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ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 20

Full Syllabus Test-4 : (Paper-II)

Answer Key

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

1. (d)

The chief advantages of air vessels in a reciprocating pump are:

- Air vessel on suction side:
  - (i) Reduces cavitation possibility
  - (ii) For a given minimum pressure head, the pump can run at higher speed.
  - (iii) Suction pipe length can be increased
- Air vessel on delivery side:
  - (i) Almost constant delivery discharge is obtained
  - (ii) Reduction in friction loss and hence saving in power

2. (a)

Given: Q = 150 L/s = 0.15 m^3/s, D_2 = 0.3 m, b_2 = 0.08 m

As we know,

$$Q = \pi D_2 b_2 V_{f_2}$$

$$0.15 = \frac{22}{7} \times 0.3 \times 0.08 \times (V_{f_2})$$

$$(V_{f_2}) = \frac{0.15 \times 7}{22 \times 0.3 \times 0.08} = 1.988 \approx 1.99 \text{ m/s}$$

3. (b)

For geometrically similar turbines, the unit speed.

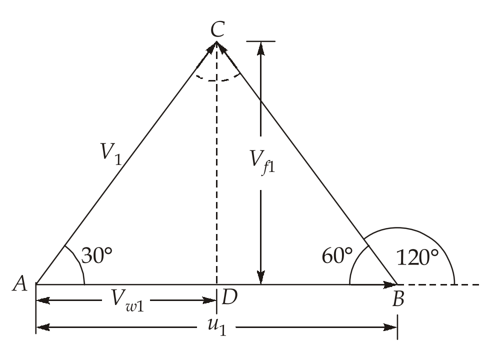
$$N_u = \frac{N}{\sqrt{H}}$$

$$\therefore \quad \frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}}$$

$$N_2 = N_1\sqrt{\frac{H_2}{H_1}} = 200\sqrt{\frac{18}{30}} = 200 \times 0.774$$

$$N_2 = 154.8 \text{ rpm} \approx 155 \text{ rpm}$$

4. (c)



In triangle ABC,

$$\frac{V_1}{u_1} = \cos 30°$$

$$V_1 = u_1 \cos 30°$$

In triangle ADC,

$$\frac{V_{w1}}{V_1} = \cos 30°$$

$$V_{w1} = V_1 \cos 30° = u_1 \cos^2 30° = 0.75\, u_1$$

As we know,
$$\eta_H = \frac{u_1 V_{w1}}{gH}$$

$$0.75 = \frac{u_1 \times 0.75 u_1}{10 \times 14.4}$$

$$u_1^2 = 144$$

$$u_1 = 12 \text{ m/s}$$

Also,
$$u_1 = \frac{\pi D_1 N}{60}$$

$$12 = \frac{22}{7} \times \frac{D_1 \times 1200}{60}$$

$$\frac{60}{314} = D_1$$

$$D_1 = 0.1911 \text{ m}$$

$$D_1 = 19.11 \text{ cm}$$

5. **(c)**

6. **(d)**

The ramjet engine cannot operate under static conditions, as there will be no pressure rise in the diffuser, it is not self-propelling at zero flight velocity. To initiate its operation, the ramjet must be either launched from an airplane in flight or be given an initial velocity by some auxiliary means, such as launching rockets. Since the ramjet is an air breathing engine, its maximum altitude is limited. Its field of operations is inherently in speed ranges above those of the other air breathing engines. However, it has a limited use in the high subsonic speed range. Its best performance capabilities, however, are in supersonic speed range of Mach numbers between 2 and 5. The upper speed is limited by the problem of cooling of the outer skin of the engine body at the high flight Mach numbers.

7. **(d)**

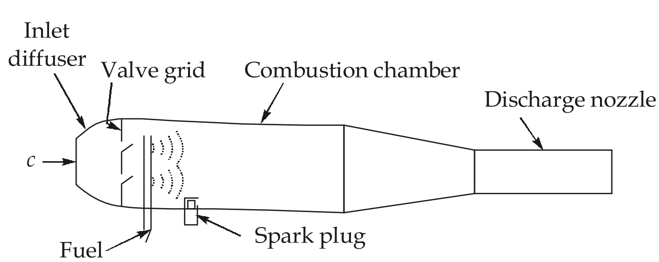


Fig: The pulse jet engine

The basic features of the pulse jet engine are illustrated in figure. It consists essentially of the following parts:

(i) a diffuser,

(ii) a valve grid which contains springs that close on their own spring pressure,

(iii) a combustion chamber,

(iv) a spark plug, and
(v) a tail pipe or discharge nozzle.

8. (b)

Given: C_i = 1375 m/s, C_j = 2750 m/s

$$\alpha = \frac{C_i}{C_j} = \frac{1375}{2750} = 0.5$$

$$\eta_p = \frac{2\alpha}{1+\alpha} = \frac{2\times0.5}{1+.5} = \frac{1}{1.5} = 0.6667$$

$$\eta_p = 66.67\%$$

9. (d)

The main effects of cavitation in a flow device, such a hydraulic machine, are:

1. Alteration of the performance of the system, for instance reduction of lift, increase in the drag, fall in the turbo-machine efficiency, etc.
2. Occurrence of noise and vibration of the component.
3. Pitting damage in the wall region of the component undergoing cavitation.
4. Significant shortened life of the machinery/equipment.

10. (a)

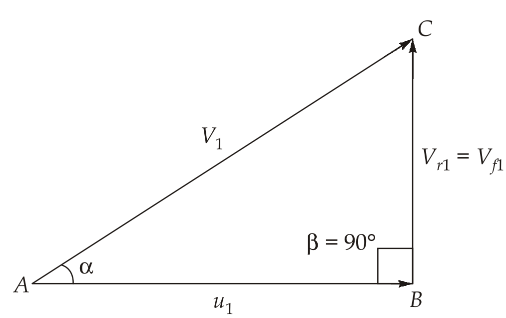
The maximum discharge which occurs when the net head is zero is known as free delivery. At the free delivery condition, the inlet and the outlet are not throttled and there is no restriction of any kind. Thus, there is no load on the pump at free delivery.

11. (b)

As entrance is radial,

$\therefore$ $$V_{r1} = V_{f1} = 4 \text{ m/s}$$

In ΔABC,



$$\sin\alpha = \frac{BC}{AC} = \frac{V_{r1}}{V_1} = \frac{4}{8} = \frac{1}{2}$$

$$\alpha = \sin^{-1}\left(\frac{1}{2}\right) = 30°$$

12. (c)

It helps to guide the vertical flow immediately after the runner to a horizontal flow of low velocity to enable the discharge to flow downstream in the tailrace channel.

13. (c)

Given: $\dot{m} = 4\text{ kg/s}$, T_1 = 20°C = 273 + 20 = 293 K, P_1 = 100 kPa, P_2 = 21.6 × 1000 kPa, n = 1.5.

$$W_{comp} = \dot{m} \times \frac{nRT_1}{(n-1)}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$= 4 \times \frac{1.5 \times 0.287 \times 293}{0.5}\left[\left(\frac{21600}{100}\right)^{\frac{1.5-1}{1.5}} - 1\right]$$

$$= 4 \times 3 \times 0.287 \times 293\ (6 - 1) = 4 \times 3 \times 0.287 \times 293 \times 5$$

$$W_{comp} = 5045.46\text{ kW}$$

14. (b)

Given: T_1 = 25°C = 273 + 25 = 298 K, $(C_P)_{gas} = (C_P)_{air}$ = 1.005 kJ/kgK, T_3 = 850°C = 273 + 850 = 1123 K.

$$Q_{add} = (C_P)_{gas}\ (T_3 - T_2)$$

$$654.255 = 1.005\ (1123 - T_2)$$

$$T_2 = 1123 - 651 = 472\text{ K}$$

$$\text{Back work ratio} = \frac{\omega_{compression}}{\omega_{turbine}} = \frac{(C_P)_{air}(T_2 - T_1)}{(C_P)_{gas}(T_3 - T_4)}$$

$$= \frac{T_2 - T_1}{T_3 - T_4} = \frac{472 - 298}{1123 - 709} = 0.4203 \approx 0.42 \text{ or } 42\%$$

15. (b)

Actual enthalpy drop in nozzle $(\Delta h)_a$ = 200 × 0.9 = 180 kJ/kg

$$\text{Velocity of steam leaving nozzle } (V) = \sqrt{2 \times (\Delta h)_a + (50)^2}$$

$$= \sqrt{2 \times 180 \times 10^3 + 2500} = 602.08\text{ m/s}$$

Also, $\frac{u}{V} = 0.6$

∴ u = 0.6 × 602.08 = 361.24 m/s

16. (c)

The temperature rise per heater for maximum cycle efficiency

$$= \frac{295 - 39.03}{2 + 1} = 85.32°\text{C}$$

Optimum temperature of heater 1 = 295 – 85.32 = 209.68°C

Optimum temperature of heater 2 = 209.68 – 85.32 = 124.36°C

17. (d)

18. (c)

The factors which influence spontaneous combustion and can lead to big fire are:

1. Rank of coal, low rank coals are more susceptible because of their higher porosity.
2. Amount of surface area exposed to air.

3. Ambient temperature, with high solar insolation aiding it.
4. Oxygen content of coal.
5. Free moisture in coal.
6. Configuration of the coal stockpile.

19. (b)

Mass of dry flue gas produced per kg fuel

$$= \frac{\text{Mass fraction of carbon} \times (44O_2 + 28CO + 32O_2 + 28N_2)}{12(CO_2 + CO)}$$

$$= \frac{0.60 \times (44 \times 0.12 + 28 \times 0.015 + 32 \times 0.07 + 28 \times 0.795)}{12(0.12 + 0.015)}$$

$$= \frac{0.60 \times (5.28 + 0.42 + 2.24 + 22.26)}{12 \times 0.135}$$

$$= \frac{0.6 \times 30.2}{1.62} = 11.18 \text{ kg}$$

20. (a)

21. (d)

Surface condensers are mostly used in power plants. They are essentially shell-and-tube heat exchangers. For the convenience of cleaning and maintenance, cooling water flows through the tubes and steam condenses outside the tubes. A surface condenser with two passes on the water side. It consists of a steel shell with water boxes on each side. The right water box is divided to allow for two water passes. At each end there are tube sheets into which the water tubes are rolled. This prevents leakage of circulating water into the steam.

22. (c)

23. (d)

24. (a)

25. (d)

Given: μ = 0.30 Pa.s, v = 0.15 m/s, $h = \frac{(35.030\text{-}35)}{2} = 0.015 \text{ cm}$.

$$\tau = \frac{\mu V}{h} = \frac{0.3 \times 0.15}{0.015 \times 10^{-2}} = 300 \text{ N/m}^2$$

$$\text{Frictional resistance, } F_s = \tau \times A = \tau \times \pi DL$$

$$= 300 \times \frac{22}{7} \times \frac{35}{100} \times 3 = 990 \text{ N}$$

26. (b)

$$P_{atm} = 750 \text{ mm of Hg}$$

$$= 13.6 \times 1000 \times 9.81 \times \frac{750}{1000} \text{ N/m}^2$$

$$= 100.062 \text{ kPa}$$

$$P_{N\,(abs)} = P_{atm} + 30 \text{ kPa} = 100.062 + 30 = 130.062 \text{ kPa}$$

$$P_{M\,(abs)} = 130.062 + 20 = 150.062 \text{ kPa} \approx 150.06 \text{ kPa}$$

27. (a)

$$\text{Vertical force } (F_V) = \text{Weight of fluid above the hemisphere}$$

$$= \rho g\left(\pi R^2 H - \frac{1}{2}\times\frac{4}{3}\times\pi R^3\right)$$

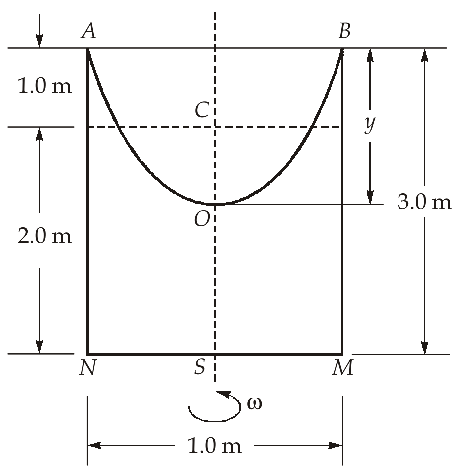
$$= 1000\times 9.81\left(\frac{22}{7}\times(0.7)^2\times 3 - \frac{2}{3}\times\frac{22}{7}\times(0.7)^3\right)$$

$$= 1000 \times 9.81\ (4.62 - 0.718)$$

$$= 1000 \times 9.81 \times 3.90 = 38.27 \text{ kN}$$

Resultant force is the same as the vertical force, F_V = 38.27 kN acting vertically at the centre of the hemisphere.

28. (a)



Let C represent the original water level at the axis. As the water surface is a paraboloid of revolution, rise of water surface at the edge above C = Distance OC = $\frac{y}{2}$.

Where y = Water surface elevation at the outer edge above vertex O.

Hence, $y = 2(3 - 2) = 2$ m

As we know, $y = \dfrac{r^2\omega^2}{2g}$

$$2 = \frac{\omega^2\times(0.5)^2}{2\times 9.81}$$

$$\omega^2 = \frac{2\times 2\times 9.81}{(0.5)^2} = 16\times 9.81$$

$$\omega = 4 \times 3.132 = 12.53 \text{ rad/sec}$$

29. (d)

Given: $u = 3x$, $v = -3y$

Equation of streamline in two dimensional flow is

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

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

On integrating,

$$\int \frac{dx}{x} = -\int \frac{dy}{y}$$

$$\ln x = -\ln y + \ln c$$

$$\ln x + \ln y = \ln c$$

$$\ln xy = \ln c$$

$$xy = c \quad \text{... (i)}$$

When, $x = 1$ and $y = 1$, from equation (i).

$$1 \times 1 = c$$

$$c = 1$$

∴ Required streamline equation in : $xy = 1$

30. (b)

Applying Bernoulli equation to a point on the water surface 3 and point 1. (for orifice)

$$0 + 0 + H = \frac{P_1}{\rho g} + \frac{V_{1a}^2}{2g} + 0$$

As the orifice discharges to atmosphere, $\frac{P_1}{\rho g} = 0$

∴
$$0 + 0 + H = 0 + \frac{V_{1a}^2}{2g} + 0$$

$$V_{1a} = \sqrt{2gH}$$

Hence, Discharge, $Q_a = \frac{\pi}{4} D^2 \sqrt{2gH}$

At point 2, the pressure is atmospheric and hence by applying Bernoulli equation between points 3 and 2. (for pipe)

$$0 + 0 + (H + L) = 0 + \frac{V_{2b}^2}{2g} + 0$$

$$V_{2b} = \sqrt{2g(H+L)}$$

Hence, Discharge, $Q_1 = \frac{\pi}{4} D^2 \sqrt{2g(H+L)}$

∴ Required ratio $= \dfrac{Q_a}{Q_b} = \dfrac{\frac{\pi}{4} D^2 \sqrt{2gH}}{\frac{\pi}{4} D^2 \sqrt{2g(H+L)}} = \sqrt{\dfrac{H}{H+L}}$

31. (d)

Power spent in fluid friction $= 5.5 \times 0.6 = 3.3$ kW

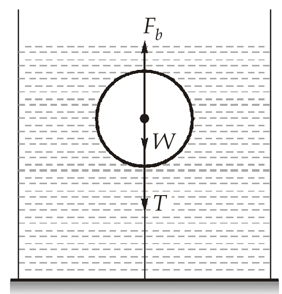
Also,
$$P = \frac{128\mu Q^2 L}{\pi D^4}$$

$$3300 = \frac{128 \times 0.2 \times L}{\pi \times (0.075)^4} \times \left(\frac{300}{1000 \times 60}\right)^2$$

$$L = 512.54 \text{ m}$$

32. (c)

The tension in the chain indicates that the buoyant force is larger than weight of the object in air.



Hence,
$$T = F_b - W$$
$$W = F_b - T$$
$$W = \frac{4}{3} \times \pi \times \left(\frac{1.4}{2}\right)^3 \times 9.81 - 5 = 9.10 \text{ kN}$$

33. (d)

34. (b)

35. (d)

36. (d)

The stream function ψ and the velocity potential function ϕ for line source is given by
$$\psi = m\theta \text{ and } \phi = m \ln r$$

37. (b)

Given: $L = 0.08$ m, $d = 0.06$ m, $W = 160$ N, $r = 0.4$ m, $N = 3000$ rpm, Torque
$$T = W \times r = 160 \times 0.4 = 64 \text{ N-m}$$

$$\text{B.P.} = \frac{2\pi NT}{60} = \frac{2 \times \pi \times 3000 \times 64}{60} \text{ Watt}$$

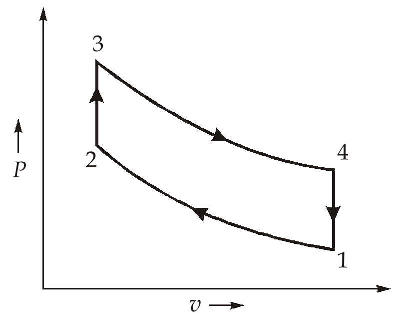
Also,
$$\text{B.P.} = \frac{p_{m_b} \times LANn}{2 \times 60}$$

$$p_{mb} = \frac{120 \times 2 \times \pi \times 3000 \times 64}{0.08 \times \frac{\pi}{4} \times (0.06)^2 \times 3000 \times 4 \times 60} = 8.88 \times 10^5 \text{ Pa}$$

$$p_{mb} = 8.89 \text{ bar}$$

38. **(a)**

39. **(c)**



Given: $r = \frac{V_1}{V_2} = 12$

$$\% \text{ clearance volume} = \frac{V_2}{V_1 - V_2} \times 100 = \frac{V_2}{V_2\left(\frac{V_1}{V_2} - 1\right)} \times 100$$

$$= \frac{1}{12-1} \times 100 = \frac{100}{11} = 9.09\%$$

40. **(b)**

Catalytic Converters: 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. When emissions of oxides of nitrogen are high, it is necessary to use a reducing catalytic converter. Since a reducing catalytic converter requires an atmosphere having low oxygen concentration, it is necessary to operate the engine with a slightly rich air-fuel mixture. Excess oxygen needed in the oxidizing converter is obtained by injecting secondary air between the two converters.

41. **(d)**

42. **(b)**

$$\text{Energy input per second} = \frac{\left(\frac{BP}{\eta_m}\right)}{\eta_{ith}} \quad \left[\text{As } \eta_m = \frac{B.P.}{I.P.} \text{ and } \eta_{ith} = \frac{I.P.}{\text{Energy input/sec}}\right]$$

$$= \frac{30}{0.8 \times 0.35} = 107.143 \text{ kJ/sec}$$

$$\text{Number of power strokes/sec} = \frac{N}{2 \times 60} = \frac{6000}{120} = 50$$

$$\text{Energy input/power stroke} = \frac{107.143}{50} = 2.143 \text{ kJ}$$

43. (b)

The normal range of volumetric efficiency at full throttle for S.I. engines is between 80 to 85%, where as for C.I. engine, it is between 85 to 90%.

44. (c)

As we know,

$$(\rho - 1) = \frac{20}{3 \times 100}(r-1)$$

$$= \frac{20}{300} \times (16-1) = \frac{2}{30} \times 15$$

$$\rho = 2$$

Also,

$$\eta_d = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}\right] = 1 - \frac{1}{(16)^{0.5}}\left[\frac{(2)^{1.5}-1}{1.5 \times (2-1)}\right]$$

$$= 1 - \frac{1}{4} \times \frac{(2.83-1)}{1.5} = 1 - \frac{1.83}{6}$$

$$= 1 - 0.305$$

$$\eta_d = 0.695 \text{ or } 69.5\%$$

45. (b)

As the mixture becomes richer, after a certain point both thermal efficiency and power output falls. This is because in addition to higher specific heats and chemical equilibrium losses, there is insufficient air which will result in formation of CO and H_2 during combustion which represents a direct wastage of fuel.

46. (c)

In throttle body MPFI system an injector is placed slightly above the throat of the throttle body.

47. (d)

48. (c)

Given: $\sigma_x = 200\sqrt{2}\cos 45° = 200 \text{ MPa}$, σ_y = –100 MPa, $\tau_{xy} = 200\sqrt{2}\sin 45° = 200 \text{ MPa}$

Principal stresses,

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

$$= \left(\frac{200-100}{2}\right) \pm \sqrt{\left(\frac{200+100}{2}\right)^2 + (200)^2}$$

$$= 50 \pm \sqrt{(150)^2 + (200)^2} = 50 \pm 250$$

$$= 300 \text{ MPa}, -200 \text{ MPa}$$

49. (d)

Given: P = 10 kN = 10000 N, v = 1 m/s, l = 500 m, $A = 1 \times 10^{-4}$ m², $E = 200 \times 10^6$ Pa.

$$\text{Kinetic energy in the cable} = \frac{WV^2}{2g} = \frac{10000 \times (1)^2}{2 \times 10} = 500 \text{ N-m}$$

$$\text{Strain energy in the cable} = \frac{\sigma^2}{2E} \times \text{Volume} \Rightarrow \frac{\sigma^2}{2 \times 200 \times 10^6} \times 1 \times 10^{-4} \times 500$$

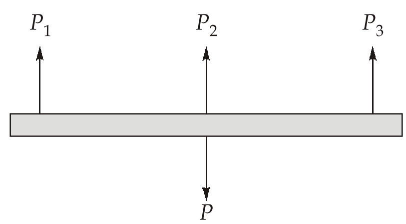
$$\frac{\sigma^2 \times 500}{400 \times 10^{10}} = 500$$

$$\sigma^2 = \frac{500 \times 400 \times 10^{10}}{500}$$

$$\sigma = 2 \text{ MPa}$$

50. (a)

Let us use suffix 1 for outer bars and suffix 2 for the inner bar.



From statically equilibrium, $2P_1 + P_2 = P$

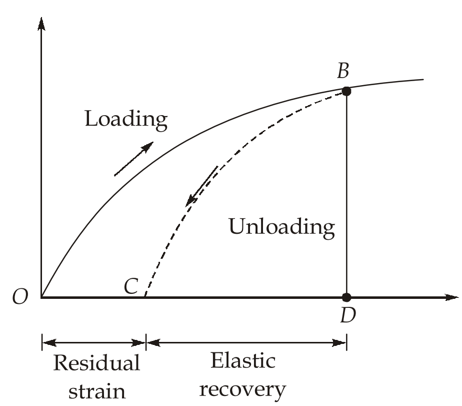
From compatibility, $\Delta_1 = \Delta_2$

$$\frac{P_1 L_1}{A_1 E_1} = \frac{P_2 L_2}{A_2 E_2}$$

$$\frac{P_1 (L)}{AE} = \frac{P_2 (3L)}{AE}$$

$$\frac{P_1}{P_2} = 3$$

51. (b)



$$\text{Elastic recovery} = 0.008 - 0.002 = 0.006$$

$$\text{Stress} = 500 \text{ N/mm}^2$$

$$E = \frac{\text{Stress}}{\text{Elastic recovery}} = \frac{500}{0.006}$$

$$= 83.33 \times 10^3 \text{ N/mm}^2$$

52. (b)

According to maximum principal stress theory.

Since σ_3 is numerically the largest stress, it will be the basis of failure,

$$\sigma_3 = \frac{f_y}{N} \text{ or } N = \frac{f_y}{\sigma_3}$$

$$N = \frac{200}{100} = 2$$

53. (b)

The elastic limit caused by bending moment M,

$$\sigma_y = \frac{32M}{\pi d^3}$$

Shear stress τ produced by torque T,

$$\tau = \frac{16T}{\pi d^3}$$

This shear stress is accompanied by complementary shear stress,

$$\sigma_1 = -\sigma_2 = \frac{16T}{\pi d^3}$$

By maximum principal stress theory,

$$\frac{16T}{\pi d^3} = \sigma_y = \frac{32M}{\pi d^3}$$

$$\frac{M}{T} = 0.5$$

54. (d)

Given: $d = 100$ mm, $t = 2$ mm, $\sigma_y = 400\ \text{N/mm}^2$, $N = 4$, $(\tau_{max})_{allowable} = \frac{\tau_{max}}{FOS} = \frac{1}{4}\left(\frac{400}{2}\right) = 50\ \text{N/mm}^2$

By using M.S.ST, $$\tau_{max} = \frac{Pd}{4t}$$

$$P = \frac{50 \times 4 \times 2}{100} = 4\ \text{N/mm}^2$$

55. (b)

Lame analyzed the problem of stress distribution in thick shells, based on following assumptions.

1. The material of the shell is homogeneous and isotropic.
2. Plane sections perpendicular to the longitudinal axis remain plane after deformation.
3. Longitudinal strain remains uniform throughout the thickness of cylinder.
4. Cylinder is subjected to only internal and external radial pressure.
5. The radial stress is compressive, while circumferential stress is tensile.

56. (b)

When the load of 10 kN is uniformly distributed over a span of 1 m.

$$M_{max} = \frac{\omega L^2}{8}$$

$$w = \frac{80}{1} = 80\text{ kN/m} = 80\text{ N/mm}$$

$$= \frac{80 \times (1000)^2}{8} = 10 \times 10^6 \text{ N-mm}$$

$$M_r = \sigma z = 300 \times \left(\frac{bd^2}{6}\right) = 300 \times \left[\frac{b(2b)^2}{6}\right]$$

$$= 300 \times \frac{4b^3}{6} = 300 \times \frac{2}{3} b^3$$

Equating the moment of resistance to the maximum bending moment

$$200b^3 = 10 \times 10^6$$

$$b = 36.84 \text{ mm}$$

57. (a)

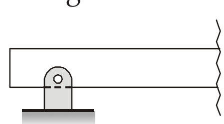
Given: D = 100 mm, σ_y = 50 N/mm^2

$$T = \frac{\tau \pi D^3}{16} = \frac{50 \times \pi \times (100)^3}{16} \text{ Nmm}$$

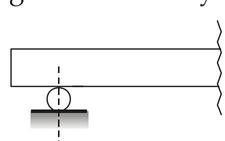
$$T = 9812.5 \text{ Nm} = 9.81 \text{ kNm}$$

58. (c)

A pinned support is capable of resisting a force in any direction of the plane.



A roller support is capable of resisting a force in only one specific line of action.



59. (c)

- The pressure angle of the cam decreases with increase in the base circle diameter.
- In a cam follower motion, the followers has constant acceleration when it moves with parabolic motion.
- The most suitable follower motion programme for high speed engine is cycloidal.

60. (a)

Given: Length of slotted bar = 250 mm, Quick return ratio = 2.

$$\text{QRR} = 2 = \frac{\beta}{\alpha}$$

$$\alpha + \beta = 360°$$
$$\alpha + 2\alpha = 360°$$
$$\alpha = 120°$$

Also, $$\frac{\text{Crank length}}{\text{Length of connecting rod}} = \cos\frac{\alpha}{2} = \cos\frac{120}{2} = 60°$$

$$\text{Stroke} = 2 \times \left[\text{Length of slotted lever} \times \frac{\text{Crank length}}{\text{Length of connecting rod}}\right]$$
$$= 2 \times 250 \times \cos 60°$$
$$\text{Stroke} = 250 \text{ mm}$$

61. (c)

When the elements of a pair are held together mechanically, it is known as a closed pair. When two links of a pair are in contact either due to gravity or some spring action, they constitute an unclosed pair.

62. (a)

- Cycloid is the locus of a point on the circumference of circle that rolls without slipping on a fixed straight line.
- Epicycloid is the locus of a point on the circumference of a circle that rolls without slipping on the circumference of another circle.
- Hypocycloid is the locus of a point on the circumference of a circle that rolls without slipping inside the circumference of another circle.

63. (a)

The comparison is between primary force and secondary unbalance force.

$$\text{Primary force} = mr\omega^2 \cos\theta$$
$$\text{Secondary force} = mr\omega^2 \frac{\cos 2\theta}{n}$$

[Where, $n = \frac{l}{R} = \frac{\text{Connecting rod length}}{\text{Crank radius}}$]

- Usually the length of connecting rod is greater than crank radius. So, $n > 1$.
- As a result, the secondary forces are less than the primary forces.
- Furthermore, at low speeds, the secondary forces becomes negligible.

64. (c)

Given: $M_{reci} = 20$ kg, $M_{rot.} = 10$ kg, $N = 275$ rpm, Stroke = 250 mm, $r = \frac{\text{Stroke}}{2} = \frac{250}{2} = 125 \text{ mm}$.

$$\text{Mass to be balanced} = M_{rot} + 0.5M_{reci} = 10 + 0.5(20) = 20 \text{ kg}$$
$$mr\omega^2 = Bb\omega^2 \quad \text{(where, } B \text{ is balance mass)}$$
$$mr = Bb$$
$$20 \times 125 = B \times 100$$
$$B = 25 \text{ kg}$$

65. (a)

- For undamped system the frequencies depends upon the static deflection under the weight of its mass.
- When the system is under damped ($\xi < 1$), the frequency of the system decreases to $\omega_d\left(\omega_d = \omega_n\sqrt{1-\xi^2}\right)$ and the time period increases to $T_d = 2\pi/\omega_d$.
- At critical damping $\xi = 1$, $\omega_d = 0$ and $T_d = \infty$. The system does not vibrate and the mass, m moves back slowly to the equilibrium position.

66. (d)

The effort of the governor is the mean force acting on the sleeve to raise or lower it for a given change of speed. At constant speed, the governor is in equilibrium and the resultant force acting on the sleeve is zero.

67. (a)

Given: Mass = 50 kg, Spring stiffness = 25 × 1000 N/m

$$C = 0.2\,C_c$$

$$\frac{C}{C_c} = \xi = 0.2$$

Natural frequency of damped vibration $= \omega_n\sqrt{1-\xi^2} = \sqrt{\frac{k}{m}} \times \sqrt{1-\xi^2}$

$$= \sqrt{\frac{25\times1000}{50}} \times \sqrt{1-0.2^2} = \sqrt{500}\times\sqrt{0.96} = \sqrt{480}$$

$$\omega_d = 21.908 \text{ rad/sec}$$

68. (c)

Given: Arm length = 200 mm

At minimum speed, $h_1 = \sqrt{200^2 - 120^2} = 160 \text{ mm}$

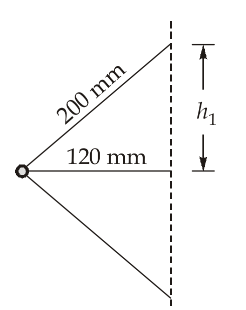


Fig 1: At minimum speed

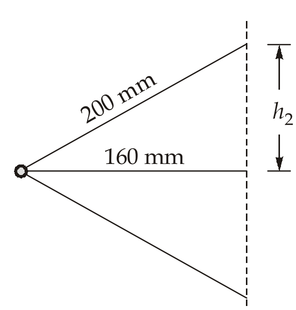


Fig 2: At maximum speed

At maximum speed, $h_2 = \sqrt{200^2 - 160^2} = 120 \text{ mm}$

Difference in height, $\Delta h = h_1 - h_2 = 160 - 120 = 40$ mm

69. (a)

For basic hole standard limit

$$\text{Lower limit of hole} = 70 \text{ mm}$$

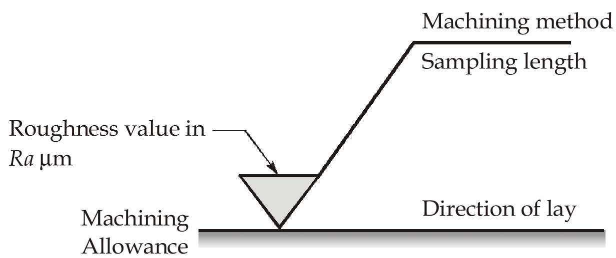
$$\text{Higher limit of hole} = \text{Low limit + Tolerance}$$

$$= 70 + 0.075 = 70.075 \text{ mm}$$

$$\text{Higher limit of shaft} = \text{Lower limit of hole – Allowance}$$

$$= 70 - 0.2 = 69.8 \text{ mm}$$

70. (a)



71. (b)

$$\Sigma A = \frac{\text{Sum of all areas}}{\text{Verticle magnification} \times \text{Horizontal magnification}}$$

$$= \frac{920}{10000 \times 100} = 0.00092$$

$$\text{CLA value} = \frac{\Sigma A}{L} = \frac{0.00092}{1} = 0.00092 \text{ mm}$$

$$= 0.00092 \times 1000 \text{ µm} = 0.92 \text{ µm}$$

72. (b)

Electrical stylus instruments convert vertical movements of the stylus into electrical signals to provide a numerical/graphical representation of surface roughness.

73. (b)

Honing is primarily used to remove the grinding or tool marks left on the surface by previous operations.

74. (d)

Given : Volume of air, $V = 4000$ cm^3; Height of sand specimen, $H = 5.2$ cm; A = 21.2264 cm^2

$$P = \frac{VH}{pAT}$$

$$\Rightarrow \quad P = \frac{4000 \times 5.2}{20 \times 21.2264 \times 2}$$

$$\therefore \quad P = 24.49$$

75. (b)

Press forging is considerably quieter operation than drop forging.

76. (c)

Flexible manufacturing transfer line consists of a multimachine layout including several CNC machine tools and other specialist pieces of equipment all under supervisory computer control. This system is used for high volume production.

77. (a)

- **Hour angle :** It is the angle through which the earth must turn to bring the meridian of the observer directly in line with the Sun's rays.
- **Inclination angle :** The angle between Sun's ray and its projection on horizontal surface is known as inclination angle.
- **Solar azimuth angle :** It is the angle on a horizontal plane, between the line due to south and the projection of Sun's rays on the horizontal plane.

78. (b)

- Fuel is supplied at the negative electrode, also known as fuel electrode or anode.
- Oxidant is supplied at positive electrode, also known as oxidant electrode or cathode.

79. (c)

EMF of a fuel cell is given by, $\frac{-\Delta G}{nF}$

where, $\Delta G \rightarrow$ Change in gibb's free energy in kJ/kg mol

$F \rightarrow$ Faraday's constant 96500 Coulombs per gram mole

$n \rightarrow$ Number of electrons transferred per molecule of the reactant

$$E = \frac{-\Delta G}{nF} = \frac{-(-817.97 \times 1000)}{8 \times 96500}$$

$$E = 1.059 \text{ V}$$

80. (b)

81. (d)

$$\text{Average power, } P = \frac{\frac{1}{2} \times A \times \rho \times g\left(R^2 - r^2\right)}{22350}$$

$$\Rightarrow \quad P = \frac{1 \times 22 \times 10^6 \times 1025 \times 9.81 \times \left(10^2 - 3^2\right)}{2 \times 22350}$$

$$\therefore \quad P = 450.35 \text{ MW}$$

82. (a)

- **Carbon to nitrogen ratio :** Methanogenic bacteria needs carbon and nitrogen for its survival. Carbon is required for energy while nitrogen for building cell protein. The consumption of carbon is 30-35 times faster than that of nitrogen.

- **Volumetric loading rate :** It is expressed as the quantity or organic waste fed into the digester per day per unit volume.
- **Solid to water ratio :** Raw cow dung contains about 80-82% moisture (by weight). It is usually mixed with equal amount of water to reduce solid content to 9-10%.

83. (b)

$$\text{Total power density} = \frac{1}{2}\rho V_u^3 = \frac{1}{2} \times 1.23 \times 10^3 = 615 \text{ W/m}^2$$

$$\text{Actual power density} = 0.5 \times 615 = 307.5 \text{ W/m}^2$$

$$\text{Power output} = \frac{307.5}{1000} \times \frac{\pi}{4} \times (10)^2 = 24.15 \text{ kW}$$

84. (a)

$$\text{Fill factor} = \frac{P_{max}}{V_{oc} \times I_{sc}}$$

$$0.7 = \frac{P_{max}}{0.6 \times 0.8}$$

$$P_{max} = 0.7 \times 0.6 \times 0.8$$

$$= 0.336 \text{ W}$$

85. (c)

$$(\tau\alpha)_{net} = \frac{\tau\alpha}{1-(1-\alpha)\times\rho d}$$

$$= \frac{0.8 \times 0.9}{1-(1-0.9)\times 0.7} = 0.774 \text{ or } 77.4\%$$

86. (a)

Fresnel lens refraction type focussing collector is made of an acrylic paste, flat on one side, with fine longitudinal grooves on the other side. The angle of grooves are designed to bring radiation to a line focus. The CR ranges between 10 and 80 with temperature varying between 150°C to 400°C

87. (b)

88. (b)

$$P_1 = 2 \text{ MPa}$$

$$P_2 = 0.5 \text{ MPa}$$

$$\text{Piston area} = 0.15 \text{ m}^2$$

Here, $\Delta V = A \times L$

We know, $W = \int P.dV$

= Area under P-v diagram

$$= \frac{1}{2}\times(P_1+P_2)\times A\times L$$
$$= \frac{1}{2}\times(2+0.5)\times 0.15\times 0.4 \text{ MJ}$$
$$= 75 \text{ kJ}$$

89. (a)

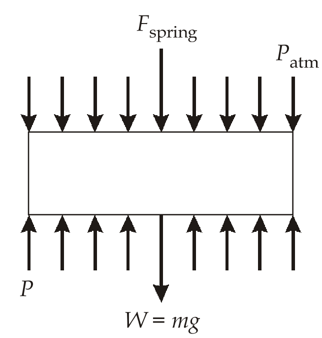
Given : P = 1 MPa; V_1 = 0.01 m^3; V_2 = 0.05 m^3; Q = 50 kJ

From first law of thermodynamics,

$$\delta Q = \Delta U + \delta W$$
$$\text{Work done} = P(V_2 - V_1)$$
$$= 1 \times (0.05 - 0.01)$$
$$= 40 \text{ kJ}$$
$$50 = \Delta U + 40$$
$$\Delta U = 10 \text{ kJ}$$

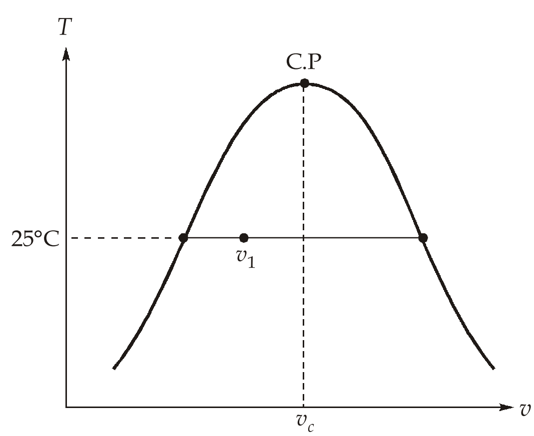
90. (b)

The free body diagram of the piston as shown in figure,



$$PA = P_{atm}A + W + F_{spring}$$
$$P = P_{atm} + \frac{mg + F_{spring}}{A}$$
$$P = 90 + \frac{2\times 10 + 100}{40\times 10^{-4}}$$
$$= 90 + \frac{120}{40\times 10^{-4}\times 10^3}$$
$$P = 120 \text{ kPa}$$

91. (a)



Considering volume and mass to be constant.

$$v_2 = v_1 = \frac{v}{m} = \frac{0.025}{12} = 0.00208 \text{ m}^3/\text{kg}$$

Eventually reaches saturated liquid and level rises to top.

92. (d)

The relation between the Joule-Thomson coefficient, constant pressure specific heat and the *p-v-T* behaviour of a substance is given by

$$C_p = \frac{1}{\mu}\left[T\left(\frac{\partial V}{\partial T}\right)_P - v\right]$$

when μ = 0 as it does on the inversion line, the equation becomes

$$T\left(\frac{\partial V}{\partial T}\right)_P = v \quad \text{...(i)}$$

using equation of state to evaluate the partial derivative

$$\left(\frac{\partial V}{\partial T}\right)_P = \frac{3R}{P} + \frac{2a}{T^2} \quad \text{...(ii)}$$

Substituting equation (ii) into (i), we get

$$T\left(\frac{3R}{P} + \frac{2a}{T^2}\right) = \frac{3RT}{P} - \frac{2a}{T} + \frac{b}{2}$$

$$\frac{4a}{T} = \frac{b}{2}$$

$$\Rightarrow \quad T = \frac{8a}{b}$$

93. (a)

We know,

By thermal efficiency, $\eta_H = \frac{\dot{W}}{\dot{Q}_H}; \quad \left(1 - \frac{T_L}{T_H}\right) = \frac{\dot{W}}{Q_H}$

$$\left(1 - \frac{T_L}{T_H}\right) \times 2(T_{res} - T_H) = \dot{W}$$

For maximum work, $\frac{d\dot{W}}{dT_H} = \frac{T_L}{T_H^2} \times 2(T_{res} - T_H) + \left(1 - \frac{T_L}{T_H}\right) \times 2(-1)$

$$\frac{d\dot{W}}{dT_H} = 0$$

$$2(T_{res} - T_H) \times \frac{T_L}{T_H^2} = 2\left(1 - \frac{T_L}{T_H}\right)$$

$$\frac{T_{res}T_L}{T_H^2} - \frac{T_L}{T_H} = 1 - \frac{T_L}{T_H}$$

$$T_H = \sqrt{T_{res}T_L}$$

$$\frac{d^2W}{d^2T_H} = k\left(-2T_{res}T_LT_H^{-3} + T_LT_H^{-2} - T_LT_H^{-2}\right)$$

$$= k\left(-2T_{res}T_LT_H^{-3}\right)$$

$$\frac{d^2W}{dT_H} < 0$$

So, should for high temperature,

$$T_H = \sqrt{T_{res}T_L}$$

94. (b)

If the entropy generated within the system is exactly equal to the entropy lost (e.g. by rejecting heat), then the net entropy change would be zero, and hence process will be isentropic.

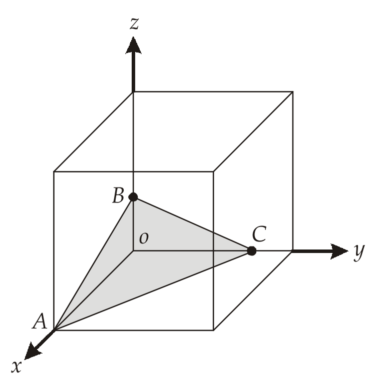
95. (b)

Triclinic crystal structure is least symmetric.

96. (c)

Atomic packing factor for FCC is 0.74.

97. (d)



For plane *ABC*

Intersection at x, y and z axes are at 1, $\frac{1}{2}$, $\frac{1}{2}$ respectively.

Taking reciprocal of intersects (1 2 2)
Miller indices will be (1 2 2).

98. (b)

Strain hardening occurs due to increase in dislocation density within a material which is plastically deformed. Annihilation of dislocations of opposite nature will reduces the dislocation density, which reduces internal stresses.

99. (a)

Given : Initial diameter = 12 mm; d_f = 10 mm

Engineering fracture strength, $\sigma_f = 400$ MPa

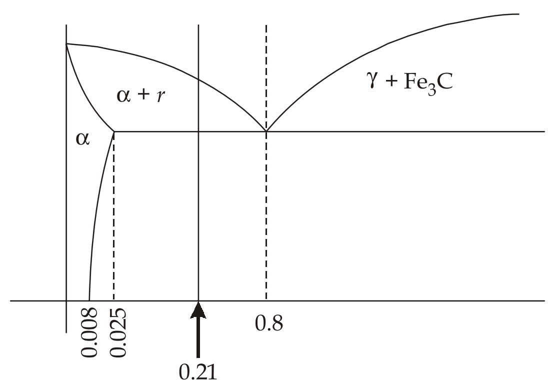
$$\text{True fracture stress, } \sigma_T = \sigma_f \frac{A_0}{A_f} = \sigma_f \left(\frac{d_o}{d_f}\right)^2$$

$$\sigma_T = 400\left(\frac{12}{10}\right)^2 = 576 \text{ MPa}$$

100. (c)

Fretting is the surface damage, which results when two surfaces in contact experience slight periodic relative motion.

101. (b)



By lever rule,

$$\text{Wt\% of proeutectoid ferrite} = \frac{0.8 - 0.21}{0.8 - 0.025}$$

$$= 0.76$$

102. (a)

By using Gibbs phase rule,

$$P + F = C + 1$$

C = 2, Number of components; i.e. lead + Tin

P = 3, Number of phase (liquid, α, β)

$$3 + F = 1 + 2$$

$$F = 0$$

The system has zero degrees of freedom, neither temperature nor composition can be changed without bearing the eutectic equilibrium.

103. (c)

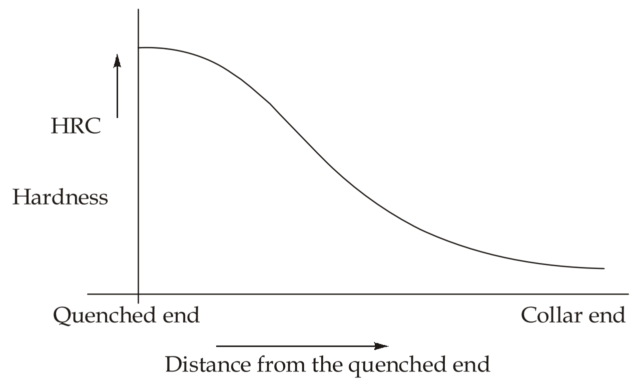


Fig. Jominy bar quench test

104. (b)

Laser and electron beams can focus energy on small area, these processes are extremely fast and energy efficient, also these processes are extremely costly.

105. (a)

Pickling, electroplating and heat treatments in hydrogen-rich environments promote hydrogen entry into metals. Inert gas shielding prevents hydrogen contact and is not a caused.

106. (c)

- Taper roller bearings allow adjustment of radial clearance by moving one bearing ring axially relative to other.
- Taper roller bearings are designed to carry both radial and axial (thrust) load.
- Back-to-back and face-to-face are two types of popular constructions used to balance the thrust reaction.

107. (a)

Given : C = 300 kN, L_{10h} = 60000 hours; n = 370 rpm

$$L_{10} = \frac{60 \times n \times L_{10h}}{10^6} = \frac{370 \times 60000 \times 60}{10^6} = 1332 \text{ million rev.}$$

$$\text{Equivalent radial load, } L_{10} = \left[\frac{C}{P}\right]^3$$

$$1332 = \left[\frac{300}{P}\right]^3$$

$$(1332)^{1/3} = \frac{300}{P}$$

$$11.003 = \frac{300}{P}$$

$$P = 27.265 \text{ kN} \simeq 27.27 \text{ kN}$$

108. (c)

Given : for plates $w = 100$ mm; $t = 10$ mm; $\sigma_t = 200$ MPa

$$\text{Tensile force on plates, } P = \sigma_t (wt)$$
$$= 200 \times 100 \times 10$$
$$= 200 \text{ kN}$$
$$\text{Length of the weld, } P = 2 \times (0.707t)l \times \sigma_t$$
$$P = 2 \times 0.707 \times 10 \times l \times 200$$
$$200 \times 10^3 = 2 \times 0.707 \times 10 \times l \times 200$$
$$l = \frac{1000}{2 \times 0.707 \times 10}$$
$$l = 50\sqrt{2} \text{ mm}$$

109. (a)

Goodman line is widely used as the criterion of fatigue failure when component is subjected to mean stress as well as stress amplitude, because:

(a) Goodman line is safe from design consideration because it is completely inside the failure points of test data.

(b) Equation is straight line and simple.

(c) It is not necessary to construct scale diagram.

110. (b)

Given : $k_t = 0.8$, $q = 0.9$

For fatigue stress concentration factor,

$$q = \frac{k_f - 1}{k_t - 1}$$
$$0.9 \times (0.8 - 1) = k_f - 1$$
$$1 - 0.18 = k_f$$
$$k_f = 0.82$$

111. (b)

Given : $S_{ut} = 500$ N/mm^2; $k_a = 0.7$, $k_b = 0.85$, $k_c = 1$

$$\text{Endurance limit stress for rod, } S_e' = 0.5 S_{ut}$$
$$= 0.5 \times 500 = 250 \text{ N/m}^2$$
$$S_e = k_a k_b k_c S_e'$$
$$= 0.7 \times 0.85 \times 1 \times 250$$
$$= 148.75 \text{ N/mm}^2$$

112. (a)

Sharp notches introduce high stress concentration rather than reducing it. A V-notch creates localized stress risers, increasing the chances of failure.

113. (b)

Given : ΔT = 225 – 25 = 200°C; E = 200 GPa; $\alpha = 10 \times 10^{-6}$ per°C

$$\text{Stress} = \alpha \Delta T E$$
$$= 10 \times 10^{-6} \times 200 \times 200 \times 10^{3}$$
$$= 400 \text{ MPa}$$

114. (d)

Given : P = 2 MPa = 2 N/mm^2; $\mu = 25 \times 10^{-9}$ N-s/mm^2; r/c = 500; $n_s = \frac{2940}{60} = 49$ rps

$$\text{Sommerfeld number, } S = \left(\frac{r}{c}\right)^2 \frac{\mu n_s}{P}$$

$$S = (500)^2 \times \frac{25 \times 10^{-9} \times 49}{2}$$

$$S = 0.153$$

115. (a)

The desirable properties of lubricating oil are as follows:

(i) It should be available in a wide range of viscosities.

(ii) There should be little change in viscosity of the oil with change in temperature.

(iii) The oil should be chemically stable with bearing material and atmosphere at all temperatures encountered in the application.

(iv) The oil should have sufficient specific heat to carry away frictional heat, without abnormal rise in temperature.

(v) It should be commercially available at reasonable cost.

116. (a)

According to Lewis assumption, the tangential component (P_t) is uniformly distributed over the face width of the gear.

117. (d)

The velocity factor for helical gears is given by,

$$C_v = \frac{5.6}{5.6 + \sqrt{v}}$$

where, v is the pitch line velocity in m/s.

118. (a)

Given : ω_1 = 60 rad/s; μ = 0.2; m = 1 kg; z = 4; r_d = 140 mm; r_g = 100 mm; ω_2 = 150 rad/s

We know, torque transmitting capacity of clutch is given by

$$M_t = \frac{\mu m r_g r_d z\left(\omega_2^2 - \omega_1^2\right)}{1000}$$

$$= \frac{0.2 \times 1 \times 140 \times 100 \times 4\left(150^2 - 60^2\right)}{1000}$$

$$= \frac{0.2 \times 140 \times 100 \times 4 \times 18900}{1000}$$

$$= 211680 \text{ Nmm} = 211.68 \text{ Nm}$$

119. (a)

The PIC microcontroller, PIC16F877 is a 40-pin device with five ports giving a total of 33 I/O pins. It has 198k RAM data memory, 128k EEPROM data memory, and 4k flash program memory. Some pins are reserved for specific functions: pins C1 and C2 can be configured as a timer or a pulse width modulator, pins C3 and C4 can be configured with I²C used to communicate with a compass, while pins C6 and C7 can be configured as a USART (universal synchronous/asynchronous transmitter/receiver) clock. Moreover, C5 can also be configured with the SPI data out (SPI mode).

120. (b)

$$\text{Drill resolution} = \frac{\text{Range}}{2^n - 1} = \frac{2000 - 0}{2^8 - 1}$$

$$= \frac{2000}{256} = 7.8125 \text{ rpm}$$

121. (b)

Data lines : The data lines used to communicate words to and from data registers in the various system components such as memory, CPU, and input/output peripherals.

Control lines : The control lines transmit read and write signals the system clock signal, and other control signals such as system interrupts, which are described in subsequent section.

Random Access Memory : RAM is used for sterility data that is used during the program run-time, Data can be read from or written to RAM at any time, provided power is maintained.

122. (a)

123. (d)

A resolver provides a measure of shaft angle, typically with sine and cosine analog outputs. It uses an AC magnetic technique similar to the LVDT, and similar support electronics to provide synchronous detection. Resolvers are very rugged and for this reason are often preferred over optical encoders on motor shafts, although they are not as accurate and they have greater support electronics requirements. Some resolver drives have extra outputs as if they were incremental encoders, for compatibility. Additionally, resolvers provide an absolute measure of shaft angle. The resolver, like the LVDT, is a well established and evolved technology.

124. (c)

$$R_{35} = R_{27}[1 + \alpha(35 - 27)] = 110[1 - 0.06(8)]$$

$$R_{35} = 57.2\ \Omega$$

125. (a)

126. (a)

A path is defined as the collection of a sequence of configurations a robot makes to go from one place to another without regard to the timing of these configuration whereas trajectory is related to the timing at which each part of the path must be attained.

127. (c)

Since, the point is attached to the rotating frame, the co-ordinates of the point relative to the rotatory frame remain the same after the rotation. The co-ordinate of the point relative to the reference frame will be

$$\begin{bmatrix} P_x \\ P_y \\ P_z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos 90° & -\sin 90° \\ 0 & \sin 90° & \cos 90° \end{bmatrix} \times \begin{bmatrix} 5 \\ 2 \\ 3 \end{bmatrix}$$

$$\begin{bmatrix} P_x \\ P_y \\ P_z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix} \times \begin{bmatrix} 5 \\ 2 \\ 3 \end{bmatrix} = \begin{bmatrix} 5 \\ -3 \\ 2 \end{bmatrix}$$

128. (c)

129. (b)

A humanoid robot normally has four limbs (two legs and two arms) which are open kinematic-chains. If one adopts the scheme of one-to-many coupling for the kineto-dynamic pairs in a limb, it is better to employ a device called a serial splitter of motion. A serial splitter of motion is a mechanism which duplicates the input rotary motion into multiple output motions at multiple output shafts aligned in a series.

130. (a)

Visual perception is an information process which takes digital images as input, and produces descriptions of the objects in a scene as output.

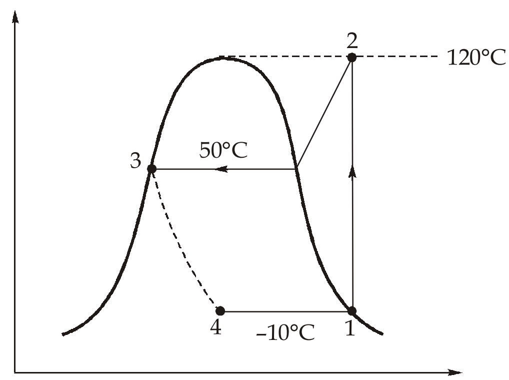
A scene is a collection of objects and physical entities which are in proximity to an observer such as a robot.

The monocular-vision system takes images as input, and produces geometrical measurement as output. A monocular-vision system is normally composed of: a) a single electronic camera (either color or monochrome), b) an image digitizer (if the camera's output is analogue video), and c) computing hardware.

Binocular vision uses two cameras, usually placed at a fixed distance from each other, to capture slightly different views of the same scene.

131. (d)

Given : $h_4 = h_3 = 133$ kJ/kg; $h_1 = 460$ kJ/kg; $v_{g_1} = 0.233$ m^3/kg



Effective swept volume of the compressor,

$$v = \frac{\pi}{4} d^2 L \times \eta_v \times N \text{ m}^3/\text{min}$$
$$= \frac{\pi}{4}(0.07)^2 \times (0.07) \times (0.8) \times 500$$
$$= 0.1077 \text{ m}^3/\text{min}$$

Mass flow of refrigerant, $m_r = \frac{v}{v_{g1}} = \frac{0.1077}{0.233}$

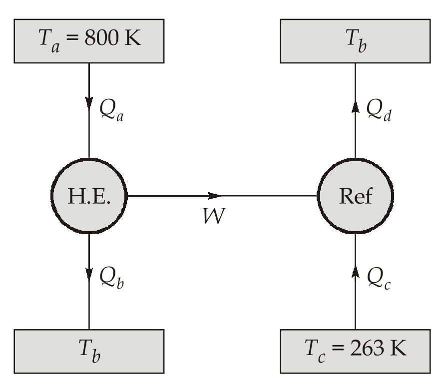
$$= 0.46 \text{ kg/min}$$

132. (b)

At reduced loads the absorption unit is almost as efficient as at full load. The load variations are met by controlling the quantity of steam supplied to the generator.

133. (a)

Given : $Q_c = Q_a$



$$\eta_{\text{engine}} = \frac{W}{Q_a} = \left(\frac{T_a - T_b}{T_a}\right)$$

$$(\text{COP})_{\text{ref}} = \frac{Q_c}{W} = \frac{T_c}{T_b - T_c}$$

$$Q_c = Q_a$$

$$\frac{Q_c}{Q_a} = \left(\frac{T_a - T_b}{T_a}\right) \times \left(\frac{T_c}{T_b - T_c}\right)$$

$$1 = \left(\frac{800 - T_b}{800}\right) \times \left(\frac{263}{T_b - 263}\right)$$

$$\frac{800}{263} = \frac{800 - T_b}{T_b - 263}$$

$$\frac{800}{263}(T_b - 263) = 800 - T_b$$

$$\frac{800}{263}T_b - 800 = 800 - T_b$$

$$3.04T_b = 1600 - T_b$$

$$4.04T_b = 1600$$

$$T_b = 123.03°C \simeq 123°C$$

134. (a)

Given : at 12°C, P_v = 1.480 kN/m²

$$\text{Partial pressure of dry air } P = 1.01325 \text{ bar}$$

$$P_a = P - P_v$$

$$= 101.325 - 1.480$$

$$= 99.845 \text{ kN/m}^2$$

$$\text{The specific humidity, } W = 0.622\,\frac{P_v}{P_a}$$

$$= 0.622 \times \frac{1.48}{99.845}$$

$$= 9.219 \text{ g/kg of d.a.}$$

135. (c)

The Hot Gas Bypass System prevents the evaporator surface from frosting and avoids high back pressure.

136. (c)

Energy absorbed by aluminium will be

$$= 0.20 \times 1000 \text{ W/m}^2$$

$$= 200 \text{ W/m}^2$$

$$\text{Energy re-radiated} = 200 \times 0.5 = 100 \text{ W/m}^2$$

$$100 = \varepsilon\sigma T_s^4$$

$$100 = 0.05 \times 5.67 \times 10^{-8} \times (T_s)^4$$

$$\left(\frac{100}{0.05 \times 5.67 \times 10^{-8}}\right)^{0.25} = T_s$$

$$T_s = 433.37 \text{ K}$$

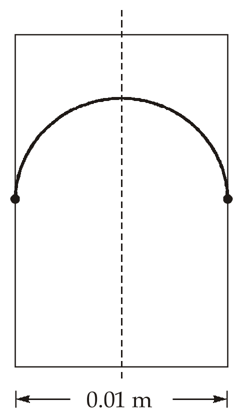
137. (c)

Given : $k = 0.2$ W/mK; $h = 15$ W/m^{2}K

$$\text{Critical radius of insulation} = \frac{k}{h} = \frac{0.2}{15} = 13.33 \text{ mm}$$

$$\text{Critical thickness of insulation} = r_c - r_i = 13.33 - 10 = 3.33 \text{ mm}$$

138. (c)

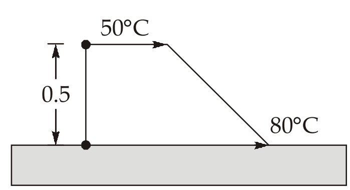


$$\text{Total heat generated, } Q_g = 5 \times 10^8 \times (1 \times 0.01)$$
$$= 50 \times 10^5 \text{ W/m}^2$$

Under steady state conditions,

$$50 \times 10^5 = hA(t - 127)$$
$$= 2.5 \times 10^4 \times (t - 127)$$
$$t = 327°\text{C}$$
$$t = 600 \text{ K}$$

139. (b)



$$\text{The heat transfer coefficient, } h = \frac{-k}{(t_s - t_\infty)}\left(\frac{dt}{dy}\right)_{y=0}$$

Assuming linear variation of temperature,

$$\left(\frac{dt}{dy}\right) = \frac{50 - 80}{0.5 \times 10^{-3}} = -60000°\text{C/m}$$

$$h = \frac{-0.0266}{(80 - 27)}(-60000)$$

$$h = 30.11 \text{ W/m}^2\text{-°C}$$

140. (b)

Nucleate boiling is promoted on rough or irregular surfaces, as surface cavities and imperfections act as nucleation sites for bubble formation.

141. (c)

Given :

Maximum demand = 360
Maximum lead time = 1.5 months
Average demand = 310
Lead time = 1 month
Optimum buffer stock = Maximum lead time demand – Normal lead time demand
= 1.5 × 360 – 1 × 310
= 230

142. (b)

A basic feasible solution in a transportation problem must satisfy:

- It has exactly $(m + n - 1)$ independent allocations.
- The allocations should be independent i.e. no closed loop should exist within the allocated cells.

143. (c)

Total float for 4 - 5 = 37 – 26 – 1 = 10

and Total float for 5 - 6 = 40 – 27 – 3 = 10

Difference = 10 – 10 = 0

144. (c)

- Product layout or assembly line, arranges activities in a line according to the sequence of operations that need to be performed to assemble a particular product. Each products has its own "line" specifically designed to meet its requirements.
- Product layout are suitable for mass production or repetitive operations in which demand is stable and volume is high.

145. (a)

Standard time includes fatigue, tool setting and job checking.

Standard time = Average time or observed time × Rating factor + Allowances

S.T = Basic time or Normal time + Allowances

Allowance such as fatigue, setting of tool and job, repairing of tool and checking of job etc are added to basic time to get standard time.

146. (b)

147. (d)

Taking moment at end A,

$$W \times \frac{R}{2} = R_{BV} \times 2R$$

$$R_{BV} = \frac{W}{4} \text{ and } R_{AV} = W - \frac{W}{4} = \frac{3W}{4}$$

Considering portion *ACD* only.

Moment about *D*, $\Sigma M_0 = 0$

$$R_{AH}(R) + W \times \frac{R}{2} = R_{BV} \times R$$

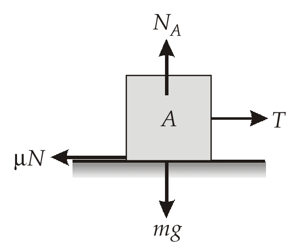
$$R_{AH} + \frac{W}{2} = \frac{3W}{4}$$

So, $R_{BH} = 20 \text{ N}$ (For equilibrium)

So, $W = 80 \text{ N}$

148. (d)

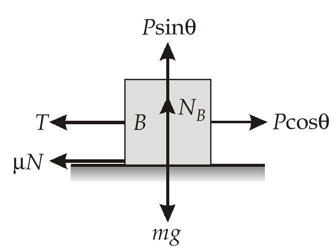
For block *A*,



$$T = \mu N_A$$

$$T = \mu mg$$

For block *B*,



Net vertical force, $N_B = mg - P\sin\theta$

For horizontal equilibrium,

$$T + \mu N_B = P\cos\theta$$

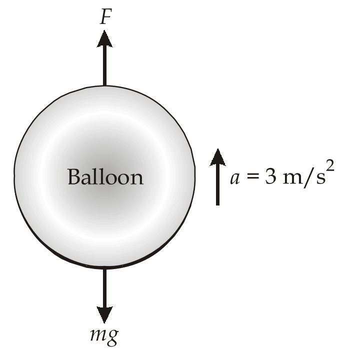
$$\mu mg + \mu(mg - P\sin\theta) = P\cos\theta$$

$$\mu mg + \mu mg = \mu P\sin\theta + P\cos\theta)$$

$$P = \frac{2\mu mg}{\mu\sin\theta + \cos\theta}$$

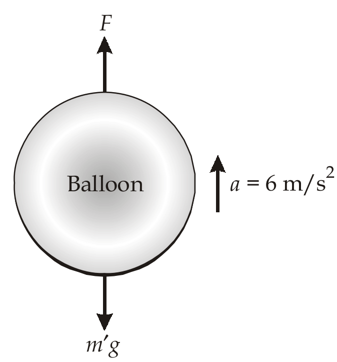
149. (a)

Initially balloon was moving upward at 3 m/s^2



$$F - mg = ma$$
$$F = m(g + a)$$
$$F = m(9.81 + 3) \quad ...(i)$$

When some sand is removed then weight of sand becomes m'



$$F - m'g = m'a$$
$$F = m'(9.81 + 6) \quad ...(ii)$$

Dividing equation (i) and (ii), we have

$$\frac{m'}{m} = \frac{9.81 + 3}{9.81 + 6} = 0.81$$

$$\text{Fraction removed} = \frac{m - m'}{m} = 1 - \frac{m'}{m} = 0.189$$

$$\text{Fraction of sand removed} \simeq 0.19$$

150. (b)

- For a two force body to be in equilibrium, the sufficient condition is that the forces must be equal in magnitude, opposite in direction and collinear.
- Lami's theorem states that if a body is in equilibrium under the action of three forces, each force is proportional to sine of the angle between the other forces.