DETAILED SOLUTIONS

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ESE 2026 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

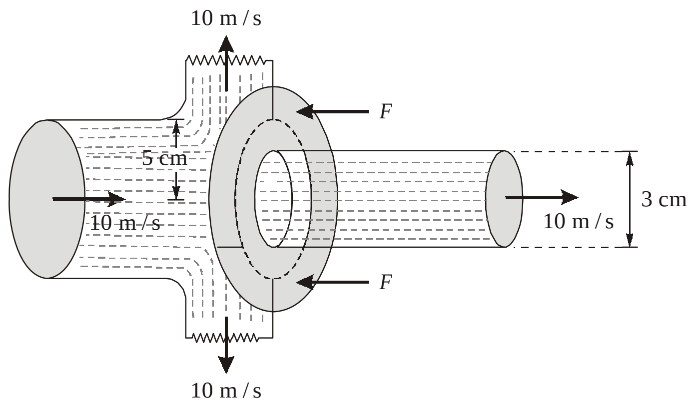
Test 20

Full Syllabus Test 4 : Paper-II

Answer Key

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

1. (b)



$$F = (\dot{m}_{strike})(V_2 - V_1) = (\rho_w)(A_{strike})(V_{relative})(0 - V)$$

$$= (1000)\left[\pi\left(5^2 - 3^2\right) \times 10^{-4}\right](10)(-10)$$

$$= -10\pi\ (4^2) = -160\ \pi\ \text{N} \simeq -502.65\ \text{N}$$

2. (c)

Hydraulic efficiency of pelton wheel $= 2\left(\frac{u}{v}\right)\left(1 - \frac{u}{v}\right)(1 + k\cos\alpha)$

$$\frac{\partial \eta}{\partial u} = 0 \text{ at maximum efficiency}$$

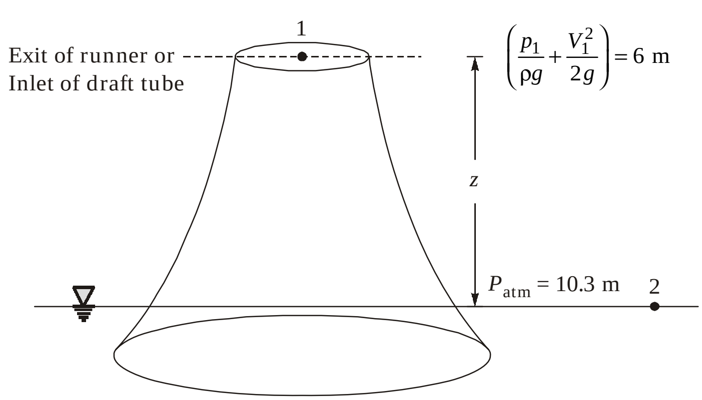
$$2(1 + k\cos\alpha)\left[\left(\frac{1}{v}\right)\left(1 - \frac{u}{v}\right) + \left(-\frac{1}{v}\right)\left(\frac{u}{v}\right)\right] = 0$$

$\Rightarrow$ $(v - u) = u$

$\Rightarrow$ $v = 2u$

$\Rightarrow$ $\frac{v}{u} = 2$

3. (b)



Applying Bernoulli's theorem between 1 and 2

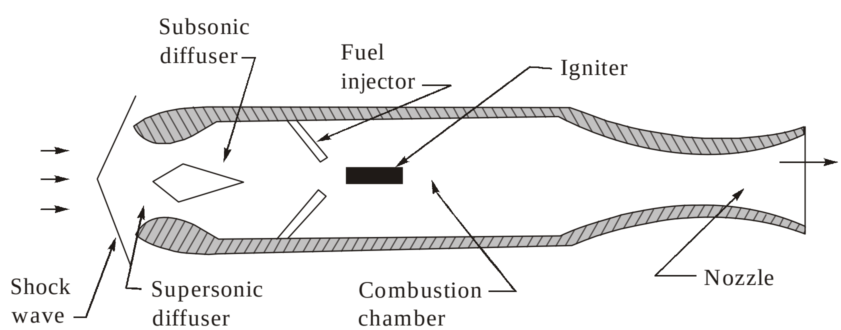
$$\left(\frac{p_1}{\rho g}+\frac{V_1^2}{2g}\right)+z = \frac{p_2}{\rho g}+\frac{V_2^2}{2g}$$

$$\Rightarrow \quad 6 + z = 10.3 + 0$$

$$\Rightarrow \quad z = 10.3 - 6 = 4.3 \text{ m}$$

4. (a)

(i) Supersonic diffuser (1 – 2),
(ii) Subsonic diffuser section (2 – 3),
(iii) Combustion chamber (3 – 4), and
(iv) Discharge nozzle section (4 – 5).



5. (d)

$$E_T = V_{w_1}u_1 - V_{w_2}u_2 \quad \text{...(i)}$$

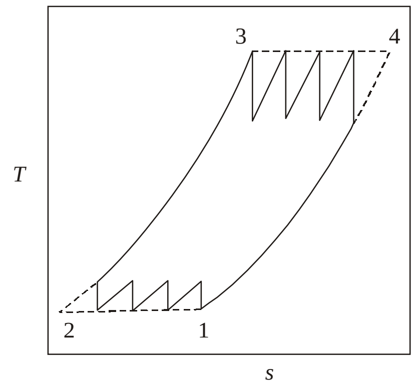
$$E_C = V_{w_2}u_2 - V_{w_1}u_1 \quad \text{...(ii)}$$

Equations (i) and (ii) can be used freely for any type of turbine or compressor respectively which satisfy the following few conditions.

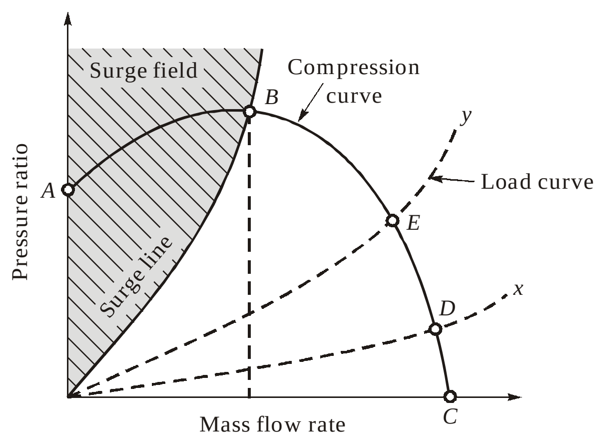
(i) The flow must be steady, i.e., there should not be any change in angular velocity, flow rate, fluid properties and heat transfer rate with respect to time.
(ii) The relationship applies strictly to every infinitesimal stream line, i.e., if the velocity is not uniform over the inlet and exit areas then an integration over each area must be done.
(iii) There should not be any discontinuity of pressure, i.e., a choked nozzle at the rotor discharge.

6. (c)

A discussion of ideal cycles for the gas turbine would not be complete without some reference to the theoretical cycle of Ericsson. In introducing multi-stage compression with intercooling, and multistage expansion with reheating, it is immediately seen from the *T-s* diagram that an approach is being made towards isothermal processes. This would, of course, be achieved only if the number of stages were infinite. In this case, the cycle would follow the outline 1234 given in figure below.

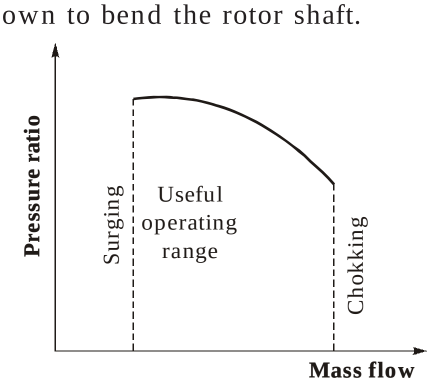


7. (c)



Surging

Surging is an unstable limit of operation of both centrifugal and axial flow compressors. Surging is caused due to unsteady, periodic and reversal of flow through the compressor when the compressor has to operate at less mass flow rate than a predetermined value (value corresponding to maximum pressure, at a particular speed). As the flow is drastically reduced than this predetermined value, this surge can reach such a magnitude as to endanger the compressor and in many cases mechanical failures may result. The alternating stresses to which the rotor of the machine is subjected during this irregular working condition, may damage the compressor bearings, rotor bladings and seals. Severe surges have been known to bend the rotor shaft.



Theoretically, the mass flow rate becomes maximum when the pressure ratio is unity i.e. there is no compression. This generally occurs when the Mach number corresponding to the relative velocity at inlet becomes sonic. Under this condition, the mass flow rate possible from a centrifugal or axial flow compressor becomes maximum which is known as choking flow. Choking means fixed mass flow rate regardless of pressure, i.e. the characteristics becomes vertical.

8. (d)

Radial entry $\Rightarrow$ $\alpha_1 = 90°$

Forward entry $\Rightarrow$ $\beta_2 > 90°$

9. (c)

Nickel alloys have also been developed extensively and are currently being used for turbines. These alloys have superior strength and oxidation resistance even though nickel by itself has poor oxidation resistance. This weakness is overcome by alloying with chromium. In alloys, chromium is generally 15–30% and forms chromium oxide (Cr_2O_3) a protective layer and chromium carbide. Other elements generally added are aluminium, titanium and niobium to improve the strength at high temperatures. Current alloys also use cobalt, hafnium, boron, zirconia, molybdenum etc., Nimonic 118 the most advanced alloy developed has working capacity approximately upto 925°C and has composition 9.0% (Ti + Al + Nb), 3.5% Mo, 14.8%Cr, 14.9% Cobalt. For working with nickel alloys it is necessary to use vacuum melting techniques to encourage the use of hardened metals and reduce trace elements which affect the ductility.

10. (b)

Water Hammer : Like hydroelectric plants where the flow of water in a pipeline is required to be decreased suddenly by manipulating a valve downstream. This causes a phenomenon like knocking of the pipe system due to repeated up and down motion of a pressure wave within the pipe. It is also our common experience that when a domestic water tap is turned off very quickly, a heavy knocking sound is heard and the entire pipe vibrates. This typical phenomenon is known as water hammer. The name is perhaps a little unfortunate because, not only water, but any liquid in a pipe under such situation will cause the phenomenon of water hammer.

11. (a)

Geneva mechanism : Produces intermittent rotary motion from continuous rotary motion.

Exact straight line motion : Peaucellier, Hart mechanism, Scott-Russel mechanism, Kempe mechanism etc.

Approximate straight line mechanisms : Modified Scott-Russel mechanism, Watt mechanism, Tchebicheff mechanism etc.

Oscillating cylinder engine : Piston reciprocates in the oscillating cylinder.

12. (c)

- An inertia governor is based on the principle of inertia of matter and is operated by the acceleration or deceleration of the rotating masses in addition to centrifugal forces.
- In an inertia governor, when the acceleration or deceleration is very small or the change in velocity is very slow, the additional inertia force is practically zero and an inertia governor in effect, becomes a centrifugal governor.

13. (c)

A governor is said to be isochronous when the equilibrium speed is constant for all radii of rotation of the balls within the working range.

For Porter governor, $$\omega_1^2 = \left(\frac{g}{\omega h_1}\right)\left[\omega + \left(\frac{W}{2}\right)\left(1+\frac{h_1}{l}\right)\right]$$

For isochronism, $$N_{max} = N_{min}$$

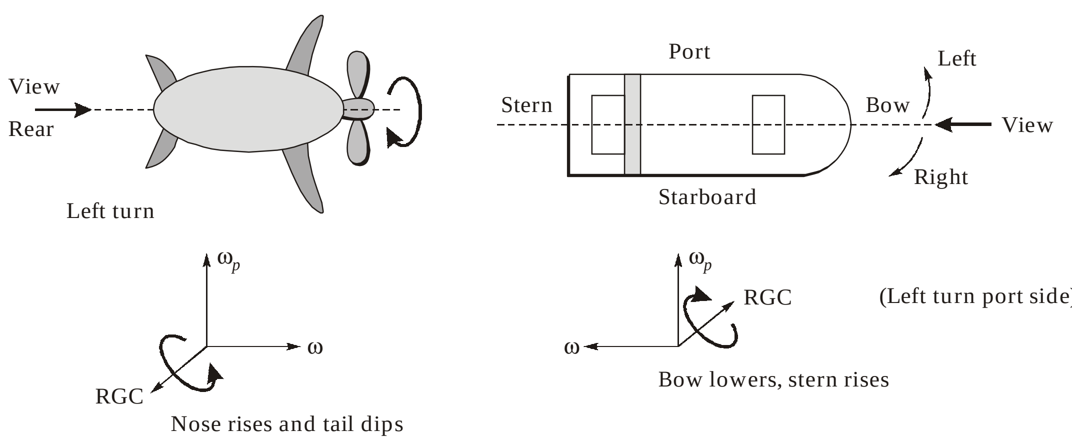
$$\Rightarrow \quad h_2 = h_1$$

which is not possible for porter governor and other pendulum type governors

For Hartnell governor, $$W + s_1 = 2F_{c_1}\frac{a}{b} = 2\left(\frac{\omega}{g}\right)(2\pi N_{min})^2 r_1 \frac{a}{b}$$

Therefore, a Hartnell governor can be isochronous.

14. (c)



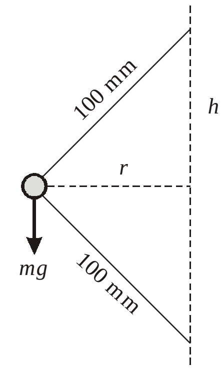
15. (c)

- For an overdamped system, the system does not oscillate and mass moves back slowly to the equilibrium position.
- At resonance, the amplitude of vibration depends on frequency and it will be very large only in the case of frequency becomes equal to the natural frequency.
- The ratio of magnitude of the steady state response to the static deflection under the action of force.

$$MF = \frac{\dfrac{F_0}{\sqrt{(s-\omega^2)^2 + (c\,\omega)^2}}}{\dfrac{F_0}{s}} = \frac{s}{\sqrt{(s-m\omega^2)^2 + (c\,\omega)^2}}$$

16. (b)

Given : r_1 = 60 mm; r_2 = 80 mm



$$h_1 = \sqrt{100^2 - 60^2} = 80 \text{ mm}$$

$$h_2 = \sqrt{100^2 - 80^2} = 60 \text{ mm}$$

$$\because \quad N^2 = \frac{895}{h}\left(\frac{m+M}{m}\right)$$

$$\therefore \quad N \propto \frac{1}{\sqrt{h}}$$

$$\frac{N_{max}}{N_{min}} = \sqrt{\frac{80}{60}} = \sqrt{\frac{4}{3}} = \frac{2}{\sqrt{3}}$$

17. (b)

In a positive-drive cam, constant touch between the cam and the follower is maintained by a roller follower operating in a groove of a cam or a conjugate cam, thus maintaining continuous contact mechanically.

18. (d)

Given : m = 60 kg; $N = \frac{600}{\pi}$ rpm ; $\varepsilon = \frac{1}{24}$

$$\omega = \frac{2\pi}{60} \times \frac{600}{\pi} = 20 \text{ rad/s}$$

$$\because \quad \varepsilon = \frac{1}{\left(\frac{\omega}{\omega_n}\right)^2 - 1} \qquad \{\because \xi = 0\}$$

$$\Rightarrow \quad \left(\frac{\omega}{\omega_n}\right)^2 = \frac{1}{\varepsilon} + 1 = 25$$

$$\Rightarrow \quad \frac{\omega}{\omega_n} = 5$$

$$\Rightarrow \quad \omega_n = \frac{\omega}{5} = \frac{20}{5} = 4 \text{ rad/s}$$

Also
$$\omega_n = \sqrt{\frac{s}{m}} = 4$$

$$\Rightarrow \quad \sqrt{\frac{s}{60}} = 4$$

$$\Rightarrow \quad s = 60 \times 16$$

$$\Rightarrow \quad s = 960 \text{ N/m}$$

19. (d)

Given : σ_x = 50 MPa; σ_y = 20 MPa; τ_{xy} = 8 MPa

$$\text{Principal stress, } \sigma_{1,2} = \left(\frac{\sigma_x + \sigma_y}{2}\right) \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \left(\frac{50+20}{2}\right) \pm \sqrt{\left(\frac{50-20}{2}\right)^2 + 8^2}$$

$$= 35 \pm \sqrt{15^2 + 8^2} = 35 \pm 17$$

$\Rightarrow$ σ_1 = 52 MPa and σ_2 = 18 MPa

$$\text{Maximum in-plane shear stress} = \frac{\sigma_1 - \sigma_2}{2} = \frac{52-18}{2} = 17 \text{ MPa}$$

$$\text{Maximum absolute shear stress} = \max\left\{\left|\frac{\sigma_1 - \sigma_2}{2}\right|, \left|\frac{\sigma_2 - \sigma_3}{2}\right|, \left|\frac{\sigma_3 - \sigma_1}{2}\right|\right\}$$

$$= \frac{\sigma_1}{2} = \frac{52}{2} = 26 \text{ MPa}$$

20. (c)

Given : F = 60 kN; τ_{max} = 4 MPa; b = 300 mm

For a rectangular cross-section beam

$$\tau_{max} = \frac{3}{2}\tau_{avg}$$

$$\tau_{max} = \frac{3}{2} \times \frac{F}{A}$$

$$4 = \frac{3}{2} \times \frac{(60 \times 10^3)}{(300 \times d)}$$

$$\Rightarrow \quad d = \frac{3}{2} \times \frac{60 \times 10^3}{300 \times 4} = 75 \text{ mm}$$

21. (c)

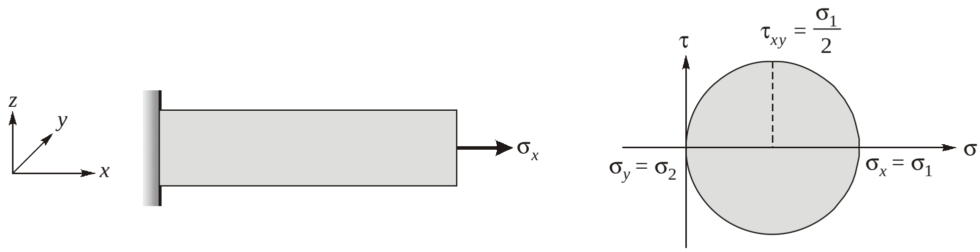
Given : L = 400 mm; σ = 200 MPa; E = 75 GPa

$$\text{The elongation in the rod,} \quad \delta = \frac{\sigma L}{E} = \frac{200 \times 400}{(75 \times 10^3)}$$

$$= 1.06666 \text{ mm} \simeq 1.067 \text{ mm}$$

22. (c)

When a shaft is subjected to pure axial tensile load (P)



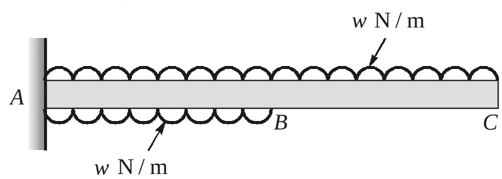
$$\sigma_x = \frac{P}{A};\ \sigma_2 = \sigma_3 = 0;\ \sigma_1 = \sigma_x = \text{largest principal stress}$$

$$\tau_{xy} = \tau_{xz} = \frac{\sigma_1}{2} = \text{maximum shear stress}$$

Hence, $$\frac{\text{largest principal stress}}{\text{maximum shear stress}} = 2$$

23. (a)

The above beam can be equivalently drawn like



∴ Deflection of beam due of upper udl,

$$\delta_1 = \frac{wL^4}{8EI}(\downarrow)$$

Deflection of beam due to lower udl,

$$\delta_2 = \frac{w(L/2)^4}{8EI} + \frac{w(L/2)^3}{6EI} \times \frac{L}{2} = \frac{7wL^4}{384EI}(\uparrow)$$

The deflection at the free end,

$$\delta_c = \delta_1 - \delta_2 = \frac{wL^4}{8EI} - \frac{7wL^4}{384EI} = \frac{41wL^4}{384EI}$$

∴ $$\alpha = \frac{41}{384}$$

24. (c)

Modulus of elasticity, $$\delta L = \frac{PL}{AE}$$

or, $$E = \frac{PL}{A \times \delta L} = \frac{50 \times 10^3 \times 200}{\frac{\pi}{4} \times (30)^2 \times 0.08} = 176.838 \text{ GPa}$$

$$\text{Poisson's ratio, } \mu = -\frac{\delta d / d}{\delta L / l} = \frac{0.004/30}{0.08/200} = 0.33$$

$$\therefore \quad \text{Modulus of rigidity, } E = 2G(1 + \mu)$$

$$\Rightarrow \quad G = \frac{E}{2(1+\mu)} = \frac{176.838}{2 \times 1.33} = 66.48 \text{ GPa}$$

25. (d)

Given : $F = 100$ N; $l = 5$ cm $= 0.05$ m; $a = 2$ cm $= 0.02$ m

The axial normal compression at point P,

$$\sigma_P = \text{(Compressive stress due to bending moment)} - \text{(Tensile stress due to axial tension)}$$

$$= \left[\frac{F \times l}{\left(\frac{a^4}{12}\right)} \times \frac{a}{2}\right] - \left[\frac{F}{a^2}\right]$$

$$= \frac{F}{a^3}(6l - a) = \frac{100}{(0.02)^3} \times (6 \times 0.05 - 0.02)$$

$$= 3.5 \times 10^6 \text{ Pa} = 3500 \text{ kPa}$$

26. (a)

Given : $L = 2$ m; $a = 20$ mm; $b = 40$ mm

For a column with one end fixed and other end free, the effective length of the column is given as

$$L_e = \frac{L}{\sqrt{2}} = \frac{2}{\sqrt{2}} = \sqrt{2} \text{ m}$$

$$\text{Slenderness ratio, } S = \frac{L_e}{\sqrt{\frac{I_{min}}{A}}} = \frac{L_e}{\left(\frac{\frac{1}{12} \times a^3 \times b}{a \times b}\right)^{1/2}}$$

$$= \frac{\sqrt{2} \times 1000}{\left(\frac{\frac{1}{12} \times 20^3 \times 40}{20 \times 40}\right)^{1/2}} = \left(\frac{2 \times 12}{20^2}\right)^{1/2} \times 1000$$

$$= 244.9489 = 244.95$$

27. (d)

The maximum shear stress in case of triangular cross-section is $\frac{3}{2}$ times the average shear stress and it occurs at a height of $\frac{h}{2}$ from the base.

28. (b)

Air-fuel ratio is given by

$$\frac{A}{F} = \frac{\dot{m}_a}{\dot{m}_f}$$

or $$\dot{m}_f = \frac{60}{80} = 0.75 \text{ kg/s}$$

$$\text{Thrust produced, } F_T = \dot{m}_a\left(V_{jet} - V_a\right)$$

$$= 60\left(620 - \frac{1000 \times 1000}{3600}\right) = 20533.33 \text{ N}$$

$$\therefore \quad \text{Thrust SFC} = \frac{\text{Fuel-flow rate}}{\text{Thrust produced}}$$

$$= \frac{0.75}{20533.33} = 3.65 \times 10^{-5} \text{ kg/Ns}$$

29. (c)

For perfect intercooling, $$\frac{P_2}{P_1} = \left(\frac{P_4}{P_1}\right)^{1/3}$$

or $$P_2 = 20 \times \left(\frac{20000}{20}\right)^{1/3} = 200 \text{ kPa}$$

30. (a)

Given : P = 11.56 kPa; P_{atm} = 100 kPa; P_{sat} = 7.4 kPa; v_a = 19.5 m^3/kg

The partial pressure of air is $P_a = P - P_{sat} = 11.56 - 7.4 = 4.16$ kPa

Volume of air/kg of steam = Specific volume of steam at 40°C

$$\therefore \quad v_a = 19.5 \text{ m}^3\text{/kg of steam}$$

$$\therefore \quad \text{The mass of air, } m_a = \frac{P_a v_a}{R_a T_{sat}} = \frac{4.16 \times 19.5}{0.287 \times (40 + 273)}$$

$$\therefore \quad \dot{m}_a = 0.903 \text{ kg/kg of steam}$$

31. (d)

32. (c)

33. (d)

Salient features of Cochran boiler are:

1. The spherical crown and spherical shape of a fire box are the special features of this boiler. These shapes require least material for a given volume.
2. It is very compact and requires minimum floor area.
3. Any type of fuel can burn in the boiler.

4. It is well suited for small industries.
5. It gives about 70% thermal efficiency with coal firing.

34. (c)

35. (d)

A good fuel should have the following qualities:

(i) It should have a high heating value.
(ii) It should be free from moisture and non-combustible matter, i.e. ash, etc.
(iii) It should have high combustion efficiency.
(iv) It should have moderate ignition temperature. High ignition temperature may cause difficulty in combustion and low ignition temperature may cause fire hazards.
(v) It should be easy to transport and store in minimum space.
(vi) It should have moderate rate of combustion and controlled combustion.

36. (d)

Advantages of reheating:

(i) Erosion and corrosion problems in the steam turbine are avoided.
(ii) The output of the turbine is increased.
(iii) The thermal efficiency is increased due to increase in mean temperature of heat addition. A gain of 4 to 7% of thermal efficiency over an equivalent non-reheat cycle is possible. The gain in the thermal efficiency due to single stage reheating.
(iv) Final dryness fraction in increased.
(v) Nozzle and blade efficiencies are increased.

Disadvantage:

(i) Relative to the expenditure incurred in reheating, the thermal efficiency does not increase appreciably.

37. (d)

38. (d)

Impulse turbine compounding methods:

a. **Velocity compounding (Curtis stage)** → Single pressure drop in one nozzle, multiple moving blades for velocity reduction.
b. **Pressure compounding (Rateau stage)** → Total pressure drop divided among several stages ? pressure drops in nozzles, moving blades only redirect flow.
c. **Velocity-pressure compounding (Parsons stage)** → Combination of above

39. (c)

40. (a)

For impulse turbine,
$$\frac{u}{V_1} = \frac{\cos\alpha}{2}$$
$$\frac{V_1^2}{2} = (\Delta h)_{\text{stage}}$$

$$V_1^2 = 2(\Delta h)_{stage}$$

$$V_1 = \sqrt{2(\Delta h)_{stage}} = \frac{2u}{\cos\alpha} = \sqrt{2(\Delta h)_{stage}}$$

$$\frac{4u^2}{\cos^2\alpha} = 2(\Delta h)_{stage}$$

$$(\Delta h)_{stage} = \frac{2u^2}{\cos^2\alpha}$$

41. (d)

For plane truss the force system acting at each hinge joint is concurrent and coplanar.

42. (d)

Given : s_1 = 100 m, t_1 = 5s, s_2 = (100 + 700) = 800 m, t_2 = 5 + 5 = 10s

Under uniform acceleration,

$$s = ut + \frac{1}{2}at^2$$

$$\Rightarrow \quad 100 = 5u + \frac{1}{2}a(5)^2 \quad \text{...(i)}$$

and,

$$800 = 10u + \frac{1}{2}a(10)^2 \quad \text{...(ii)}$$

On solving equation (i) and (ii);

$$800 - 100 \times 2 = \frac{1}{2}a\left(10^2 - 5^2 \times 2\right)$$

$$\Rightarrow \quad a = \frac{800 - 200}{\frac{1}{2}\times\left(10^2 - 5^2 \times 2\right)} = 24 \text{ m/s}^2$$

43. (c)

Given : m = 0.4 kg; F_{avg} = 80 N; $t = 20 \times 10^{-3}$s, u = 0, v = ?

Force is given as the rate of change of linear momentum, so

$$F_{avg} = \frac{mv - mu}{t}$$

$$\Rightarrow \quad 80 = \frac{0.4 \times v - 0.4 \times 0}{20 \times 10^{-3}}$$

$$\Rightarrow \quad v = \frac{80 \times 20 \times 10^{-3}}{0.4} = 4 \text{ m/s}$$

44. (a)

Given:Velocity of first particle, u_1 = 10 m/s

Angle of projection for first particle, $\alpha_1 = 60°$

Angle of projection for second particle, $\alpha_2 = 30°$

Velocity of second particle, $u_2 = ?$

Given, Time of flight is same.

$$t_1 = t_2$$

$$\frac{2u_1 \sin\alpha_1}{g} = \left(\frac{2u_2 \sin\alpha_2}{g}\right)$$

$$u_2 = \frac{10 \times \sin 60°}{(\sin 30°)} = \frac{10 \times \frac{\sqrt{3}}{2}}{\frac{1}{2}} = 10 \times \sqrt{3}$$

$$u_2 = 17.32 \text{ m/s}$$

45. (d)

Given : $\sigma_a = 60$ MPa, $\sigma_m = 0$; $\sigma_{ut} = 400$ MPa; $\sigma_e = 240$ MPa; $\sigma_{yt} = 300$ MPa

Using Langer (Yield line) criteria

$$\frac{\sigma_m}{\sigma_{yt}} + \frac{\sigma_a}{\sigma_{yt}} = \frac{1}{N}$$

$$\Rightarrow \quad \frac{60}{300} = \frac{1}{N}$$

$$\Rightarrow \quad N = 5$$

46. (c)

Given : $P = 900$ N; $\delta = 5$ mm; $d = 10$ mm; $D = 50$ mm; $G = 81 \times 10^3$ N/mm^2

We know that, $$\delta = \frac{8PD^3 n}{Gd^4}$$

$$\Rightarrow \quad 5 = \frac{8 \times 900 \times 50^3 \times n}{81 \times 10^3 \times 10^4}$$

$$\Rightarrow \quad n = 4.5 \simeq 5$$

For square and ground ends springs,

$$N_t = n + 2 = 5 + 2 = 7$$

47. (d)

Given : $c = 6$

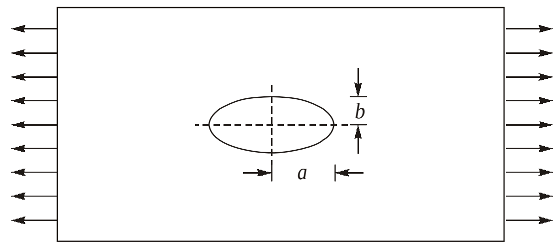
We know that, $$k_w = \frac{4c-1}{4c-4} + \frac{0.615}{c}$$

$$= \frac{23}{20} + \frac{0.615}{6}$$

$$\Rightarrow \quad k_w = 1.15 + 0.1025 = 1.2525$$

48. (a)

Given : $\frac{a}{b} = 2$



$$k_t = 1 + 2\left(\frac{b}{a}\right) = 1 + 2\left(\frac{1}{2}\right) = 2$$

49. (c)

Let $P_1 = P$, $P_2 = 2P$

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

$\Rightarrow$
$$L_{10} \propto \frac{1}{P^3}$$

$$\frac{L_2}{L_1} = \left(\frac{P_1}{P_2}\right)^3 = \left(\frac{1}{2}\right)^3 = \frac{1}{8}$$

$\Rightarrow$
$$1 - \frac{L_2}{L_1} = \frac{7}{8}$$

$\Rightarrow$
$$\left(\frac{L_1 - L_2}{L_1}\right) \times 100 = \frac{7}{8} \times 100 = 87.5\%$$

50. (c)

Given : $R_i = 100$ mm; $R_o = 200$ mm

$$T = \mu W \bar{R}$$

According to UPT,
$$\bar{R} = \frac{2}{3}\left(\frac{R_o^3 - R_i^3}{R_o^2 - R_i^2}\right) = \frac{1400}{9} \text{ mm}$$

and according to UWT,
$$\bar{R} = \frac{R_o + R_i}{2} = 150 \text{ mm}$$

$\therefore$
$$\frac{T_{UPT}}{T_{UWT}} = \frac{(\bar{R})_{UPT}}{(\bar{R})_{UWT}} = \frac{1400}{9 \times 150}$$

$$= \frac{28}{27} = 1.037$$

51. (d)

A typical analysis of bolt failures indicate that,

(i) 15% failures occur at the fillet under the head.

(ii) 20% failures of bolt occur at the end of threads on the shank.

(iii) 65% failures of bolt occur in the threads that are in contact with the nut.

52. (a)

Given : P_s = 300 kN; P_t = 250 kN; P_c = 315 kN; P = 350 kN

$$\eta = \frac{\text{Minimum of } P_s, P_t, P_c}{P} \times 100$$

$$= \frac{250}{350} \times 100 = 71.4\%$$

53. (c)

Given : $(\sigma_t)_{per}$ = 80 MPa; D = 2 m; t = 10 mm

$$\text{Tensile load} = \sigma_t \times (lt)$$

$$\text{Length of weld, } l = \pi D = 2\pi \text{ m}$$

$$(P_t)_{max} = 80 \times \left(\pi \times 2 \times 10^3 \times 10\right)$$

$$= 5026.5 \times 10^3 \text{ N} = 5026.5 \text{ kN}$$

54. (d)

- Cylindrical roller bearing cannot take thrust load.
- Angular contact bearing can take radial and thrust loads.
- Taper bearing (taper roller bearing) can carry both radial and axial loads.
- Self-aligning bearing permit minor angular misalignment of the shaft relative to the housing.
- Thrust ball bearing carry thrust load in only one direction and cannot carry any radial load.

55. (c)

The theory of hydrodynamic lubrication is based on a differential equation derived by Reynolds: This equation is based on the following assumptions:

1. The lubricant obeys Newton's law of viscosity.
2. The lubricant is incompressible.
3. The inertia forces in the oil film are negligible.
4. The viscosity of lubricant is constant.
5. The effect of curvature of the film with respect to film thickness is neglected. It is assumed that the film is so thin that the pressure constant across the film thickness.
6. The shaft and the bearing are rigid.
7. There is a continuous supply of lubricant.

56. (d)

Given : I = 150 kg-m^2, t = 2s, ω_1 = 36 rad/s, ω_2 = 0

Energy absorbed by brake = Kinetic energy of flywheel

$$E = \frac{1}{2} I\left(\omega_1^2 - \omega_2^2\right)$$

$\Rightarrow$
$$E = \frac{1}{2} \times 150 \times \left(36^2 - 0\right)$$
$$= 97200 \text{ J} = 97.2 \text{ kJ}$$

57. (c)

Given : I = 150 kg-m^2, t = 2s, ω_1 = 36 rad / s, ω_2 = 0

$$\text{Average angular velocity} = \frac{(\omega_1 + \omega_2)}{2} = 18 \text{ rad/s}$$

$$\theta = \left(\frac{\omega_1}{2}\right)t = 36 \text{ rad}$$

$$T = \frac{E}{\theta} = \frac{97200}{36} = 2700 \text{ Nm}$$

58. (c)

Given : h = 15 W / m^2°C, d_o = 10 mm; k = 0.12 W / m°C

$$r_c = \frac{k}{h} = \frac{0.12}{15} = 0.008 \text{ m} = 8 \text{ mm}$$

$$r_o = \frac{d_o}{2} = 5 \text{ mm}$$

$$t_c = r_c - r_o = 3 \text{ mm}$$

59. (c)

Given : T_s = 476.8 K; T_∞ = 35°C = 308 K; L = 0.5 m; Pr = 0.8; $\nu = 2 \times 10^{-5}$ m^2/s

$$T_f = \frac{T_s + T_\infty}{2} = 392.4 \text{ K}$$

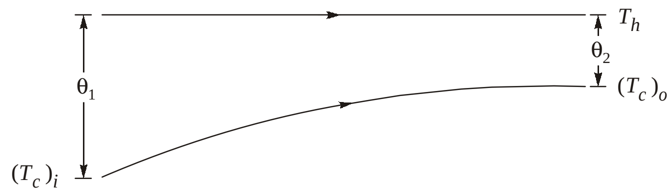
$$\beta = \frac{1}{T_f} = \frac{1}{392.4}$$

$\therefore$
$$Ra_L = \frac{g\beta\Delta T L^3 \text{ Pr}}{\nu^2}$$

$$= \frac{9.81 \times 168.8 \times (0.5)^3 \times 0.8}{(2 \times 10^{-5})^2 \times 392.4} = 1.055 \times 10^9$$

60. (c)

Given : $\left(T_{h_i}\right)_i = \left(T_{h_o}\right) = 40°\text{C}$; $\left(T_c\right)_i = 20°\text{C}$, $\left(T_c\right)_o = 30°\text{C}$



$$\theta_1 = 40 - 20 = 20°\text{C};\ \theta_2 = 40 - 30 = 10°\text{C}$$

$$\text{LMTD} = \frac{\theta_1 - \theta_2}{\ln\left(\frac{\theta_1}{\theta_2}\right)} = \frac{20 - 10}{\ln(2)} = 14.43°\text{C}$$

61. (a)

Given : $k_2 = 2k_1$, $\left(\frac{P}{A_c}\right)_2 = \frac{1}{2}\left(\frac{P}{A_c}\right)_1$

We know that,

$$\in_{\text{long fin}} = \sqrt{\frac{kP}{hA_c}}$$

$$\therefore \quad \frac{\in_2}{\in_1} = \frac{\left(\sqrt{\frac{kP}{hA_c}}\right)_2}{\sqrt{\left(\frac{kP}{hA_c}\right)_1}} = \sqrt{\frac{k_2}{k_1}\frac{\left(\frac{P}{A_c}\right)_2}{\left(\frac{P}{A_c}\right)_1}}$$

$$\Rightarrow \quad \frac{\in_2}{\in_1} = \sqrt{2 \times \frac{1}{2}} = 1$$

or $\in_2 = \in_1$

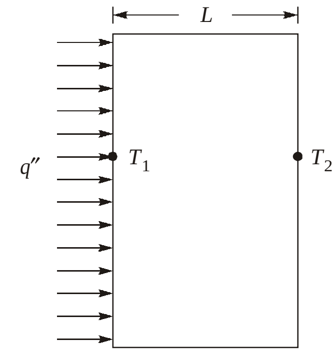
62. (d)

$$\text{Thermal diffusivity, } \alpha = \frac{k}{\rho c_p} = \frac{\text{Heat conduction}}{\text{Heat storage}}$$

The larger the thermal diffusivity, the faster the propagation of heat into the medium. A small value of thermal diffusivity means that heat is mostly absorbed by the material and a small amount of heat is conducted further.

63. (a)

Given : $L = 0.4$ m; $k = 2$ W/°C; $A = 8$ m^2



$$q'' = 400 \text{ W/m}^2$$

$$T_1 = 50°\text{C}$$

$$q'' = -k\frac{dT}{dx}$$

$$\Rightarrow \quad 400 = 2 \times \frac{(50 - T_2)}{0.4}$$

$$\Rightarrow \quad T_2 = -30°\text{C}$$

64. (d)

- **Cartesian coordinate robots:** Linear movement along three different axes.
- **Cylindrical coordinate robots:** Two linear and one rotary movement.
- **Spherical coordinate or Polar coordinate robots:** One linear and two rotary movement.
- **Revolute coordinate or Articulated coordinate robots:** Rotary movement about three independent axes.

65. (b)

It is combined rotation and translation

$$^1T_2 = \begin{bmatrix} ^1R_2 & ^1D_2 \\ 0 & 1 \end{bmatrix}$$

$$^1R_2 = R_x(\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$$

$$^1D_2 = \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$$

$$^1T_2 = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & \cos45° & -\sin45° & 2 \\ 0 & \sin45° & \cos45° & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

66. (b)

67. (a)

It provides a larger work envelope than the cartesian, cylindrical or spherical configuration.

68. (c)

Number of memory location each chips = 2^{12}

Number of bits in each chip = $2^{12} \times 4$ bits

So, total number of bits in memory system

$$= 8 \times 4 \times 2^{12}$$

$$= 8 \times 4 \times 2^2 \times 2^{10} \qquad (1 \text{ byte} = 8 \text{ bits})$$

$$= 16 \text{ kB} \qquad (2^{10} \text{ byte} = \text{kB})$$

69. (d)

Speed: 8-bit processors typically perform fewer operations per clock cycle than 16-bit processors → limited speed.

Data handling capacity: 8-bit processors handle only 8 bits at a time vs 16 bits for 16-bit processors → limited data handling.

Directly addressable memory: 8-bit processors usually have smaller address buses (e.g., 16-bit address → 64 KB) than 16-bit processors → limited memory.

70. (b)

Integral controller can give zero steady state error.

71. (d)

Here, $$A = \begin{bmatrix} 2 & 1 \\ 0 & b \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

The controllability matrix $= [B \quad AB]$

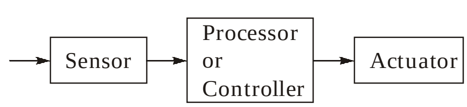
$$AB = \begin{bmatrix} 2 & 1 \\ 0 & b \end{bmatrix}\begin{bmatrix} 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ b \end{bmatrix}$$

So, controllability matrix $[B \quad AB]$ or $[Q_c] = \begin{bmatrix} 0 & 1 \\ 1 & b \end{bmatrix}$

$$|Q_c| = 0 - 1 \neq 0$$

Hence, given system is controllable at any value of b.

72. (b)



From flow chart it is clear, statement I is incorrect.

73. (d)

$$1 \text{ rev} = 700 \text{ pulses}$$

$$1 \text{ sec} = 7700 \text{ pulses}$$

$$1 \text{ sec} = \frac{7700}{700} = 11 \text{ rev}$$

$$1 \text{ min (60 sec)} = 11 \times 60 \text{ rev} = 660 \text{ rev}$$

74. (c)

Register Array:

- Registers are small storage devices that are available to CPU or processors.
- They act as temporary storage for processing of intermediate data by mathematical or logical operations.

75. (c)

76. (c)

Actual power produced by a rotor would be decided by the efficiency with which this energy transfer from wind to the rotor takes place. This efficiency is usually termed as the power coefficient (C_P). Thus, the power coefficient of the rotor can be defined as the ratio of actual power developed by the rotor to the theoretical power available in the wind. Hence,

$$C_P = \frac{2P_T}{\rho_a A_T V^3}$$

77. (b)

$$\text{Concentration ratio} = \frac{\text{Area of aperture of concentrating system}}{\text{Area of receiver}}$$

$$= \frac{(W - D_0)_L}{\pi D_0 \times L}$$

$$= \frac{2000 - 70}{\pi \times 70} = \frac{2000 - 70}{220} = 8.77 \simeq 8.8$$

78. (d)

Given: $\rho = 1.03 \times 1000 = 1030 \text{ kg/m}^3$, $A = 20 \text{ km}^2 = 20 \times 10^6 \text{ m}^2$, $g = 10 \text{ m/s}^2$, $R = 10$ m

$$\text{Energy potential available, } E_f = \frac{1}{2}\rho A g R^2$$

$$= \frac{1}{2} \times 1030 \times 20 \times 10^6 \times 10 \times 10^2$$

$$= 1030 \times 10^{10} = 10.3 \times 10^{12} \text{ Joule}$$

$$E_f = 10.3 \times 10^6 \text{ MJ}$$

79. (a)

According to Betz's law, no turbine can capture more than 16/27 (59.3%) of the kinetic energy in wind. The factor 16/27 (0.593) is known as Betz's coefficient.

$$P_{max} = (0.593) \times \left(\frac{1}{2}\rho \times A \times V_u^3\right) = (0.593) \times \frac{1}{2} \times \left(\frac{P}{RT} \times A \times V_u^3\right)$$

$$= \left(\frac{0.593}{2}\right) \times \left[\frac{100 \times 287 \times 10^3}{0.287 \times 300}\right] = (0.2965) \times \left(\frac{10^6}{3}\right)$$

$$= \left(\frac{296.5}{3}\,\text{kW}\right)$$

$$P_{max} = 98.83 \text{ kW}$$

80. (d)

The electromagnetic radiation emitted by the sun covers a very large range of wavelengths, from radio waves through the infrared, visible and ultraviolet to X-rays and gamma rays. However, 99 per cent of the energy of solar radiation is contained in the wavelength band from 0.2 to 4 μm, comprising the near ultraviolet, visible and near infrared regions of the solar spectrum, with a maximum at about 0.48 μm. About 48 per cent of the solar radiation received at the earth's surface on clear days is visible radiation within the spectral range 0.38 to 0.78 μm, while 45.6 per cent is infrared radiation in the spectral region 0.78 to 4 μm.

81. (b)

The irradiation absorbed by the surface can be found by multiply the total irradiation by cosθ

$$I_i = I_t \cos\theta$$

I_i = Irradiation absorbed by the surface

I_t = Total irradiation

θ = Incident angle

As, $\theta\uparrow \Rightarrow \cos\theta\downarrow \Rightarrow I_i\downarrow$

82. (d)

The principal disadvantages of VAWTs are:

1. Many vertical axis machines have suffered from fatigue failures arising from the many natural resonances in the structure.
2. The rotational torque from the wind varies periodically within each cycle, and thus unwanted power periodicities appear at the output.
3. Guyed tower support is complex, as a result the great majority of working machines are horizontal axis, not vertical.

A major advantage of vertical-axis machines is to eliminate gravity-induced stress/strain cycles (which occurs during every rotation in the blades of horizontal axis turbines), so vertical-axis blades may be very large. For small machines, gearing and generators may be directly coupled to the vertical main shaft at ground level. However, for larger vertical-axis machines, the high torque of the main shaft requires it to be short, so generators are not at ground level.

83. (c)

Statements 1 is correct reason of local winds. And statements 2 and 3 are the main reason for planetary wind.

84. (b)

Porous carbon electrodes contains platinum catalyst.

85. (d)

86. (d)

87. (c)

Run size represents the total number of the parts produced in a run.

$$q = 6000 \text{ parts}, \qquad d = 300 \text{ parts/day}$$

$$p = 50 \times 8 = 400 \text{ parts/day}$$

$$\text{Maximum inventory level, } I_o = \left(\frac{p-d}{p}\right) \times q = \left(\frac{400-300}{400}\right) \times 6000$$

$$= 1500 \text{ parts}$$

88. (d)

An MRP system requires:

1. **Master Production Schedule (MPS) :** Determines what products to produce and when.
2. **Inventory Status File :** Provides current inventory levels, on-hand and on-order quantities.
3. **Bill of Material (BOM) :** Provides the components required for each product and their hierarchical structure.

89. (b)

Slack is the amount of time that an activity can be delayed past its earliest start or earliest finish without delaying the project. The critical path is the path through the project network in which none of the activities have slack, that is, the path for which ES = LS and EF = LF for all activities in the path. Therefore statement 3 is incorrect.

90. (a)

	W_1	W_2	W_3	Penalties
F_1	[7] 20	[6]	[4] 30	2 2 1
F_2	[8]	[5] 60	[6]	1 1 [3]
F_3	[6] 40	[8]	[9]	[2]
Penalties	1, 1, 1	1, 1, 1	2, [2]	

Transportation cost = 20 × 7 + 4 × 30 + 5 × 60 + 6 × 40 = `800

91. (a)

Given: s = `20/unit, $v$ = `14/unit, F = `270000, C = 60000 units

$$\text{Breakeven point (in units), } Q_B = \frac{F}{s-v} = \frac{270000}{20-14} = 45000 \text{ units}$$

$$\text{Margin of safety} = 60000 - 45000 = 15000 \text{ units}$$

92. (a)

Fault prognosis is concerned with predicting the future behavior of a system and estimating how long the system can operate before a failure occurs.

Remaining Useful Life (RUL) is the key output of fault prognosis.

Fault detection (option b) and residue generation (option c) are part of fault diagnosis, not prognosis.

Alarm bounds (option d) are used in fault detection / monitoring, not directly in prognosis.

93. (a)

Duty cycle is the percentage of time in a 10 minute period that a welding machine can be used at its rated output without over loading. For automatic continuous welding, the duty cycle is 100%.

Given, $I_1 = 200\text{A}, D_1 = 0.4$

$I_2 = ?, D_2 = 1$

$$I_1^2 D_1 = I_2^2 D_2$$

$$(200)^2 \times 0.4 = I_2^2 \times 1$$

$$I_2 = 200\sqrt{0.4}$$

$$I_2 = 200\sqrt{\frac{40}{100}} = \frac{200 \times 2\sqrt{10}}{10} = 40\sqrt{10}\text{ A}$$

94. (a)

The production of washer consists of two operations : Blanking the outside diameter and piercing the inner hole.

Blanking force, $F_1 = \pi D t \tau$

$$F_1 = \frac{22}{7} \times 50 \times 4 \times 350 = 220000\text{ N}$$

$$F_1 = 220\text{ kN}$$

Piercing force, $F_2 = \pi d t \tau$

$$F_2 = \frac{22}{7} \times 24 \times 4 \times 350 = 105600\text{ N} = 105.6\text{ kN}$$

Thus, total force required will be

$$F = F_1 + F_2 = 220 + 105.6 = 325.6\text{ kN}$$

95. (a)

- Telescopic gauge is used to measure holes or slots.
- Tool maker's microscope can be used for linear measurements, to measure screw pitch, pitch diameter and thread angle.
- Autocollimator is used to measure small angular inclinations. It is also used to check straightness, flatness and alignment.

96. (d)

Given : $V_c = 1.5$ m / s

Since uncut chip thickness (t_c) is lesser than cut chip thickness,

$$t_c - t = 20\% \text{ of } t_c$$

$$0.8t_c = t$$

Thus, chip thickness ratio, $r = \dfrac{t}{t_c} = 0.8$

And hence, chip velocity, $V_f = rV_c$

$$V_f = 0.8 \times 1.5 = 1.2 \text{ m / s}$$

97. (b)

Thickness of the shell depends on the contact time between pattern and moulding material known as dwell time.

98. (a)

99. (a)

A fluid for which apparent viscosity decreases with rate of deformation is Pseudoplastic fluid and its examples are milk, blood, Gelatine etc.

100. (a)

Turbulent flow delays the separation.

101. (d)

$$\text{Total energy line, TEL} = \frac{P}{\rho g} + \frac{v^2}{2g} + z$$

$$\text{Hydraulic gradient line, HGL} = \frac{P}{\rho g} + z$$

$$\text{TEL} - \text{HGL} = \frac{v^2}{2g} = \text{Velocity head}$$

102. (b)

$$\vec{V} = 4x^3\hat{i} - 12x^2 y\,\hat{j}$$

$\Rightarrow$ $u = 4x^3$; $v = -12x^2y$ and $w = 0$

$$\vec{\nabla}\cdot\vec{V} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = \frac{\partial}{\partial x}\left(4x^3\right) + \frac{\partial}{\partial y}\left(-12x^2 y\right) = 12x^2 - 12x^2 = 0$$

As $\vec{\nabla}\cdot\vec{V} = 0$, so the velocity field is incompressible

$$\vec{\nabla} \times \vec{V} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ u & v & w \end{vmatrix}$$

$$= \left(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}\right)\hat{i} - \left(\frac{\partial w}{\partial x} - \frac{\partial u}{\partial z}\right)\hat{j} + \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)\hat{k}$$

$$= (0-0)\hat{i} - (0-0)\hat{j} + (-24xy - 0)\hat{k}$$

$$= -24xy\,\hat{k}$$

As $\vec{\nabla} \times \vec{V} \neq 0,$ so the velocity field is rotational.

103. (d)

The equation of a streamline is given by

$$\frac{dy}{dx} = \frac{v}{u}$$

$$\Rightarrow \quad \frac{dy}{dx} = \frac{-12x^2y}{4x^3}$$

$$\Rightarrow \quad \frac{dy}{dx} = \frac{-3y}{x}$$

$$\Rightarrow \quad \frac{dy}{-3y} = \frac{dx}{x}$$

On integration, $-\frac{1}{3}\ln(y) = \ln(x) + \text{constant}$

$\Rightarrow \quad \ln(y) + 3\ln(x) = \text{constant}$

$\Rightarrow \quad yx^3 = \text{constant}$

Hence, the equation of streamline is yx^3 = constant

104. (c)

Given : $V = 5$ m^3; $W = 40$ kN

$$\text{Specific volume, } v_s = \frac{V}{m} = \frac{V}{\left(\frac{W}{g}\right)} = \frac{V \times g}{W}$$

$$= \frac{5 \times 9.81}{(40 \times 10^3)} = 1.22625 \times 10^{-3} \text{ m}^3/\text{kg} \simeq 1.23 \times 10^{-3} \text{ m}^3/\text{kg}$$

105. (b)

Given : K = 2 GPa, $-\frac{\Delta V}{V} = 0.5\% = 0.005$

$$\text{Bulk modulus, } K = \frac{\Delta P}{\left(-\frac{\Delta V}{V}\right)}$$

$$\Rightarrow \quad \Delta P = k \times \left(-\frac{\Delta V}{V}\right)$$

$$\Rightarrow \quad (P_2 - 0) = 2 \times 0.005$$

$$\Rightarrow \quad P_2 = 0.01 \text{ GPa} = 10 \text{ MPa}$$

106. (d)

Given : L = 500 m; D = 80 mm; f = 0.05

The diameter of nozzle for maximum power transmission is given as,

$$d = \left(\frac{D^5}{2fL}\right)^{1/4} = \left(\frac{(0.080)^5}{2 \times 0.05 \times 500}\right)^{1/4}$$

$$= 0.08 \times \left(\frac{8}{10 \times 500}\right)^{1/4} = 0.08 \times \left(\frac{1}{625}\right)^{1/4}$$

$$= \frac{0.08}{5} = 0.016 \text{ m} = 16 \text{ mm}$$

107. (a)

Given : d_1 = 200 mm; v_1 = 1 m/s; d_2 = 400 mm

$$v_2 = \frac{\frac{\pi}{4} d_1^2 v_1}{\frac{\pi}{4} d_2^2} = \left(\frac{d_1}{d_2}\right)^2 \times v_1$$

$$= \left(\frac{200}{400}\right)^2 \times 1 = \frac{1}{4} \text{ m/s} = 0.25 \text{ m/s}$$

Head loss due to sudden expansion,

$$h = \frac{(v_1 - v_2)^2}{2g} = \frac{(1 - 0.25)^2}{2 \times 9.81} = 0.02867 \text{ m} \simeq 0.0287 \text{ m}$$

108. (b)

- Nichrome : 80% Ni and 20% Cr
- Inconel : 76% Ni, 16% Cr, 7% Fe
- Stainless steel : 74% Fe, 18% Cr, 8% Ni
- Chromel : 90% Ni, 10% Cr

109. (b)

- If steel alloy having either pearlitic or bainitic microstructures is heated to, and left at, a temperature below the eutectoid for a sufficiently long period of time, yet another microstructure will form called spheroidite.
- Instead of the microstructure of pearlite and bainite, the Fe_3C phase appears as sphere like particles embedded in a continuous α-phase matrix.
- This transformation occurs by additional carbon diffusion with no change in the compositions or relative amounts of ferrite and cementite phases.

110. (a)

Larger is the extend of mushy zone, lesser will be the fluidity.

111. (c)

Vacancy, Schottky - Point defects

Edge dislocation - Line defects

112. (b)

Silicon – one of the principal deoxidizers used in steel making.

In low-carbon steels, silicon is generally detrimental to surface quality.

113. (c)

Polyethylene: Characteristic: Chemically resistant, tough, low friction coefficient, low strength.

Application: Flexible bottles, toys, battery parts ice trays, film wrapping materials.

114. (c)

Eutectic transformation:

$$L \rightleftharpoons \gamma + Fe_3C$$

As iron-carbon alloy with 4.3% carbon exists as a mixture of austenite and liquid iron above 1130°C. Below 1130°, it becomes completely solid and exists as a mixture of austenite and cementite.

115. (c)

- Ceramic particles embedded in metal matrix to form a composite material known as cermet.
- A cermet is ideally designed to have the optimal properties of high temperature resistance, abrasion resistance, and hardness from ceramics and the ability of a metal to undergo plastic deformation.

116. (d)

Miller indices of a crystal plane are defined as the reciprocals of the fractional intercepts which the plane makes with the crystallographic axes.

Let the lattice parameters be $4x$, $3x$ and $2x$

	x	y	z
Intercepts	2Å	3Å	4Å
Lattice parameters	$4x$	$3x$	$2x$
Fractional intercepts	$\frac{2}{4x}$	$\frac{3}{3x}$	$\frac{4}{2x}$
Reciprocals	$2x$	x	$\frac{x}{2}$

$\therefore$ Miller indices : (4 2 1)

117. (c)

- The higher is the prior degree of deformation, the lower is the recrystallization temperature.
- The higher is the temperature of cold working, the less is the strain energy stored in the material. The recrystallization temperature is correspondingly higher.
- The finer is the initial grain size, the lower is the recrystallization temperature.

118. (b)

$$\text{Brake power} = (W - S) \times \frac{\pi D N}{60}$$

$$D = 600 + 25 = 625 \text{ mm}$$

$$\text{BP} = (200 - 20) \times \frac{\pi \times 625 \times 500}{1000 \times 60}$$

$$= 2945.24 \text{ W} = 2.945 \text{ kW}$$

119. (c)

Advancing the fuel injection results in lesser compression, temperature of charge will be lesser, hence tendency of knocking will increase.

120. (d)

The actual cycles for IC engines differ from the fuel-air cycles and air-standard cycles in many respects. The actual cycle efficiency is much lower than the air-standard efficiency due to various losses occurring in the actual engine operation. The major losses are due to:

(i) Variation of specific heats with temperature
(ii) Dissociation of the combustion products
(iii) Progressive combustion
(iv) Incomplete combustion of fuel
(v) Heat transfer into the walls of the combustion chamber
(vi) Blowdown at the end of the exhaust process
(vii) Gas exchange process

121. (d)

Normal paraffins exhibit the poorest antiknock quality when used in a SI engine. But the antiknock quality improves with the increasing number of carbon atoms and the compactness of the molecular structure. The aromatic hydrocarbon fuel offers the best resistance to knocking in SI engines.

122. (c)

Velocity of injection is given by,

$$V_{inj} = C_d\sqrt{\frac{2\left(P_{inj} - P_{cyl}\right)}{\rho_f}}$$

$$V_{inj} = 0.85\sqrt{\frac{2(150-40)\times 10^5}{900}} = 132.89 \simeq 133 \text{ m/s}$$

123. (b)

$$\text{Volume of fuel injected/cycle, } V = \frac{bsfc \times B.P. \times 2}{N \times 60 \times \rho}$$

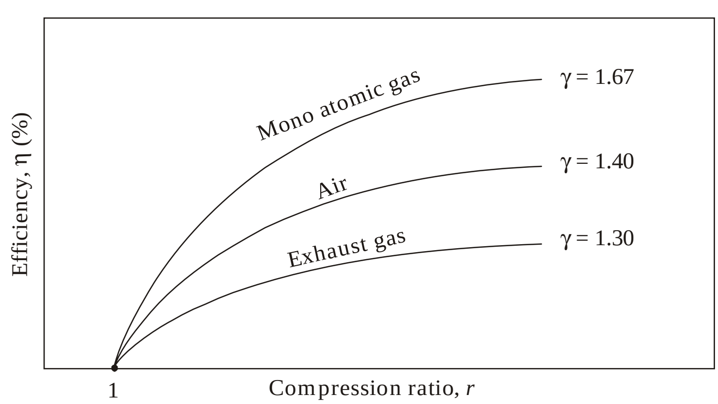
$$V = \frac{0.3 \times 30 \times 2}{2400 \times 60 \times 900}$$

$$\therefore \quad V = 1.38 \times 10^{-7} \text{ m}^3\text{/cycle}$$

124. (b)

We know, $$\eta_{\text{air-standard}} = 1 - \frac{1}{r^{(\gamma-1)}}$$

Note that the thermal efficiency of Otto cycle is a function of compression ratio r and the ratio of specific heats, γ. As γ is assumed to be a constant for any working fluid, the efficiency is increased by increasing the compression ratio. Further, the efficiency is independent of heat supplied and pressure ratio. The use of gases with higher γ values would increase efficiency of Otto cycle. Figure below shows the effect of γ and r on the efficiency.



Effect of *r* and γ on efficiency for Otto cycle

125. (b)

Maximum NO_x formation occur at maximum temperature which occur due to higher combustion and use of water emulsion decrease the temperature of combustion chamber which leads to decrease in NO_x.

126. (c)

$$\eta = 1 - \frac{1}{(r)^{\gamma-1}}\left[\frac{\alpha\rho^{\gamma} - 1}{\alpha\gamma(\rho-1)+(\alpha-1)}\right]$$

127. (d)

During polytropic process, PV^n = Constant

$$p_1 v_1^n = p_2 v_2^n$$

Taking log both side,

$$\ln(p_1) + n\ln(v_1) = \ln(p_2) + n\ln(v_2)$$

$$\ln\left(\frac{p_1}{p_2}\right) = n \times \ln\left(\frac{v_2}{v_1}\right)$$

$$\text{Polytropic index, } n = \frac{\ln(p_1/p_2)}{\ln(v_2/v_1)} = \frac{\ln(p_2/p_1)}{\ln(v_1/v_2)}$$

128. (c)

129. (b)

Given : m_{N_2} = 1.4 kg; m_{CO_2} = 2.2 kg; M_{N_2} = 28 kg; M_{CO_2} = 44 kg

$$\therefore \quad \text{Number of moles, } n_{N_2} = \frac{1.4}{28} = 0.05$$

$$\text{Number of moles, } n_{CO_2} = \frac{2.2}{44} = 0.05$$

$$\therefore \quad \text{Total number of moles, } n = n_{N_2} + n_{CO_2}$$

$$= 0.05 + 0.05 = 0.1$$

$\therefore$ Apparent molecular weight of the mixture,

$$M = y_{N_2}M_{N_2} + y_{CO_2}M_{CO_2},$$

where y_{N_2} and y_{CO_2} are mole fractions of N_2 and CO_2 respectively

$$\therefore \quad M = \frac{0.05}{0.1} \times 28 + \frac{0.05}{0.1} \times 44 = 36 \text{ kg/kg mole}$$

$\therefore$ Apparent gas constant of the mixture,

$$R = \frac{R_u}{M} = \frac{8.314}{36} = 0.23 \text{ kJ/kgK}$$

130. (d)

131. (b)

Given : $\eta_I = 0.3$; $\eta_{II} = 0.6$

$$\text{Carnot efficiency, } \eta_I = 1 - \frac{T_{L_1}}{T_H}$$

$$\Rightarrow \quad 0.30 = 1 - \frac{T_{L_1}}{T_H}$$

$$\text{or} \quad T_{L_1} = 0.7\,T_H \quad \text{...(i)}$$

When the sink temperature is lower by 60°C, then

$$\eta_{II} = 0.6$$

$$\text{or} \quad 0.6 = 1 - \frac{T_{L_1} - 60}{T_H}$$

$$\text{or} \quad T_L - 60 = 0.4T_H$$

$$\therefore \quad 0.7T_H - 60 = 0.4T_H$$

$$\therefore \quad T_H = 200 \text{ K}$$

132. (d)

$$\text{Swept volume, } V_S = \frac{\pi}{4}D^2L = \frac{\pi}{4} \times 20^2 \times 30 = 3000\,\pi \text{ cm}^3$$

$$\therefore \quad \text{Compression ratio, } r = 1 + \frac{V_S}{V_C} = 1 + \frac{3000\pi}{1500}$$

$$r = 7.28$$

133. (b)

Reversible isothermal process,

$$W = p_i v_i \ln\left(\frac{p_i}{p_f}\right) = 10 \times 200 \ln\left(\frac{2}{15}\right)$$

$$= 10 \times 200\left[2.303 \log_{10}\left(\frac{2}{15}\right)\right]$$

$$= 10 \times 200 \times 2.303\ [\log_{10}2 - \log_{10}15]$$

$$= 10 \times 200 \times 2.303\ [0.301 - 1.176]$$

$$= 10 \times 200 \times 2.303\ [-0.875] = -4030.25 \text{ kJ}$$

134. (d)

Advantages of absorption refrigeration over compression refrigeration :

- Electrolux system of absorption system has no moving parts and hence very quiet.
- Absorption system can use any type of low grade thermal energy directly.
- Absorption units can be built in capacities well above 1000 tons each, which is a rare case for VCRS with single compressor.

- It is very insensitive to part load operation.
- Very easy to maintain.

135. (d)

Psychrometric chart:

- DBT lines are straight parallel and vertical.
- Humidity ratio (ω) lines are straight, parallel and horizontal.
- Vapour pressure (P_v) line are straight, parallel with non-uniform spacing and horizontal.
- WBT lines are inclined, straight and not uniformly spaced.
- Relative humidity (ϕ) lines are curved.
- Volume lines are straight and inclined.
- Enthalpy lines are long WBT lines.

136. (c)

Vortex tube refrigeration:

- The device using the compressed air discharged hot and cold stream simultaneously at its two ends, and creates a cooling effect.
- The air enters the main tube through the nozzle and forms a free vortex. Due to the centrifugal acceleration, the vortex travels along the periphery of the tube and when it reaches the throttle valve, the rotation almost ceases, so there is a point of stagnation in this region. As the pressure in this region exceeds the atmospheric pressure, a reverse axial flow starts. This flow comes in the contact with the free vortex which is moving with the increasing speed, therefore, the axial stream forms a forced vortex.

137. (d)

Refrigerant	ODP
R - 11	1.00
R - 12	0.93
R - 22	0.025
R - 123	0.02
R - 134a	0
R - 153a	0
Ammonia	0

138. (c)

Base circle is the smallest circle tangent to the cam profile drawn from the centre of rotation of a radial cam.

139. (a)

140. (c)

Example of isomorphous system: Cu-Ni phase diagram.

141. (d)

For a perfect incompressible liquid, the flow always takes place in a direction from higher total head to lower total head.

142. (b)

143. (b)

144. (a)

Steam-Jet Refrigeration: In a steam-jet refrigeration system, water acts as a refrigerant and cooling is produced by partial vapourization at very low evaporator pressure (~7 mmHg), resulting in very large vapour volume to be compressed by the ejector.

Steam jet ejectors are ideally suited to handle such large volume flows. Since the motive steam energizing the ejector must be condensed along with the water vapour drawn from the evaporator, it is necessary to reject 2 to 3 times the amount of heat in the condenser that a conventional mechanical refrigeration cycle would require. Thus, a large condenser and a relatively higher cooling water flow must be employed in steam-jet units.

145. (a)

A compressor consisting of more than one stage of equal isentropic efficiency, will require more work input, because it receives fluid at increased temperature from the preceeding stage.

146. (a)

The modulus of toughness of mild steel is more than that of cast iron as a result of which it can absorb more strain energy without fracture. Thus, mild steel is excellent at withstanding sudden impacts without bending, deforming or breaking.

147. (a)

Degree of reaction, or reaction for short, is defined as the change in static enthalpy across the rotor divided by the static enthalpy change across the entire stage. For the turbine this is given as

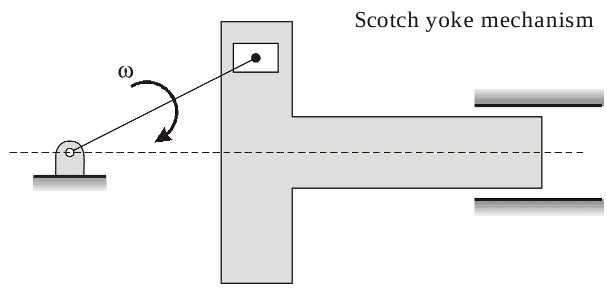
$$R = \frac{h_2 - h_3}{h_1 - h_3}$$

$$R = \frac{U_2^2 - U_3^2 + W_3^2 - W_2^2}{V_2^2 - V_1^2 + U_2^2 - U_3^2 + W_3^2 - W_2^2}$$

In a flow in which $V_1 = V_2$, the reaction $R = 1$. Such a machine is a pure reaction machine. A lawn sprinkler, rotating about an axis is such a machine, for all the pressure drops take place in the sprinkler arms. They turn as a reaction to the momentum leaving them.

148. (d)

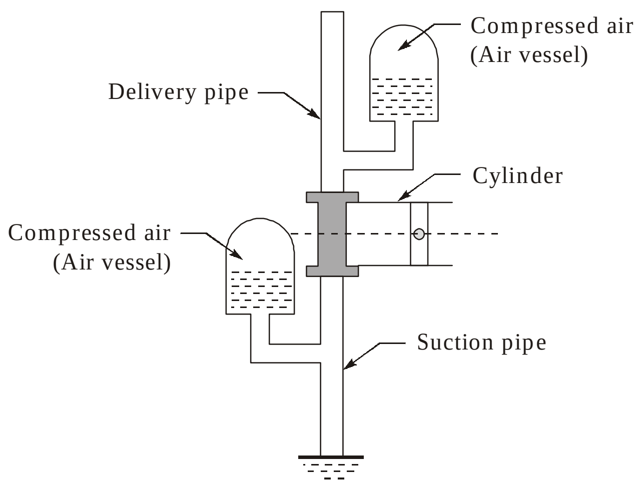
Scotch yoke mechanism



- In scotch yoke mechanism, there is not any sliding body present which can have movement on a rotating link.
- When crank and slot are parallel, as there is no perpendicular component of relative velocity exist, coriolis acceleration becomes zero.

149. (a)

Air Vessel : The pulsation of pressure due to inertia or acceleration heads in suction and delivery pipe and the non-uniformity of discharge during the delivery stroke may largely be eliminated by connecting a large and closed chamber to both the suction and delivery pipes at points close to the pump cylinder as shown in figure below. These vessels are known as air vessels.



Working Principle : An air vessel in a reciprocating pump acts like a fly-wheel of an engine. The top of the vessel contains compressed air which can contract or expand to absorb most of the pressure fluctuations. Whenever the pressure rises.

150. (d)

There is no relation of calorific value with the air supplied.