar}$$

$$w = 0.622 \times \frac{P_v}{P_t - P_v}$$

$$0.0095 = 0.622 \times \frac{P_v}{1.013 - P_v}$$

$$0.0152 = \frac{P_v}{1.013 - P_v}$$

$$0.0153 - 0.0152P_v = P_v$$

$$0.0153 = 1.0152P_v$$

$$P_v = 0.016 \text{ bar}$$

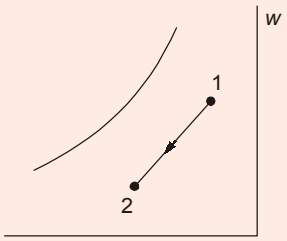
End of Solution

123. In air-conditioning systems, air may be cooled and dehumidified by
1. Spraying chilled water to air in the form of fine mist.
2. Circulating chilled water or brine in a tube placed across the air flow.
3. Placing the evaporator coil across the air flow.

Which of the above statements are correct ?

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

Ans. **(d)**



Spraying water less than DPT of air can also cool and dehumidify the air.

End of Solution

124. A duct of rectangular cross-section 600 mm x 400 mm carries 90 m^3/min of air having density of 1.2 kg/m^3. When the quantity of air in both cases is same, the equivalent diameter of a circular duct will be nearly

(a) 0.86 m (b) 0.76 m
(c) 0.64 m (d) 0.54 m

Ans. **(d)**

$$A_1 = A_2$$

$$0.6 \times 0.4 = \frac{\pi}{4} \times D^2$$

$$D = 0.55 \text{ m}$$

End of Solution

125. A room having dimensions of 5 m x 5 m x 3 m contains air at 25°C and 100 kPa at a relative humidity of 75%. The corresponding value of p_s is 3.169 kPa. The partial pressure of dry air will be nearly

(a) 106 kPa (b) 98 kPa
(c) 86 kPa (d) 78 kPa

Ans. **(b)**

$$\phi = \frac{P_v}{P_s}$$

$$0.75 = \frac{P_v}{3.169}$$

$$P_v = 2.376 \text{ kPa}$$

$$P_t = P_a + P_v$$

$$101.3 = P_a + 2.376$$

$$P_a = 98.92 \text{ kPa}$$

End of Solution

126. A measure of feeling warmth or coolness by the human body in response to the air temperature, moisture content and air motion is called

(a) Dry bulb temperature
(b) Effective temperature
(c) Wet bulb temperature
(d) Dew point temperature

Ans. **(b)**

End of Solution

127. While designing a Pelton wheel, the velocity of wheel 'u' is

(a) $K_u\sqrt{gH}$
(b) $2K_u\sqrt{gH}$
(c) $K_u\sqrt{2gH}$
(d) $2K_u\sqrt{2gH}$

where, K_u = speed ratio; H = net head on turbine; g = gravity

Ans. **(c)**

$$\text{Speed ratio, } K_u = \frac{U}{\sqrt{2gH}}$$

End of Solution

128. The turbines of the same shape will have the same

(a) Thomas number
(b) Reynolds number
(c) Specific speed
(d) Rotational speed

Ans. **(c)**

The specific speed remains same for all the similar turbine.

End of Solution

129. A centrifugal pump is required to lift 0.0125 m^3/s of water from a well with depth 30 m. If rating of the pump motor is 5 kW, and the density of water is 1000 kg/m^3, the efficiency of the pump will be nearly

(a) 82%
(b) 74%
(c) 66%
(d) 58%

Ans. **(b)**

$Q = 0.0125\ m^3/sec$

$H_s = 30\ m$

Power = 5 kW

$$\eta_0 = \frac{\rho g Q H_m}{S_p} = \frac{1000 \times 9.81 \times 0.0125 \times 30 \times 100}{5000} = 74\%$$

End of Solution

130. An inward flow reaction turbine has an external diameter of 1 m and its breadth at inlet is 250 mm. If the velocity of flow at inlet is 2 m/s and 10% of the area of flow is blocked by blade thickness, the weight of water passing through the turbine will be nearly

(a) 10 kN/s (b) 14 kN/s

(c) 18 kN/s (d) 22 kN/s

Ans. **(b)**

$d_1 = 1\ m$

$b_1 = 0.25\ m$

$V_{F_1} = 2\ m/s$

$k = 0.9$ = coefficient of blade thickness

$Q = k \cdot \pi d_1 b_1 V_{F_1}$

$Q = 0.9 \times \pi \times 1 \times 0.25 \times 2 = 1.413\ m^3/sec$

Weight of water passing through turbine = $\rho g Q = 1000 \times 9.81 \times 1.413 = 14$ kN/s

End of Solution

131. The process of abstracting steam at a certain section of the turbine and subsequently using it for heating feed water supplied to the boiler is called

(a) Reheating (b) Regeneration

(c) Bleeding (d) Binary vapour cycle

Ans. **(b)**

Regeneration is the process of bleeding steam and using it for feed water heating.

End of Solution

132. When blade speed ratio is zero, no work is done because the distance travelled by the blade is zero even if the torque on the blade

(a) is minimum (b) is zero

(c) is maximum (d) remains the same

Ans. **(c)**

Power = Torque × Angular velocity

$\because$ Distance travelled by blade is zero, this implies $\frac{U}{V} = 0 \Rightarrow \omega = 0$

Hence, $P = 0$ even if T = maximum.

End of Solution

133. In an axial flow turbine, the utilization factor has an absolute maximum value of unity, for any degree of reaction if the value of nozzle angle α is

(a) 270° (b) 180°
(c) 90° (d) 0°

Ans. **(d)**

End of Solution

134. Which of the following are essential for a good combustion chamber of turbojet engine?

1. It should allow complete combustion of fuel.
2. It should maintain sufficiently high temperatures in the zone of combustion in addition to proper atomization of fuel thus leading to continuous combustion.
3. It should not have high rate of combustion.
4. The pressure drop should be as small as possible.

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

Ans. **(a)**

Combustor should not have high rate of combustion, else the flame may die out.

End of Solution

135. If m_f is the mass of fuel supplied per kg of air in one second, then the mass of gases leaving the nozzle of turbojet will be

(a) $(1 - m_f)$ kg/s (b) $\frac{1}{(1+m_f)}$ kg/s

(c) $(1 + m_f)$ kg/s (d) $\frac{1}{(1-m_f)}$ kg/s

Ans. **(c)**

For turbojet engine, total mass of gases coming out will be sum of fuel and air supplied.
Hence, mass flow = $(1 + m_f)$ kg/s

End of Solution

136. Which one of the following may be considered as a single cylinder two-stroke reciprocating engine running at 2400 rpm to 2700 rpm for rapid chain of impulses?

(a) Turbo jet (b) Pulse jet
(c) Ram jet (d) Athodyd jet

Ans. **(b)**

Pulse jet engines have stable operation in range of 45 cycles per second. This can be correlated to a 2-stroke engine running at 2400 - 2700 rpm (40 - 45 cycles/sec).

End of Solution

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7 AIR — Rahul Jain — Classroom Course

8 AIR — Kuldeep Kumar — Classroom Course

9 AIR — Shubham Karnani — Classroom Course

10 AIR — Gaurav Srivastava — Classroom Course

137. In jet propulsion of ships, when the inlet orifices are at right angles to the direction of motion of the ships, the efficiency of propulsion η is

(a) $\frac{2u^2}{V+u}$ (b) $\frac{2Vu}{(V+u)^2}$

(c) $\frac{2u}{(V+u)^2}$ (d) $\frac{2Vu}{V+u}$

where; V = Absolute velocity of the issuing jet, u = Velocity of the moving ship

Ans. **(b)**

End of Solution

138. 0.8 kg of air flows through a compressor under steady state conditions. The properties of air at entry are: pressure 1 bar, velocity 10 m/s, specific volume 0.95 m^3/kg and internal energy 30 kJ/kg. The corresponding values at exit are 8 bar, 6 m/s, 0.2 m^3/kg and 124 kJ/kg. Neglecting change in potential energy, the power input will be

(a) 117 kW (b) 127 kW

(c) 137 kW (d) 147 kW

Ans. **(b)**

Power input can be found from SFEE

$$H_1 + \frac{1}{2}mV_1^2 + W = H_2 + \frac{1}{2}mV_2^2 + Q$$

$\because$ PE is zero.

$$U_1 + P_1v_1 + \frac{1}{2}mV_1^2 + W = U_2 + P_2v_2 + \frac{1}{2}mV_2^2 + Q$$

$$\dot{m}\left\{30 + 100 \times 0.95 + \frac{10^2}{2 \times 1000}\right\} + W = \dot{m}\left\{124 + 800 \times 0.2 + \frac{6^2}{2000}\right\}$$

$$W = \dot{m}\left[(U_2 - U_1) + P_2 \cdot v_2 - P_1 \cdot v_1 + \frac{V_2^2 - V_1^2}{2000}\right]$$

$$= 127.17 \text{ kW}$$

End of Solution

139. In a power plant, the efficiency of the electric generator, turbine, boiler, cycle and the overall plant are 0.97, 0.95, 0.92, 0.42 and 0.33 respectively. In the generated electricity, the auxiliaries will consumes nearly

(a) 7.3% (b) 6.5%

(c) 5.7% (d) 4.9%

Ans. **(a)**

$$\eta_{overall} = \eta_{boiler} \times \eta_{cycle} \times \eta_{gen} \times \eta_{aux} \times \eta_{turbu}$$

$$0.33 = 0.92 \times 0.42 \times 0.95 \times 0.97 \times \eta_{aux}$$

$$\eta_{aux} = 0.926$$

$$\text{Power consumed} = 1 - 0.926 = 7.32\%$$

End of Solution

140. The higher power requirements for compression in a steam power plant working on Carnot vapour cycle
(a) Increases the plant efficiency as well as work ratio
(b) Reduces the plant efficiency as well as work ratio
(c) Does not affect the plant efficiency as well as work ratio
(d) Increases the plant efficiency and reduces work ratio

Ans. **(d)**
For carnot cycle, the efficiency will be increased as a consequence of cycle undergoing ideal.
Work ratio will be reduced due to high compressor work.

End of Solution

141. For the same compression ratio, the Brayton cycle efficiency is
(a) Same as the Diesel cycle efficiency
(b) Equal to the Otto cycle efficiency
(c) More than the Diesel cycle efficiency
(d) Less than the Otto cycle efficiency

Ans. **(b)**

Efficiency of Brayton cycle $= 1-\frac{1}{r^{\gamma-1}}$

Efficiency of Otto cycle $= 1-\frac{1}{R^{\gamma-1}}$

Both are same if r and R are pressure ratios.

End of Solution

142. An economizer in a steam generator performs the function of preheating the
(a) Combustion air
(b) Feed water
(c) Input fuel
(d) Combustion air as well as input fuel

Ans. **(b)**

End of Solution

143. Air enters the compressor of a gas turbine plant operating on Brayton cycle at 1 bar and 27°C. The pressure ratio in the cycle is 6. If the relation between the turbine work W_T and compressor work W_C is $W_T = 3W_C$ and $\gamma = 1.4$, the cycle efficiency will be nearly
(a) 40%
(b) 50%
(c) 60%
(d) 70%

Ans. **(a)**

End of Solution

144. A fluidized bed combustion system having an output of 35 MW at 80% efficiency when using a coal of heating value 26 MJ/kg with a sulphur content of 3.6% requires a particular limestone to be fed to it at a calcium-sulphur molar ratio of 3.0 so as to limit emissions of SO_2 adequately. The limestone used contains 85% $CaCO_3$. The required flow rate of limestone will be

(a) 2405 kg/h
(b) 2805 kg/h
(c) 3205 kg/h
(d) 3605 kg/h

Ans. **(a)**

$$\text{Output} = 35 \text{ MW}$$

$$\text{Heat input} = \frac{35}{0.8} \text{ MW}$$

$$\text{Mass of fuel} = \frac{35 \times 10^6}{0.8 \times 26 \times 10^6} = 1.682 \text{ kg/sec}$$

$$\text{Mass of sulphur} = 0.036 \times 1.682 = 0.06057 \text{ kg/sec}$$

$$\text{Moles of sulphur} = \frac{0.06057}{32} = 0.001893$$

$$\text{Moles of } CaCO_3 = 3 \times 0.001893 = 0.005679 \text{ kmoles/sec} = 20.44 \text{ kmoles/hr}$$

$$\text{Mass} = 20.44 \times 100 = 2044 \text{ kg/hr}$$

$$\text{Mass of } CaCO_3 = \frac{2044}{0.85} = 2405 \text{ kg/hr}$$

End of Solution

145. In Orsat apparatus, when the percentage of carbon dioxide, oxygen and carbon monoxide are known, the remaining gas is assumed to be

(a) Hydrogen
(b) Sulphur dioxide
(c) Nitrogen
(d) Air

Ans. **(c)**

End of Solution

146. The partial vacuum created by the fan in the furnace and flues, draws the products of the combustion from the main flue and allows them to pass up to the chimney. Such a draught is called

(a) Balanced draught
(b) Forced draught
(c) Induced draught
(d) Artificial draught

Ans. **(c)**

End of Solution

147. Which of the following are applied (used) ways of compounding steam turbines?
1. Pressure compounding
2. Temperature compounding
3. Velocity compounding

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

Ans. **(d)**
Compoundings are of two types (1) velocity compounding and (2) Pressure compounding.

End of Solution

148. A steam ejector which removes air and other non-condensable gases from the condenser is known as
(a) Wet air pump (b) Dry air pump
(c) Centrifugal pump (d) Circulating pump

Ans. **(a)**
Wet air pump is the steam ejector pump which removes air and non-condensable gases from condenser.

End of Solution

149. In a heat exchanger, 50 kg of water is heated per minute from 50°C to 110°C by hot gases which enter the heat exchanger at 250°C. The value of C_p for water is 4.186 kJ/kgK and for air is 1 kJ/kgK. If the flow rate of gases is 100 kg/min, the net change of enthalpy of air will be nearly
(a) 17.6 MJ/min (b) 15.0 MJ/min
(c) 12.6 MJ/min (d) 10.0 MJ/min

Ans. **(c)**
From energy balance equation for heat exchanger.
The rate of enthalpy decrease of water = The rate of enthalpy increase of air

$$= \dot{m}_{water} \times c_{p_{water}} \times \left(T_{water\ at\ exit} - T_{water\ at\ inlet}\right)$$
$$= 50\ kg/min \times 4.186\ kJ/kgK \times (100 - 50)\ k$$
$$= 12558\ kJ/min = 12.6\ MJ/min$$

End of Solution

150. The phenomenon that enables cooling towers to cool water to a temperature below the dry bulb temperature of air is termed as
(a) Chemical dehumidification (b) Adiabatic evaporative cooling
(c) Cooling and dehumidification (d) Sensible cooling

Ans. **(b)**
Adiabatic evaporative cooling cools the water below the dry bulb temperature.

End of Solution

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