BOOKLET SERIES

A

Simulate the Real **ESE Prelims Exam** by

ANUBHAV
OPEN MOCK TEST

ESE 2026
Preliminary Exam
MECHANICAL ENGINEERING

FULL SYLLABUS TEST • PAPER-II

Answer Key

1. (c)	26. (d)	51. (a)	76. (b)	101. (c)	126. (b)
2. (d)	27. (c)	52. (b)	77. (d)	102. (c)	127. (b)
3. (a)	28. (d)	53. (d)	78. (c)	103. (a)	128. (b)
4. (d)	29. (a)	54. (b)	79. (d)	104. (d)	129. (a)
5. (b)	30. (c)	55. (a)	80. (b)	105. (d)	130. (b)
6. (c)	31. (a)	56. (c)	81. (b)	106. (b)	131. (b)
7. (c)	32. (a)	57. (a)	82. (a)	107. (c)	132. (b)
8. (b)	33. (d)	58. (a)	83. (b)	108. (c)	133. (b)
9. (a)	34. (b)	59. (d)	84. (d)	109. (c)	134. (c)
10. (a)	35. (b)	60. (c)	85. (b)	110. (d)	135. (d)
11. (b)	36. (c)	61. (a)	86. (d)	111. (b)	136. (b)
12. (c)	37. (b)	62. (a)	87. (d)	112. (c)	137. (d)
13. (c)	38. (b)	63. (a)	88. (c)	113. (c)	138. (b)
14. (b)	39. (c)	64. (a)	89. (d)	114. (b)	139. (c)
15. (b)	40. (c)	65. (a)	90. (d)	115. (c)	140. (c)
16. (b)	41. (d)	66. (d)	91. (c)	116. (a)	141. (b)
17. (a)	42. (d)	67. (b)	92. (c)	117. (c)	142. (a)
18. (d)	43. (d)	68. (d)	93. (d)	118. (a)	143. (b)
19. (a)	44. (a)	69. (b)	94. (c)	119. (b)	144. (c)
20. (c)	45. (b)	70. (a)	95. (b)	120. (d)	145. (d)
21. (b)	46. (b)	71. (c)	96. (b)	121. (d)	146. (d)
22. (a)	47. (c)	72. (c)	97. (d)	122. (c)	147. (a)
23. (c)	48. (a)	73. (b)	98. (b)	123. (a)	148. (a)
24. (c)	49. (b)	74. (c)	99. (c)	124. (a)	149. (c)
25. (d)	50. (d)	75. (c)	100. (a)	125. (d)	150. (b)

DETAILED EXPLANATIONS

1. (c)

Given, lumped system analysis,

$$D = L = 75 \text{ mm}$$

$$L_C = \frac{V}{A_s} = \frac{\frac{\pi}{4}(D^2)L}{\pi DL + \frac{\pi}{2}D^2} = \frac{\frac{D}{4}}{1+\frac{1}{2}} = \frac{D}{6}$$

$$\Rightarrow \quad L_C = \frac{75}{6} = 12.5 \text{ mm} = 1.25 \text{ cm}$$

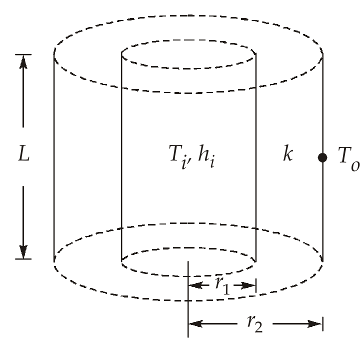
2. (d)

For fin to be most effective

- The thermal conductivity of the material should be as high as possible.
- The ratio $\frac{P}{A_c}$ should be high as possible. The criteria is satisfied by thin plate fins and slender pin fins.
- The use of fins is most effective in applications involving a low convection heat transfer coefficient.

3. (a)

Given : $(T_\infty)_i = 120°\text{C}$, $r_1 = 10$ cm, $r_2 = 27.2$ cm; $L = 8$ m; $k = 12$ W/m°C; $h_i = 60$ W/m^2°C; $T_o = 60°\text{C}$



$$Q = \frac{T_i - T_o}{R_t}$$

$$R_t = \frac{1}{h_i A_i} + \frac{\ln\left(\frac{r_2}{r_1}\right)}{2\pi kl} = \frac{1}{h_i(2\pi r_1 L)} + \frac{\ln\left(\frac{r_2}{r_1}\right)}{2\pi kL}$$

$$\Rightarrow \quad R_t = \frac{1}{60 \times 2\pi \times 0.1 \times 8} + \frac{\ln(2.72)}{2\pi \times 12 \times 8} = \frac{1}{64\pi}$$

$$Q = 64\pi \times (120 - 60) = 12063.7 \text{ W} \simeq 12 \text{ kW}$$

4. (d)

Given : ρ = 7500 kg/m^3; k = 50 W/m-K; c_p = 0.4 kJ/kg°C; d = 0.008 m; T_i = 300°C; T_∞ = 28°C; T = 128°C; h = 75 W/m^{2}K

$$Bi = \frac{hL_c}{k} = \frac{h}{k} \times \frac{D}{6} = \frac{75 \times 0.008}{50 \times 6} = 0.002$$

5. (b)

Given : ρ = 7500 kg/m^3; k = 50 W/m-K; c_p = 0.4 kJ/kg°C; d = 0.008 m; T_i = 300°C; T_∞ = 28°C; T = 128°C; h = 75 W/m^{2}K

$$\frac{T - T_\infty}{T_i - T_\infty} = e^{-bt}$$

$$b = \frac{hA}{\rho V c_p} = \frac{75 \times 6}{7500 \times 0.008 \times 400} = 0.01875$$

$$\Rightarrow \quad -bt = \ln\left(\frac{T - T_\infty}{T_i - T_\infty}\right)$$

$$\Rightarrow \quad -0.01875t = \ln\left(\frac{100}{272}\right)$$

$$\Rightarrow \quad -0.01875t = \ln\left(\frac{1}{e}\right) = -1$$

$$\Rightarrow \quad t = 53\,\text{s}$$

6. (c)

7. (c)

Given : q = 1000 W/m; A = 12 mm^2; k = 6 W/m°C

$$A = 12\ \text{mm}^2$$

$$\Rightarrow \quad R^2 = \frac{12}{\pi}\text{mm}^2$$

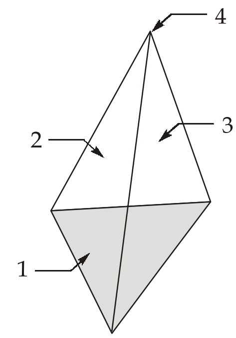
$$\dot{q} = \frac{q}{A} = \frac{1000}{12 \times 10^{-6}} = \frac{10^9}{12}\text{W/m}^3$$

$$\Delta T = \frac{\dot{q}}{4k}R^2 = \frac{10^9}{4 \times 6 \times 12} \times \frac{12}{\pi} \times 10^{-6}$$

$$\Rightarrow \quad \Delta T = 13.26°\text{C}$$

8. (b)

For a equilateral tetrahedron,



From the symmetry rule,

$$F_{12} = F_{13} = F_{14}$$

$$\because \quad F_{11} = 0$$

$\Rightarrow$ Using summation rule,

$$F_{11} + F_{12} + F_{13} + F_{14} = 1$$

$$\Rightarrow \quad F_{12} = F_{13} = F_{14} = \frac{1}{3}$$

9. (a)

Given : $\rho = 1025$ kg/m^3; $A = 0.5$ km^2 = 5×10^5 m^2; $R = 4$ m; $t = 10$ hr = 10×3600 seconds

$$P_{avg} = \frac{\frac{1}{2}\rho A g R^2}{t} = \frac{\frac{1}{2} \times 1025 \times 5 \times 10^5 \times 9.81 \times 6^2}{10 \times 3600}$$

$$\Rightarrow \quad P_{avg} = 2.51 \text{ MW}$$

10. (a)

Rotor	Driving force
HAWT Rotor	Lift force
Sail-wing rotor	Lift force
Dutch-type rotor	Drag force
Cup-type rotor	Drag force
Savonius or S-rotor	Drag force
Darrieus rotor	Lift force

11. (b)

Composition of Biogas

CH_4	55 - 70%
CO_2	30 - 45%
H_2S	1 - 2%
N_2	0 - 1%
N_2	0 - 1%

12. (c)

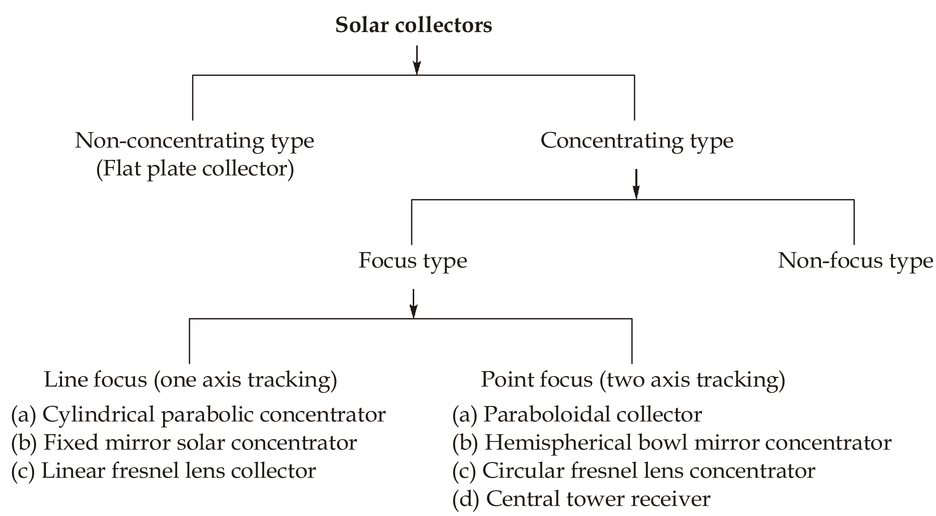
In gasifier, raw material passes through following zones:

1. Drying zone
2. Pyrolysis zone
3. Oxidation zone : Here, exothermic reaction takes place and heat is released in good amount which raises the temperature in this zone (temperature 900°C - 1200°C).

4. Reduction zone : Reaction is the process of removal of O_2 atom from combustion product, so as to return the molecules to form that can burn again (i.e. combustible gas). Temperature of this zone reduces as heat is been consumed in endothermic reaction.

Product of this zone (CO, H_2 and CH_4 also we get CO_2 and N_2) are called producer gas.

13. (c)



14. (b)

- Temperature range is the range of temperature to which the heat-transport fluid is heated up by the collector.
- In flat plate collectors, no optical system is utilized to concentrate the solar radiation and hence the concentration ratio is only 1. The temperature range is less than 100°C. Line focus collectors have CR upto 100 and a temperature range of the order of 150°C to 300°C. A concentrator ratio of the order thousands and temperature range of 500°C to 1000°C can be obtained by using point - focus collectors.
- Evacuated tube collectors are very expensive compared to conventional flat-plate collectors. Thus, it is possible to consider then only for high fluid temperatures in a range 100 to 130°C.

15. (b)

Given : $u_0 = 12$ m/s; $R = \frac{D}{2} = 40$ m ; $N = 60$ rpm

$\Rightarrow$ $$\omega = 2\pi \text{ rad/s}$$

For P_{max}, $$a = \frac{1}{3};\ c_{p,\max} = 0.593$$

$$P_o = \frac{1}{2}(\rho A)u_o^3$$

$$c_{T,\max} = \frac{c_{p,\max}}{\lambda} = \frac{0.593}{\left(\frac{R\omega}{u_0}\right)}$$

$$T_{h,\max} = c_{T,\max} \times T_m$$

$$= \frac{0.593}{R\omega} \times u_o \times \frac{P_0}{u_0} \times R$$

$$= 0.593 \times \frac{P_0}{\omega} = 0.593 \times \frac{1}{2\pi} \times \frac{1}{2} \times \rho \times \frac{\pi}{4}(80)^2(12)^3$$

$$= 0.593 \times 1 \times 13.05 \times 10^6 \text{ Nm}$$

$$= 0.484 \text{ MNm}$$

16. (b)

$$\text{Gas required for family} = 7 \times 500 \times 10^{-3} \text{ m}^3/\text{day}$$

$$= 3.5 \times \text{m}^3/\text{day}$$

Let n = number of cows

$\Rightarrow$ Cow dung produced $= 10n$ kg/day

$\therefore$ Gas production per day $= 10n \times 35 \times 10^{-3}$ m^3/day

$\therefore$ $10n \times 35 \times 10^{-3} = 3.5$

$n = 10$

17. (a)

The path length of a solar beam through the atmosphere is accounted for in the term air mass, which is defined as the ratio of the path length through the atmosphere, which the solar beam actually traverse, up to the ground to the vertical path length (which is minimum) through the atmosphere.

18. (d)

Given : V_{oc} = 0.5V, I_{sc} = 0.6A, FF = 0.84

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

$\therefore$ $P_{\max} = 0.84 \times (0.5 \times 0.6)$

$\Rightarrow$ $P_{\max} = 0.252$ W

19. (a)

Solid Oxide Fuel Cell (SOFC) : Certain solid oxides (ceramics) at high temperature can be used as electrolyte . For example, zirconium oxide containing a small amount of other oxide to stabilize the crystal structure has been used as electrolyte. The negative electrode is made of porous nickel and the positive electrode employs a metal oxide, e.g. indium oxide. The operating temperature is in range of 600°C to 1000°C.

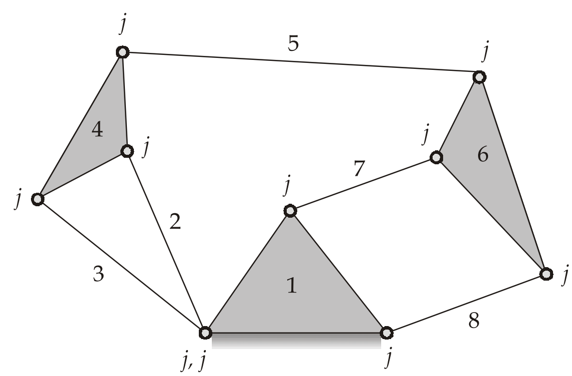
20. (c)

Retention time : The time duration for which the slurry remains in the plant or the time that is available for biodigestion. It is determined by the volume of a digester divided by the volume of slurry added per day.

21. (b)

The term firing order is used in a multi-cylinder engine. The sequence in which the power impulses occur in an engine is called the firing order. As the number of cylinders is increased, the power impulses for each revolution of the crankshaft increase in frequency, giving a more uniform torque and smoother operation. The more the cylinders in an engine, the more continuous is the flow of power if the power impulses are spaced equally, the less is the vibration, and also less work has to be done by the flywheel in storing and releasing the energy. The flywheels for the multi-cylinder engines, therefore, can be lighter than those used in engines with fewer cylinders.

22. (a)



$$n = 8 \quad \{\text{Binary links} = 5; \text{Ternary links} = 3\}$$

$$j = 10$$

$$F = 3(n-1) - 2j$$

$$= 21 - 20 = 1$$

$$F = 1 \quad \text{(completely constrained)}$$

23. (c)

Given : $n = 5$; $\omega = 2500$ rpm

$$\omega_{C.R.} = \frac{\omega\cos\theta}{n} = \frac{2500\cos\theta}{5} = 500\cos\theta$$

For $(\omega_{C.R.})_{max} \Rightarrow$ $\theta = 0°$

$\Rightarrow$ $(\omega_{C.R.})_{max} = 500$ rpm

24. (c)

Radius of curvature of cam profile: There is no restriction on the radius of curvature of cam profile, with a knife edge follower. The cam profile must be convex everywhere for a flat-face follower. In the case of roller follower, the concave portion of the cam profile must have a radius of curvature greater than that of the roller to ensure proper contact along the cam profile.

25. (d)

Given : workdone per second = 49000 W; N = 420 rpm; ; C_s = ±1.5% = 0.03; C_E = 0.3

$$\text{Workdone per stroke} = \frac{49000}{\left(\frac{N}{60}\right)} = 7000 \text{ Nm}$$

$$\Delta E = 7000 \times 0.3 = 2100 \text{ Nm}$$

$\because$ $$\Delta E = I\,\omega^2 C_s$$

$\Rightarrow$ $$2100 = I \times \left(\frac{\pi \times 420}{30}\right)^2 \times 0.03 = I \times 44^2 \times 0.03$$

$\Rightarrow$ $$I = 36.2 \text{ kg-m}^2$$

26. (d)

Pickering governor : The pickering governor consists of three straight leaf spring arranged at equal angular intervals round the spindle. Each spring carries a weight at the centre. The weight move outward and the springs bend as they rotate about the spindle axis with increasing speed. It is mostly used for driving gramophones.

27. (c)

Given : F_P = 600 N; r = 200 mm; l = 800 mm; n = 4

We know that, $$F_P = mr\omega^2 \cos\theta$$

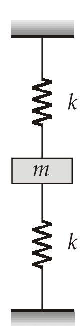
$\therefore$ $$(F_p)_{\max} = mr\omega^2 = 600$$

$\because$ $$F_{\text{secondary}} = \frac{mr\omega^2 \cos(2\theta)}{n}$$

$\therefore$ $$(F_s)_{\max} = \frac{mr\omega^2}{n} = \frac{600}{4} = 150 \text{ N}$$

28. (d)

Given : k = 1000 N/m; m = 5 kg



(In parallel)

$\therefore$ $$k_{eq} = k + k$$
$$= 2k = 2 \times 1000 = 2000 \text{ N/m}$$

$$\omega_n = \sqrt{\frac{k_{eq}}{m}} = \sqrt{\frac{2000}{5}} = 20 \text{ rad/s}$$

29. (a)

Given : MF = 20 (at $\omega = \omega_n$)

We know that, $\quad \text{MF (at } \omega = \omega_n) = \frac{1}{2\xi}$

$\therefore \quad$ Damping factor, $\xi = \frac{1}{2 \times MF}$

$\Rightarrow \quad \xi = \frac{1}{2 \times 20} = 0.025$

30. (c)

Given : ω = 6 rad/s

$$\omega_p = \frac{V}{R} = \frac{25}{600} = \frac{1}{24} \text{ rad/s}$$

$$I = 120 \text{ kg-m}^2$$

$$C = I\omega\omega_p = 120 \times 6 \times \frac{1}{24} = 30 \text{ N-m}$$

31. (a)

Given : T_P = 42, N; N_Q = 270 rpm; $r + R$ = 252 mm; m = 3 mm; $r = \frac{mT}{2} = 63$ mm

$\Rightarrow \quad R$ = 189 mm

$$\frac{N_Q}{N_P} = \frac{r}{R}$$

$\Rightarrow \quad N_P = N_Q \times \frac{R}{r}$

$\Rightarrow \quad N_P = 270 \times \frac{189}{63} = 810$ rpm

32. (a)

Due to anisotropy of the sheet metal, i.e., the material has directional variation in properties (rolling direction stronger than transverse direction).

33. (d)

Largest resistance at the contact between the two workpiece to be joined is because of non continuity of material and trapment of air. Air is having low thermal conductivity and induces high resistance between the workpiece.

34. (b)

Choke area is given as:

$$A = \frac{\rho_{CI} \times V_m}{\rho_m t C \sqrt{2gh}} = \frac{7.86 \times 10^{-6} \times 250 \times 250 \times 250}{6.9 \times 10^{-6} \times 20 \times 0.78 \times \sqrt{2 \times 10 \times 1000 \times 200}}$$

$$= 570.4 \text{ mm}^2$$

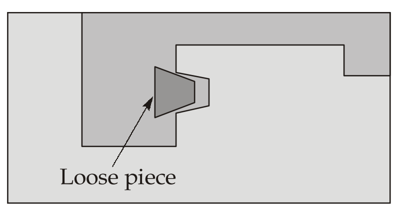
Where, C = Efficiency factor which depends on gating system

35. (b)

In locating by holes, one of the pins has to be diamond shaped to accommodate tolerance on the pins distance between the holes and their diameters.

36. (c)

1. **Gated pattern:** This is an improvement over the simple pattern where the gating and runner system are integral with the pattern. This would eliminate handcutting of the runner and gates and help in improving the productivity of a moulder.
2. **Skeleton pattern:** This type of pattern is used generally for very large castings, required in small quantities where large expense on the complete wooden pattern is not justified.
3. **Loose-piece pattern:** When one piece solid pattern has projection or back drafts which lies above or below the parting plane, it is impossible to with draw if from the mould so the projection are made with help of loose piece pattern. the drawback is possibility of shifting of loose pattern during ramming.



4. Sweep pattern used for generating large shapes which are axi-symmetrical or prismatic in nature such as bell shaped. This greatly reduces the cost of three-dimensional pattern.

37. (b)

This unique process is characterized mainly by very slow work speed but very large depth or infeed (d) which not only enables large stock removal and high MRR but also provides longer life of the grits and better surface finish.

38. (b)

39. (c)

For clearance fit allowance is equal to minimum clearance and for interference fit allowance is equal to maximum interference.

40. (c)

Governing methods used in Steam turbines are

(a) Throttle governing

(b) Nozzle control governing

(c) By-pass governing
(d) Combination of (a) and (b) or (a) and (c).
(a) Throttle Governing Employing Mechanical Speed Governor. The object of throttle governing is to throttle the steam to a suitable pressure and reduce the steam flow (i.e. to allow required quantity of steam to flow) through the turbine bladings whenever there is a reduction of load compared to economic or design load for maintaining the speed of the turbine.
(b) Nozzle Control Governing : In the nozzle control governing, the nozzles of the turbines are grouped in two, three or more groups, and each group of nozzles is fed with steam controlled by valves.
(c) By Pass Governing : The principle of by-pass governing is to by-pass some extra quantity of steam to the far down stream stages when the load is more than economic load.

Whereas, spear governing is used in hydraulic turbines to control the flow rate of water from the penstock.

41. (d)

Methods of Increasing the Thermal Efficiency:

Based on above two principles, the methods of increasing the thermal efficiency are as follows:
(i) By increasing the superheating temperature of steam
(ii) By increasing the maximum pressure of steam.
(iii) By reducing the exhaust pressure of steam.
(iv) By regenerative feed heating.
(v) By reheating of steam.
(vi) By water extraction.
(vii) By using binary-vapor.

Generally, a modern steam turbine power plant is a combination of all the above except (vii). In some case (vii) is also used.

42. (d)

Erosion and Corrosion of Blades:

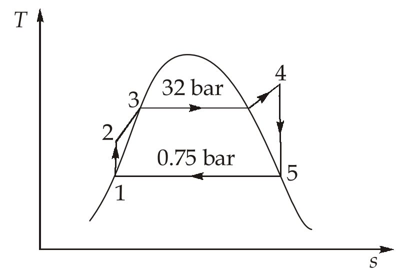
The presence of water particles in steam not only reduces the nozzle and blade efficiency but also brings about a serious erosion and corrosion of blades. Erosion of turbine blading is the wasting away or growing of the back of the inlet edge of the blade, and only occurs where the moisture in steam exceeds about 10% and the blade speed is high.

Prevention of Erosion and Corrosion:

The following are the methods to combat the erosion and corrosion problems in steam turbines:
(i) Raising initial temperature: Raising the initial temperature of steam so that the wetness never exceeds 10%, even in the last stage of the low-pressure turbine.
(ii) Reheating: Remove the whole of the steam before the moisture content in the expanding steam approaches 10% and reheat it in a reheater so that the wetness at the exhaust does not exceed 10%.
(iii) Water extraction: By passing of whole of the steam through a separator where the steam is appreciably wet.

(iv) Shielding leading edge: The leading edge of the blade may be shielded of hard has a material like tungsten.

43. (d)



$$Q_{added} = h_4 - h_2$$
$$h_2 - h_1 = W_{pump} = v_f(P_{boiler} - P_{condenser})$$
$$= 0.001037(3200 - 75) = 3.24 \text{ kJ/kg}$$
$$\therefore \quad h_2 - h_f = 3.24 \text{ kJ/kg}$$
$$h_2 = 3.24 + 384.36 = 387.6 \text{ kJ/kg}$$
$$h_4 = 3663 \text{ kJ/kg}$$
$$Q_{added} = 3663 - 387.6 = 3275.4 \text{ kJ/kg}$$

44. (a)

- Volumetric efficiency, $\eta_{vol} = 1 + C - C\left[\frac{P_H}{P_L}\right]^{1/n} = 1 - C\left[\left(\frac{P_H}{P_L}\right)^{1/n} - 1\right]$

As the clearance volume decrease, clearance ratio decrease and hence volumetric efficiency will increase.

- Clearance ratio have no impact on the power consumption of the compressor.

45. (b)

Due to finite number of vanes on a rotor the air trapped between the impeller vanes is reluctant to move round with the impeller and this results in a higher static pressure on the leading face of a vane than on the trailing face. It also prevents the air acquiring a whirl velocity equal to impeller speed. This effect is known as slip. Because of slip, we obtain $V_{w2} < U_2$. The slip factor σ is

$$\sigma = \frac{V_{w2}}{U_2}$$

The value of σ lies between 0.9 to 0.92. The energy transfer per unit mass in case of slip becomes

$$\frac{E}{m} = V_{w2}U_2 = \sigma U_2^2$$

46. (b)

As per given data: As the 22% of hydraulic losses

$$\text{hydraulic efficiency, } \eta_h = 1 - 0.22 = 0.78$$

For radial discharge, $\eta_H = \frac{V_{w1}u_1 \times \rho Q}{\rho Q g H} = \frac{V_{w1}u_1}{gH}$ ... (i)

As we know, $H = 8$ m

$u_1 = 12.03$ m/s

$V_{f1} = 4.51$ m/s

From equation (i), $0.78 = \frac{V_{w1} \times 12.03}{10 \times 8}$

$$V_{w1} = \frac{0.78 \times 10 \times 8}{12.03} = \frac{62.4}{12.03} = 5.18 \text{ m/s}$$

47. (c)

Stop valve: It regulates the flow of steam from the boiler. This is generally mounted on highest part of boiler shell and performs function of regulating the flow of steam from boiler. Stop valve generally has main body of cast steel; valve, valve seat and nut etc. are of brass.

Statement 2 is correct for feed check valve.

48. (a)

Given: Height of chimney, H = 20 m, Flue gas temperature, T_g = 380 + 273 = 653 K, Ambient temperature, T_a = 27 + 273 = 300 K

For maximum discharge condition,

$$\frac{T_g}{T_a} = 2\left(\frac{m+1}{m}\right)$$

$$2\left(\frac{m+1}{m}\right) = \frac{653}{300}$$

$\Rightarrow$ $$2m + 2 = 2.1767\text{ m}$$

$$m = \frac{2}{0.1767} = 11.32$$

$$m = 11.32 \text{ kg air per kg of fuel}$$

$$\text{Air supplied} = 11.32 \text{ kg/kg of fuel}$$

49. (b)

- Ejector condenser has water jet discharging through the series of guide cones which guide steam on to the surface of water jet. Discharge of water through these convergent nozzles causes partial vacuum due to conversion of potential energy into kinetic energy.
- Subsequently water jet enters the diffuser nozzle where kinetic energy is converted into the pressure head and water is discharged against the vacuum pull.
- Ejector condensers are well suited for moderate vacuum only.
- Steam is injected in condenser with non-return valve in between and is condensed by the mixing with cooling water. Condensation of steam further increases vacuum.
- Ejector condenser does not require air pump because of air entraining effect of water jet itself.

50. (d)

Velocity compounded impulse turbine offers advantages such as less number of stages compared to pressure compounding and so less cost. It also requires less space and is relatively more reliable and easy to start. In multi stage velocity compounded impulse turbine the first stage has large pressure drop and remaining turbine stages are subjected to constant low pressure, thus lesser number of stages. In velocity compounded impulse turbine since pressure drop occurs in nozzle itself so the rest of turbine and its' casing need not be manufactured very strong. But the efficiency is low due to large frictional losses due to large initial velocity and 'non optimum value of ratio of blade velocity to steam velocity for all blade rings'.

51. (a)

$$N = \frac{120f}{p}$$

where, N = equilibrium shaft speed (rpm); f = frequency of electrical power generated; p = number of poles

$$N = \frac{120 \times 60}{8} = 900 \text{ rpm}$$

52. (b)

$$P_{max} = \dot{m}w_{max} = \dot{m}c_p\left[\sqrt{T_{max}} - \sqrt{T_{min}}\right]^2$$

$$= 10(1.005)\left[\sqrt{1600} - \sqrt{400}\right]^2$$

$$= 10.05(40 - 20)^2$$

$$\simeq 4.020 \text{ MW}$$

53. (d)

The causes of stress concentration are as follows:

(a) Variation in properties of materials : Cavities in welds, internal cracks and flows like blow holes, air holes in steel components, non-metallic or foreign inclusions.

(b) Load application : Forces act either at a point or over a small area on the loaded component.

(c) Abrupt changes in cross-section : To mount gears, pulleys sprockets and ball bearings on shaft, steps are cut on the shaft and shoulders are provided from assembly considerations.

(d) Discontinuities in the component : Oil holes, grooves, keyways, splines, screw threads, etc.

(e) Machining scratches : Machining scratches, stamp marks or inspection marks are surface irregularities leading to stress concentration.

54. (b)

55. (a)

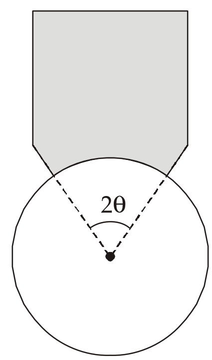
- Needle bearings have large load carrying capacity particularly at low peripheral speed.
- Needle bearings have a small outer diameter. It is due to this reason that they are often used to replace sleeve bearing. This allows replacement with little or no changes in design.

56. (c)

The bearing characteristic number is given by $\frac{ZN}{P}$ which is a dimensionless number. It is defined for sliding contact bearings. The transition from thin film lubrication to thick film-hydrodynamic lubrication can be better visualized by means of a curve called $\frac{ZN}{P}$ curve. This is an experimental curve developed by Mckee-brothers.

57. (a)

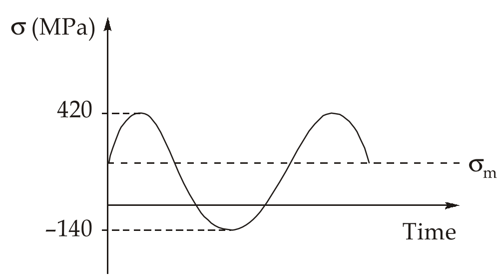
For long shoe,



$$\mu_{eff} = \mu\left(\frac{4\sin\theta}{2\theta + \sin 2\theta}\right)$$

58. (a)

Given: σ_{max} = 420 MPa, σ_{min} = –140 MPa



$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{420-(-140)}{2} = \frac{560}{2} = 280 \text{ MPa}$$

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} = \frac{420+(-140)}{2} = \frac{280}{2} = 140 \text{ MPa}$$

According to Goodman criterion,

$$\frac{\sigma_a}{\sigma_e} + \frac{\sigma_m}{S_{ut}} \le \frac{1}{N}$$

$$\Rightarrow \quad \frac{280}{280} + \frac{140}{560} \le \frac{1}{N}$$

$$\Rightarrow \quad 1.25 \leq \frac{1}{N}$$

or $$N \leq 0.8$$

$$N = 0.8$$

This indicates finite life is predicted.

59. (d)

Beam strength of gear tooth, $S_b = mbY\sigma_{per}$

where, Y = Lewis form factor/form factor/tooth geometry factor

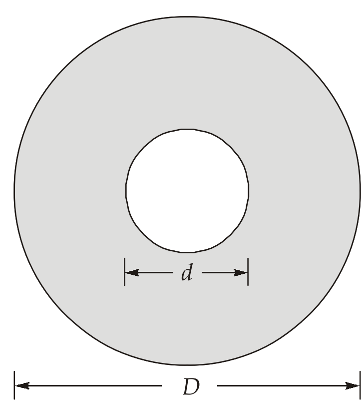
Y depends on

- Number of teeth (z)
- Addendum
- Pressure angle (ϕ)

But it is independent of module (m).

60. (c)

According to uniform wear theory torque capacity,



$$T = \frac{\pi\mu P_a d\left(D^2 - d^2\right)}{8} = \frac{\pi\mu P_a}{8}\left(D^2 d - d^3\right)$$

For maximum torque, $\frac{dT}{d(d)} = 0$

$$\Rightarrow \quad 0 = \frac{\pi\mu P_a}{8}\left(D^2 \cdot 1 - 3d^2\right)$$

$$\Rightarrow \quad d = \frac{D}{\sqrt{3}}$$

So, for maximum torque capacity $\frac{d}{D} = \frac{1}{\sqrt{3}}$

61. (a)

Given: $F_r = 8$ kN, $F_a = 3$ kN, $L_{10H} = 24000$ hr, $n = 1200$ rpm, $X = 0.6$, $Y = 1.8$, $V = 1$, $S = 1$

$$P_e = (X \times V \times F_r + Y \times F_a)S$$
$$= (0.6 \times 1 \times 8 + 1.8 \times 3) \times 1 = 10.2 \text{ kN}$$
$$L_{10} = \frac{60nL_{10h}}{10^6} = \frac{60 \times 1200 \times 24000}{10^6} = 1728 \text{ million hrs}$$

For ball bearing, $\left(\frac{C}{P_e}\right)^3 = L_{10}$

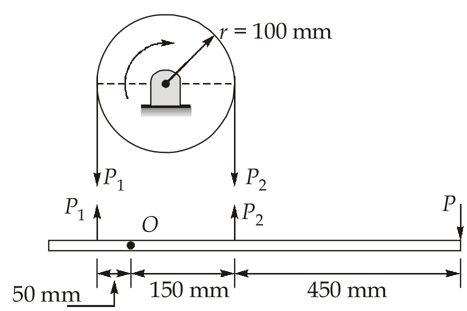
$\Rightarrow$ $C = P_e(L_{10})^{1/3} = 10.2 \times (1728)^{1/3}$

$= 122.4$ kN

62. (a)

$$\text{Torque capacity} = 1718 \text{ N-m}$$

$\Rightarrow$ $(P_1 - P_2) \times R = 1718$



$\Rightarrow$ $P_1 - P_2 = \frac{1718}{0.1} \text{N} = 17180 \text{ N}$ ... (i)

$\because$ $\frac{P_1}{P_2} = e^{\mu\theta} = e^{1/\pi \times \pi} = e = 2.718$

$P_1 = 2.718\ P_2$ ... (ii)

So, $P_2 = 10000$ N

$P_1 = 27180$ N

On balancing moment about O,

$\because$ $P_1 \times 50 + P \times 600 = P_2 \times 150$

$\Rightarrow$ $P = \frac{10000 \times 150 - 27180 \times 50}{600} = 235 \text{ N}$

63. (a)

Jaw clutches can be engaged only when both shafts are stationary or rotate with very small speed difference.

64. (a)

$$SP = FP + VC$$
$$40 \times x = 1000 + 20x$$
$$\Rightarrow \quad x = 50 \text{ units}$$

65. (a)

$$\lambda = 3.5 \text{ customer/hr}$$
$$\mu = 5 \text{ customer/hr}$$

Average length of non-empty queue or average length of queue containing at least one customer,

$$\rho = \frac{3.5}{5} = \frac{0.7}{1} = 0.7$$
$$L_q' = \frac{1}{1-\rho} = \frac{1}{1-0.7} = \frac{1}{0.3} = \frac{10}{3}$$

66. (d)

The objectives of production planning and control are :

1. To ensure efficient utilization of production facilities.
2. To coordinate the production activities of different department.
3. To provide alternative production strategies in case of emergencies.

67. (b)

For series combination, $\lambda_{sys} = \Sigma\lambda_i = 0.002 + 0.005 + 0.003$
$= 0.01$ per hour

For repairable items, MTBF $= \dfrac{1}{\lambda}$

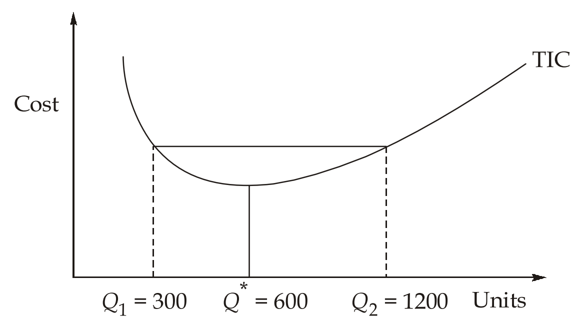
$$MTBF_{sys} = \frac{1}{\Sigma\lambda_i} = \frac{1}{0.01} = 100 \text{ hr}$$

68. (d)

It is the cost associated with storing, keeping and maintaining inventory within production system. It includes

- Storage cost
- Damage cost
- Depreciation cost
- Insurance cost
- Interest etc.

69. (b)



$$Q^* = GM(Q_1, Q_2) = \sqrt{Q_1 Q_2} = \sqrt{300 \times 1200}$$
$$Q^* = 600 \text{ units}$$

70. (a)

VED {Vital-Essential-Desirable}

71. (c)

$$t_o = 6 \text{ days};\ t_p = 12 \text{ days};\ t_m = 10 \text{ days}$$
$$t_e = \frac{t_o + 4t_m + t_p}{6}$$
$$= \frac{6 \times 4 \times 10 + 12}{6} = \frac{58}{6} = 9.67 \text{ days}$$

72. (c)

73. (b)

$$D = 100 \text{ mm} = 0.1 \text{ m}$$
$$\text{Re} = \frac{\rho(V_{\text{mean}})D}{\mu} = \frac{800 \times V_{\text{mean}} \times 0.1}{0.08}$$
$$V_{\text{mean}} = \frac{500 \times 0.08}{800 \times 0.1} = 0.5 \text{ m/s}$$
$$V_{\max} = 2\,V_{\text{mean}} = 2 \times 0.5 = 1 \text{ m/s}$$
$$\frac{V}{V_{\max}} = \left[1 - \left(\frac{r}{R}\right)^2\right]$$
$$V_{(r = 40 \text{ mm})} = 1\left(1 - \left(\frac{40}{50}\right)^2\right) = 1 - \frac{16}{25} = \frac{9}{25} = 0.36$$
$$V_{(r = 40 \text{ mm})} = 0.36 \text{ m/s}$$

74. (c)

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

$$\text{S.G.} = 2$$

$$\rho = 2000 \text{ kg/m}^3$$

$$\mu = \rho\nu = 2000 \times 6 \times 10^{-4} = 1.2 \text{ Pa.s}$$

75. (c)

$$R = 2 \text{ cm} = 0.02 \text{ m}$$

$$\Delta P = 2\left\{\sigma\left(\frac{1}{R}+\frac{1}{R}\right)\right\}; \text{ for soap bubble}$$

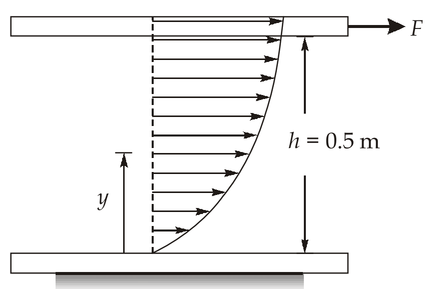
$$\Delta P = \frac{4\sigma}{R}$$

$$\Rightarrow \quad \sigma = \frac{\Delta PR}{4} = \frac{(100.01-100)\times 10^3 \times 0.02}{4}$$

$$\Rightarrow \quad \sigma = 0.05 \text{ N/m}$$

76. (b)

Given : $u = \frac{y}{2}(1-y);\ \mu = 1;\ h = 0.5 \text{ m}$

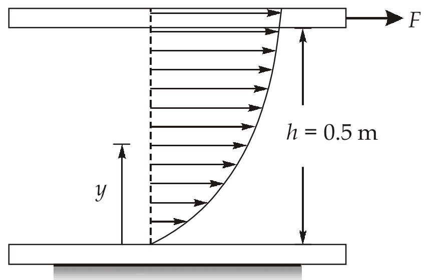


$$\tau = \mu\frac{du}{dy} = 1\cdot\frac{d}{dy}\left\{\frac{y}{2}-\frac{y^2}{2}\right\} = \left(\frac{1}{2}-y\right)\text{Pa}$$

$$\tau\big|_{y=0.25} = 0.5 - 0.25 = 0.25 \text{ Pa}$$

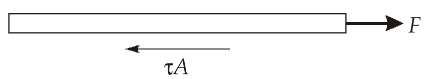
77. (d)

Given : $u = \frac{y}{2}(1-y);\ \mu = 1;\ h = 0.5\text{ m}$



$$\tau = \mu\frac{du}{dy} = 1\cdot\frac{d}{dy}\left\{\frac{y}{2}-\frac{y^2}{2}\right\} = \left(\frac{1}{2}-y\right)\text{Pa}$$

$$\tau|_{y=0.5} = 0.5 - 0.5 = 0\text{ Pa}$$



For equilibrium, $F = \tau A = \text{Zero}$

78. (c)

$$\text{Draught} = \text{Submerged height}$$

$$W = \rho V_d g = \rho_s V_{d,s} g$$

$$\Rightarrow \quad \rho(Ah_1)g = \rho_s(Ah_2)g$$

$$\Rightarrow \quad (1\times10^3)\times A\times h_1\times g = (1.2\times10^3)\times A\times h_2\times g$$

$$\Rightarrow \quad h_2 = \frac{h_1}{1.2} = \frac{1.5}{1.2} = 1.25\text{ m}$$

79. (d)

At stagnation point, $\vec{V} = 0$

$$\Rightarrow \quad u = 0 \text{ and } v = 0$$

$$\Rightarrow \quad (2x + 3y + 1) = 0 \text{ and } (x - y + 5) = 0$$

$$\Rightarrow \quad x = \frac{-16}{5} \text{ and } y = \frac{9}{5}$$

$$\Rightarrow \quad (x, y) = (-3.2, 1.8)$$

80. (b)

81. (b)

Critical point : Properties of saturated liquid and saturated vapour are identical.

Sublimation : Heating process, where solid gets directly transformed to gaseous phase.

Triple point : All the three phases-solid, liquid and vapour co-exists in equilibrium.

82. (a)

83. (b)

Pressure, volume and entropy are the properties hence they are fixed for a state.

$\oint dw$ shouldn't be zero for a reversible cyclic process.

84. (d)

- The SFEE can be applied to an ordinary electric hot-water heater under steady operation.
- Some steady-flow engineering devices:
  - Turbines
  - Compressors
  - Heat exchangers
  - Pumps
  - Throttling valves
  - Mixing chambers

85. (b)

Given : Steady flow process, h_1 = 250 kJ/kg; h_2 = 40 kJ/kg; h_3 = 180 kJ/kg

Applying SFEE, and mass balance,

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3 \quad ...(i)$$

[Since, $\dot{Q} = 0$, $\dot{W} = 0$, $\Delta KE = \Delta PE = 0$]

and
$$\dot{m}_1 + \dot{m}_2 = \dot{m}_3 \quad ...(ii)$$

By (i) and (ii),

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = (\dot{m}_1 + \dot{m}_2) h_3$$

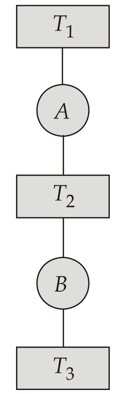
$$\Rightarrow \quad \frac{\dot{m}_1}{\dot{m}_2} h_1 + h_2 = \left(\frac{\dot{m}_1}{\dot{m}_2} + 1\right) h_3$$

$$\Rightarrow \quad x \times 250 + 40 = (x + 1)180$$

$$\Rightarrow \quad x = \frac{\dot{m}_1}{\dot{m}_2} = \frac{180 - 40}{250 - 180} = 2$$

86. **(d)**

$$\eta_A = 1-\frac{T_2}{T_1} \text{ and } \eta_B = 1-\frac{T_3}{T_2}$$



$\because$ Given $\quad \eta_A = 2\eta_B$

$\Rightarrow \quad \left(1-\frac{T_2}{T_1}\right) = \left(2-\frac{2T_3}{T_2}\right)$

$\Rightarrow \quad T_3 = \frac{T_2(T_1+T_2)}{2T_1}$

87. **(d)**

Applications of Hall effector sensor:

1. It is used as a magnetic switch for electric transducer.
2. It is used for the measurement of the position displacement and proximity.
3. It is used for measurement of current.
4. It is used for measurement of power.

88. **(c)**

Given : $N = 10$

Number of distinct position $= 2^N = 2^{10} = 1024$

Angular resolution $= \frac{360°}{1024} = 0.35°$

89. **(d)**

Given : $G_f = 1.8$

We know that, $\quad G_f = 1+2\mu+\frac{\Delta\rho/\rho}{\Delta L/L}$

Neglecting piezo-resistive effect,

$$G_f = 1 + 2\mu$$

$\Rightarrow \quad \mu = \frac{1.8-1}{2} = 0.4$

90. **(d)**

The most common type unipolar stepper motor, has six wires and four coils (actually two coils divided by center wires on each coil). The outer wires for each coil will have a definite resistance that is double the resistance between the inner wire and either of the two outer wires.

91. (c)

Feedback is that property of a closed loop system which permits the output or some other controlled variable of the system, to be compared with the input to the system, so that the appropriate control action may be formed as some function of the output and input.

92. (c)

Linear variable differential transformer (LVDT): LVDT is a passive inductive transducer and is commonly employed to measure force, in terms of amount and direction of displacement on an object.

- It consists of one primary winding and two secondary windings which are placed on either side of the primary mounted on the same magnetic core.
- It gives a high output and therefore many a times there is no need for intermediate amplification devices.

93. (d)

Micro-controllers are attractive in mechantronics system design since their small size and broad functionality allow them to physically embedded in a system to perform all of the necessary control functions.

94. (c)

Advantages:

1. Small size and a small weight.
2. High output impedance.
3. Can measure acceleration from a fraction of g to thousands of *g*.
4. High sensitivity.
5. High frequency response (10 Hz to 50 kHz)

Disadvantages:

1. Unsuitable for applications where the input frequency is lower than 10 Hz.
2. Subject to hysteresis errors.
3. Sensitive to temperature changes.

95. (b)

Inverse kinematics:

- The determination of all possible and feasible set of joint variables, which would achieve the specified position and orientation of the manipulator's end-effector with respect to the base frame.
- The number of simultaneous equation is more than the number of unknowns, making some of the equations mutually dependent. These conditions lead to the possibility of multiple solutions for the given end-effector position.
- It is obvious that if the desired point is outside the reachable workspace then no solution exists.

96. (b)

The 30° rotation of P about z-axis of frame {1} is

$$R_z(30°) = \begin{bmatrix} \cos 30° & -\sin 30° & 0 \\ \sin 30° & \cos 30° & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0.866 & -0.5 & 0 \\ 0.5 & 0.866 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

For the rotation of vectors, $'Q = R_z(30°)\ 'P$

$$'Q = \begin{bmatrix} 0.866 & -0.5 & 0 \\ 0.5 & 0.866 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 4.0 \\ 3.0 \\ 2.0 \end{bmatrix}$$

$$'Q = \begin{bmatrix} 3.464 - 1.5 + 0 \\ 2 + 2.598 + 0 \\ 0 + 0 + 2.0 \end{bmatrix} = \begin{bmatrix} 1.964 \\ 4.598 \\ 2.0 \end{bmatrix}$$

$\therefore$ Coordinate of the new point $Q = [1.964 \quad 4.598 \quad 2.0]^T$

97. (d)

The end-effector is external to the manipulator and its DOF do not combine with the manipulator's DOF, as they not contribute to manipulatability. These can be grouped into two major categories : 1. Grippers and 2. Tools.

98. (b)

- **Reachable workspace :** The region that can be reached by the origin of the end effector frame with at least one orientation is called reachable workspace.
- **Joint space :** The set of all ($n \times 1$) joint displacement vectors generates the joint vector space or joint space.
- **Cartesian space :** The configuration of the end effector is represented by three position components as displacements along three orthogonal axes of base frame and three rotations about the base frame axes. These six components can be represented by a six dimensional space called configuration space or cartesian space.

99. (c)

100. (a)

Humidity ratio, ω = 0.05 kg w.v./kg d.a.

Mass fraction of water vapour $= \dfrac{\omega}{1+\omega} = \dfrac{0.05}{1.05} = \dfrac{5}{105} = \dfrac{1}{21}$ = 0.047 kg w.v./kg of mixture

101. (c)

For temperature equal to dew point temperature, only cooling will take place.

102. (c)

- Compressed air forms a free vortex after passing through nozzle and the cold air forms forced vortex in the inner core.
- Energy transfer is from inner core having cold air to periphery having hot air.

103. (a)

Given : Δt = 15°C; cmm = 60; SHF = 0.5

$$\because \quad \text{RLH} = 0.0204(\Delta t)$$
$$= 0.0204 \times 15 = 0.306 \text{ kW}$$

and
$$\text{SHF} = \frac{\text{RSH}}{\text{RHS + RLH}}$$

$$\Rightarrow \quad \frac{1}{0.5} = 1 + \frac{\text{RLH}}{0.306}$$

$$\Rightarrow \quad \text{RLH} = \text{RSH} = 0.306 \text{ kW}$$

104. (d)

- Reciprocating compressors are often used for small-capacity applications.
- Centrifugal compressor are non-positive displacement machines, used for high-volume, low pressure applications.
- In scroll compressors, compression is achieved by two interfitting, spiral shaped scroll members. One of which is a fixed scroll and the other an orbiting scroll.
- Screw compressors are extremely suitable for large capacity low temperature applications such as in food refrigeration etc.

105. (d)

Given : T_L = –21°C = 252 K; T_H = 42°C = 315 K

$$\text{COP}_{max} = \text{COP}_{carnot} = \frac{T_L}{T_H - T_L} = \frac{252}{63}$$

$$\Rightarrow \quad \text{COP} = 4$$

$$\because \quad \text{COP} = \frac{RC}{P_{in}}$$

$$\Rightarrow \quad \text{RC} = 4 \times 1 = 4 \text{ kW}$$

or
$$\text{RC} = \frac{4}{3.5} = 1.14\,TR$$

106. (b)

The Seebeck effect is a phenomenon in which a temperature difference between two junction made by two dissimilar electrical conductors or semiconductors produces an emf between the junctions.

107. (c)

Leak detection in ammonia refrigeration systems:

The leak tendency of refrigerants should be nil. Also, the detention of a leak should be easy. The greatest drawback of fluorocarbons is the fact that they are odourless. This, at times, results in a complete loss of costly gas from leaks without being detected. An ammonia leak can be very easily detected by its pungent odour. Leaks in ammonia plants are very common due to the use of glands and lead gaskets in joints and due to corrosion.

108. (c)

$$(COP)_{cascade} = \frac{(COP)_1 \times (COP)_2}{(COP)_1 + (COP)_2 + 1}$$

Here $(COP)_1 = 7$ and $(COP)_2 = 8$

So, $$(COP)_{cascade} = \frac{7 \times 8}{7+8+1} = 3.5$$

109. (c)

A refrigerant should have low viscosity so that circulation is faster.

110. (d)

111. (b)

$$\text{Packing factor} = \frac{\text{True volume}}{\text{Bulk volume}} = \frac{\text{Bulk density}}{\text{True density}}$$

112. (c)

113. (c)

To produce bainite, the sample has to be quenched below the nose of TTT diagram but above martensite start line. The sample is then maintained at this temperature for substantial period of time till entire austenite converts into bainite.

114. (b)

- Leaded yellow brass: (29% Zn, 3% Pb 1%Sn. rest copper)- Furniture hardware, radio for fittings.
- Cartridge brass: (30% Zn, 70%Cu) Automative radiator cores, ammunition components, lamp fixtures, kickplates.
- Martensitic stainless steels-Riffle barrels, cutlery, jet engine parts.
- Compacted graphite iron-Diesel engine blocks, exhaust manifolds, gearbox housings, track discs for high speed trains and flywheels.

115. (c)

$$d \propto \sqrt{\frac{\rho}{\mu f}}$$

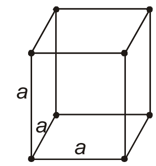
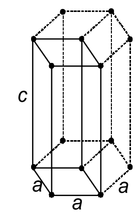
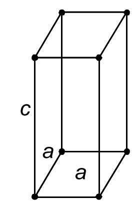
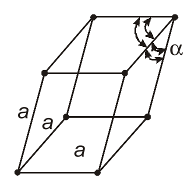
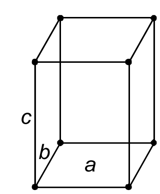
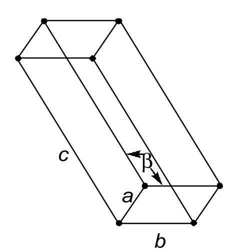
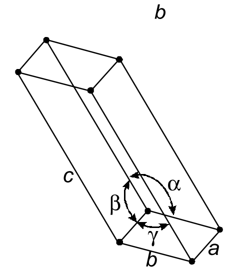
where, ρ = Resistivity; f = Frequency; μ = Magnetic permeability

Higher frequency leads to lower depth of hardening(d).

Magnetic permeability of steel decreases significantly as the temperature goes beyond Curie temperature. Therefore, there will be a sudden increases in depth of penetration '*d*' as the temperature goes beyond 750°C.

116. (a)

Bravais Lattices

Crystal system	Lattice parameters	Inter axial Angles Relationship	Unit Cell Geometry
Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90°$	
Hexagonal	$a = b \neq c$	$\alpha = \beta = 90°, \gamma = 120°$	
Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90°$	
Rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90°$	
Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90°$	
Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90° \neq \beta$	
Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90°$	

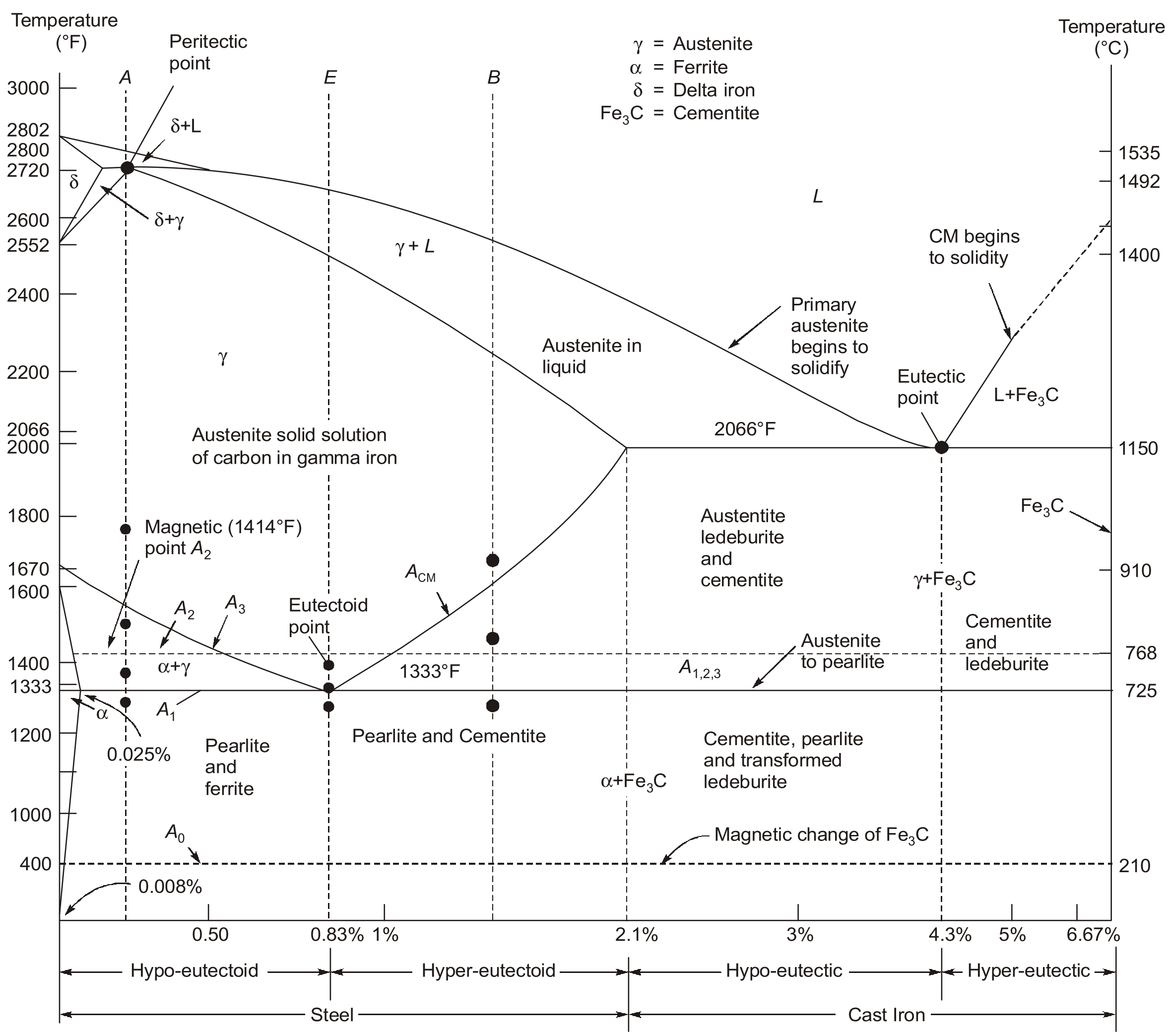
117. (c)

$Z = 4$ and $a = \dfrac{4R}{\sqrt{2}}$

$$\text{Density } (\rho) = \frac{\text{Mass}}{\text{Volume}} = \frac{zM}{VN_A}$$

$$= \frac{4(63.5)}{\left(\dfrac{4 \times 1.28 \times 10^{-8}}{\sqrt{2}}\right)^3 \times 6.023 \times 10^{23}} = 8.89 \text{ g/cm}^3$$

118. (a)



119. (b)

Materials are often placed in service at elevated temperatures and exposed to static mechanical stresses (e.g., turbine rotors in jet engines and steam generators that experience centrifugal stresses, and high-pressure steam lines). Deformation under such circumstances is termed creep. Defined as the time-dependent and permanent deformation of materials when subjected to a constant load or stress, creep is normally an undesirable phenomenon and is often the limiting factor in the lifetime of a part. It is observed in all materials types; for metals it becomes important only for temperatures greater than about $0.4T_m$ (T_m = absolute melting temperature).

120. (d)

Case hardening techniques harden the surface of metal (like low-carbon steel) while keeping the core tough, creating wear resistance, with methods like Carburizing (adding carbon via pack, liquid, or gas), Nitriding (adding nitrogen), Carbonitriding (adding both), and Cyaniding (also adding both), plus rapid heating methods like Flame & Induction Hardening, all aiming for a hard exterior and ductile interior for parts like gears and shafts.

Spheroidizing is a heat treatment for steels, especially high-carbon ones, that softens them by converting hard, layered cementite (iron carbide) into soft, dispersed, spherical particles (spheroids) within a ductile ferrite matrix, significantly improving machinability, ductility, and toughness for cold forming, achieved by prolonged heating just below the critical temperature.

121. (d)

Optical fibres : One new and advanced ceramic material that is critical component in our modern optical communications systems is the optical fiber. The optical fiber is made of extremely high purity silica, which must be free of even minute levels of contaminants and other defects that absorb, scatter and attenuate a light beam.

122. (c)

Elastic constants does not vary with the dimensions of object.

123. (a)

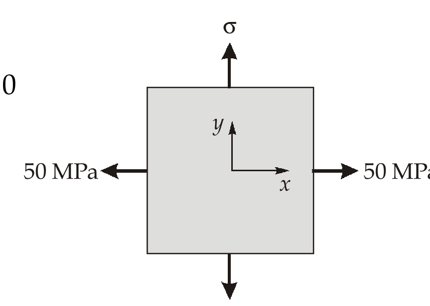
As we know,

$$E = 2G(1+\nu) \text{ and } \nu \in (0 \text{ to } 0.5)$$

For minimum value $\nu = 0$

and, $$E_{min} = 2G$$

124. (a)



$$\epsilon_v = \frac{\sigma_x+\sigma_y+\sigma_z}{E}(1-2\nu) = 0$$

$$\Rightarrow \quad \sigma_x + \sigma_y = 0$$

$$\Rightarrow \quad \sigma_y = -\sigma_x = -50 \text{ MPa}$$

$$\Rightarrow \quad \epsilon_y = \frac{\sigma_y}{E} - \nu\left(\frac{\sigma_x+\sigma_z}{E}\right)$$

$$= \frac{-50-0.25(50)}{200}\ \frac{\text{MPa}}{\text{GPa}}$$

$$= 0.3125 \times 10^{-3}$$

125. (d)

$$\sigma_1 = 4\sigma \text{ and } \sigma_2 = -\sigma$$

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{4\sigma - (-\sigma)}{2} = \frac{5}{2}\sigma$$

$$\tau_{pure} = \sqrt{-\sigma_1\sigma_2} = \sqrt{-(-\sigma)(4\sigma)} = 2\sigma$$

126. (b)

127. (b)

128. (b)

$$\in_x = \frac{1}{E}\left[\sigma_x - \nu\left(\sigma_y + \sigma_z\right)\right]$$

for plane stress condition $\sigma_z = 0$

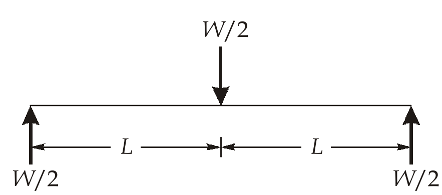
$$\in_x = \frac{1}{E}\left[\sigma_x - \nu\sigma_y\right] = \frac{1}{E}[\sigma - \nu(2\sigma)]$$

$$\in_x = \frac{\sigma}{E}[1 - 2\nu]$$

$$\frac{\sigma_x}{\in_x} = \frac{\sigma}{\in_x} = \frac{E}{1 - 2\nu}$$

129. (a)

The given condition can be represented

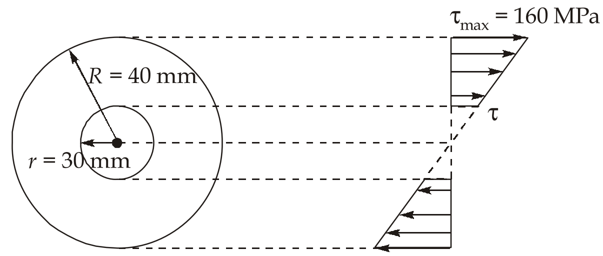


Deflection at the centre is given as

$$\delta = \frac{\left(\frac{W}{2}\right)(2L)^3}{48EI} = \frac{WL^3}{12EI}$$

$$\text{Strain energy} = \frac{1}{2}\times\left(\frac{W}{2}\right)\times\delta = \frac{1}{2}\times\left(\frac{W}{2}\right)\times\frac{WL^3}{12EI} = \frac{W^2L^3}{48EI}$$

130. (b)



$$\frac{\tau}{\tau_{max}} = \frac{r}{R}$$

$$\frac{\tau}{160} = \frac{30}{40}$$

$$\tau = 120 \text{ MPa}$$

131. (b)

$$\delta \text{ at } C = \delta \text{ due to } 2P(\delta_1) + \delta \text{ due to } P(\delta_2)$$

δ_1 due to $2P$ at C

$$\delta_1 = \frac{WL^3}{3EI} = \frac{2PL^3}{3EI}$$

δ_2 due to P at C

$$\delta_2 = \theta_B \times \frac{L}{2} + \delta_B$$

$$\delta_2 = \frac{P(L/2)^2}{2EI} \times \frac{L}{2} + \frac{P(L/2)^3}{3EI}$$

$$\delta_2 = \frac{PL^3}{16EI} + \frac{PL^3}{24EI} = \frac{(3+2)PL^3}{48EI} = \frac{5PL^3}{48EI}$$

$\therefore$
$$\delta \text{ at } C = \frac{2PL^3}{3EI} + \frac{5}{48}\frac{PL^3}{EI}$$

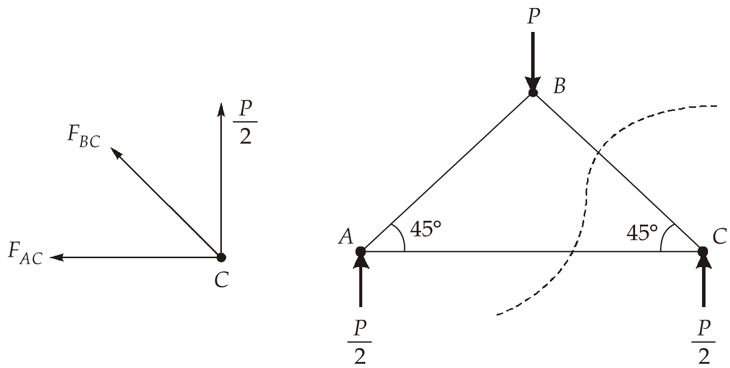
$$\delta_{\text{at } C} = \frac{37}{48}\frac{PL^3}{EI}$$

132. (b)

$$I_z = \frac{(2a)^4}{12} + \frac{(2a)^4}{12} - \frac{(a)^4}{12} - \frac{(a)^4}{12}$$

$$I_z = \frac{16a^4}{6} - \frac{a^4}{6} = \frac{15a^4}{6} = \frac{5a^4}{2}$$

133. (b)



For joint 'C'

$\Sigma F_y = 0$

$$\frac{P}{2} + F_{BC} \cdot \cos 45° = 0$$

$$F_{BC} = -\frac{P}{\sqrt{2}}$$

$\Sigma F_x = 0$

$$F_{BC} \cdot \cos 45° + F_{AC} = 0$$

$$-\frac{P}{\sqrt{2}} \cos 45° + F_{AC} = 0$$

$$F_{AC} = \frac{P}{2}$$

134. (c)

$$R = \frac{u^2 \sin 2\theta}{g} \text{ and } H_{max} = \frac{u^2 \sin^2 \theta}{2g}$$

$\because \quad R = 2\,H_{max}$

$$\frac{u^2 \sin 2\theta}{g} = 2 \times \frac{u^2 \sin^2 \theta}{2g}$$

$\Rightarrow$ $$\sin 2\theta = \sin^2\theta$$

$\Rightarrow$ $$2\sin\theta\cos\theta = \sin^2\theta$$

$\Rightarrow$ $$\tan\theta = 2$$

$$\theta = \tan^{-1}(2)$$

135. (d)

$$\vec{x} = (4 - 13t)\hat{i} + (3t^3 - 5t + 7)\hat{j}$$

$$\vec{V} = -13\hat{i} + (9t^2 - 5)\hat{j}$$

$$\vec{a} = 0\hat{i} + 18t\hat{j}$$

$$\vec{a}\Big|_{t=2s} = 18 \times 2 \text{ m/s}^2 = 36 \text{ m/s}^2$$

$$\vec{F}\Big|_{t=2s} = m\vec{a}\Big|_{t=2s} = 5 \times 36 = 180 \text{ N}$$

136. (b)

$$H_{\text{Pelton}} > H_{\text{Francis}} > H_{\text{Kaplan}}$$

and

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}; [M^{1/2}L^{1/4}T^{-5/2}]$$

$$N_{\text{Pelton}} < N_{\text{Francis}} < N_{\text{Kaplan}}$$

137. (d)

Advantages of pulse jet

(i) This is a very simple device next to ramjet and is light in weight. It requires very small and occasional maintenance.

(ii) Unlike ramjet, it has static thrust because of the compressed air starting; thus it does not need a device for initial propulsion. The static thrust is even more than the cruise thrust.

(iii) It can run on almost any types of liquid fuels without much effect on the performance. It can also operate on gaseous fuel with a little modifications.

(iv) Pulse jet engine is relatively cheap.

138. (b)

Extraction of steam from turbine for the purpose of heating feed water before it enters the boiler is known as bleeding.

139. (c)

Guide vanes or wicket gates: A series of airfoil shaped vanes, called the guide vanes or wicket gates, are arranged inside the casing to form a number of flow passages between the casing and the runner blades. The guide vanes direct the water onto the runner at an angle appropriate to the design. They direct the flow just as the nozzle of the Pelton wheel. The configuration and arrangement of the guide vanes is such that the energy of water is not consumed by eddies and other undesirable flow phenomenon causing energy losses.

140. (c)

1. Rateau turbine is pressure compounded impulse turbine.
2. Curtis turbine is velocity compounded impulse turbine.
3. Two row wheel curtis is more efficient than 3 row wheel curtis turbine.

141. (b)

Centrifugal effects of the curved blades create a bending moment and produce increased stresses which reduce the maximum speed at which the impeller can be run. Good performance can be obtained with radial impeller blades. Backward-curved blades are slightly better in efficiency and are stable over a wider range of flows than either radial or forward-curved blades. The forward-curved impeller can produce the highest pressure ratio for a given blade tip speed; but is inherently less stable and has a narrow operating range. Its efficiencies are lower than that are possible with the backward-curved or radial-curved blades.

142. (a)

In EDM process, there is material removal from both the electrodes-anode as well as cathode but MRR at anode is much higher than at cathode. This is because of high velocity 'Cold Emitted' electrons impinging on the anode surface in an instant, creating huge amount of energy that causes melting / instant vaporization of the anodic material. Since we need to protect our tool from this amount of material removal for extended life, we keep the tool at cathode and workpiece at anode.

143. (b)

The number of properties required to fix the state of a system is given by the state postulate.

- The state of a simple compressible system is completely specified by two independent, intensive properties.
- A system is called a simple compressible system in the absence of electrical, magnetic, gravitational, motion and surface tension effects.

144. (c)

- Cost of hydrostatic bearing is more than that of rolling contact bearing because hydrostatic bearing requires additional accessories like pump, filter and pipe lines.
- As in hydrodynamic bearing initially there will be metal to metal contact so in this starting torque will be more than in rolling contact bearing.

145. (d)

The endurance limit, in the true sense, is not a property of material because it gets affected by factor like size of component, temperature, surface finish, shape etc.

146. (d)

It becomes difficult to compress water with increasing pressure. Bulk modulus of elasticity of liquids generally increases with increasing pressure hence compressibility decreases with increase in pressure.

147. (a)

Use of air preheater increases steam power plant efficiency. Function of air preheater is to preheat the air before entering to the furnace by utilizing some of the energy left in the flue gases before exhaust.

148. (a)

For engines with sufficiently low level of emission of oxides of nitrogen, only a single converter to oxidize carbon monoxide and hydrocarbons may be used. In order to get an efficient oxidation of CO and HC, it is necessary that exhaust gases have sufficient oxygen with them, which is in general not found, particularly when an engine operates on a rich air-fuel mixture. Hence, secondary air is injected in the stream of exhaust gas before the catalytic converter.

149. (c)

- Good heat conduction and high thermal energy storage (high specific heat) are independent properties.
- The thermal conductivity for water is 0.607 W/m-K and for iron is 80.2 W/m-K, at room temperature. It indicates iron conducts heat more than 100 times faster than water . Thus we can say that, water is a poor heat conductor relative to iron, although water is an excellent medium to store thermal energy.

150. (b)