DETAILED SOLUTIONS

MADE EASY

India's Best Institute for IES, GATE & PSUs

Test Centres: Delhi, Hyderabad, Bhopal, Jaipur, Lucknow, Bhubaneswar, Pune, Kolkata, Patna

ESE 2022 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 22

Full Syllabus Test 6 : Paper-II

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

Q.35 : Marks to all

DETAILED EXPLANATIONS

1. (b)

According to MDET :

$$\frac{1}{2}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]\le\left(\frac{\sigma_{yt}}{\text{FOS}}\right)^2$$

$$3\times 150^2 \le \left(\frac{\sigma_{yt}}{\sqrt{3}}\right)^2$$

$$\Rightarrow \quad \sigma_{yt} = 3\times 150 = 450 \text{ MPa}$$

2. (b)

Given : d = 2 m = 2000 mm, t = 15 mm

Limiting the hoop stress to 90 N/mm^2,

$$\sigma_1 = \frac{pd}{2t}=90$$

$$p = \frac{90\times2\times15}{2000}=1.35 \text{ N/mm}^2$$

Limiting the axial stress to 60 N/mm^2,

$$\sigma_2 = \frac{pd}{4t}=60$$

$$p = \frac{4\times15\times60}{2000}=1.8 \text{ N/mm}^2$$

So, maximum safe air pressure is 1.35 N/mm^2.

3. (b)

$$\text{Vertical movement of top surface} = \frac{WL}{AE}+\frac{WL}{2AE}=\frac{3}{2}\frac{WL}{AE}$$

4. (c)

We know that

$$P_A = P_B$$

$$T_A\times\omega_A = T_B\times\omega_B$$

$$\frac{T_A}{T_B} = \frac{\omega_B}{\omega_A}=\frac{Z_A}{Z_B}\Rightarrow\frac{250}{50}=5=\text{ Gear ratio}$$

$$T_A = 5T \quad \text{...(i)} \qquad (\text{Let } T_B = T)$$

Angle of twist,

$$\theta_{A/C} = \frac{T_{A/C}L_{A/C}}{GJ_{A/C}}=\frac{5TL}{GJ}$$

$$\theta_{B/C} = \frac{T_{B/C}L_{B/C}}{GJ_{B/C}}=\frac{TL}{GJ}$$

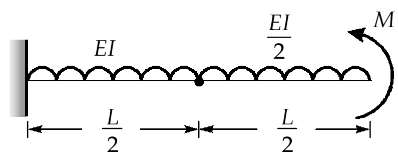
For relative rotations of ends A and B, assume end A to be fixed while the twisting effort is at B. The angular displacement of shaft AC is transmitted through the gear ratio 5. Therefore, the relative displacement of ends A and B is,

$$\theta_{A/B} = \theta_{A/C} \times 5 + \theta_{C/B}$$

$$= \frac{5TL}{GJ} \times 5 + \frac{TL}{GJ}$$

$$\theta_{A/B} = \frac{26TL}{GJ}$$

7. (b)



$$U = U_1 + U_2$$

$$= \frac{M^2\left(\frac{L}{2}\right)}{2EI} + \frac{M^2\left(\frac{L}{2}\right)}{2\times\left(\frac{EI}{2}\right)}$$

$$= \frac{M^2L}{4EI} + \frac{M^2L}{2EI}$$

$$U = \frac{3M^2L}{4EI}$$

$$\theta = \frac{\partial U}{\partial M} = \frac{6ML}{4EI} = \frac{3}{2}\frac{ML}{EI}$$

8. (b)

For thick walled cylinder,

$$p_x = -a + \frac{b}{x^2} \quad \text{...(i)}$$

$$\sigma_{hx} = a + \frac{b}{x^2} \quad \text{...(ii)}$$

$$\sigma_r = -P_x \quad \text{...(iii)}$$

Boundary condition, (1) At $r = r_i \Rightarrow p_x = p_i$

(2) At $r = r_o \Rightarrow p_x = p_o$

Putting these boundary condition in equation (i),

We obtain,

$$a = -p_o + \frac{(p_o - p_i)\times(r_o^2 \times r_i^2)}{(r_o^2 - r_i^2)}$$

and $$b = \frac{(p_o - p_i)\times(r_o^2 \times r_i^2)}{(r_o^2 - r_i^2)}$$

$$\sigma_h = -p_o + \frac{(p_o - p_i)\times(r_o^2 \times r_i^2)}{(r_o^2 - r_i^2)} + \frac{(p_o - p_i)(r_o^2 \times r_i^2)}{(r_o^2 - r_i^2)\times r^2}$$

$$\sigma_r = -p_o + \frac{(p_o - p_i)\times(r_o^2 \times r_i^2)}{(r_o^2 - r_i^2)} - \frac{(p_o - p_i)(r_o^2 \times r_i^2)}{(r_o^2 - r_i^2)\times r^2}$$

∴ The maximum shear stress $= \left[\frac{\sigma_h - \sigma_r}{2}\right]$

$$= \frac{(p_o - p_i)\times r_o^2 \times r_i^2}{(r_o^2 - r_i^2)\,r^2}$$

9. (d)

In Mohr's circle for strains radius of Mohr's circle $= \frac{\gamma_{max}}{2} = \frac{\varepsilon_1 - \varepsilon_2}{2}$

where γ_{max} = maximum value of shear strain
ε_1, ε_2 = principal strains

10. (b)

The fatigue or endurance limit of a material is defined as the maximum amplitude of completely reversed stress that the standard specimen can sustain for an unlimited number of cycles without fatigue failure. It can be also defined as the stress at which a material fractures under a large number of reversal of stress.

11. (d)

The net work done per unit weight of water (taking into account the losses)

$$= \frac{1}{g}\left[(V-u)\,u\,(1-\cos\phi)\right] - \frac{k_1(V-u)^2}{2g} - \frac{k_2u^2}{2g}$$

∴ Efficiency, $$\eta = \frac{\frac{1}{g}\left[(V-u)\,u\,(1-\cos\phi)\right] - \frac{k_1(V-u)^2}{2g} - \frac{k_2u^2}{2g}}{\frac{V^2}{2g}}$$

$$\eta = \frac{2\left[(V-u)\,u\,(1-\cos\phi)\right] - k_1(V-u)^2 - k_2u^2}{V^2}$$

12. (b)

Since $$\frac{P_1}{D_1^2 H_1^{3/2}} = \frac{P_2}{D_2^2 H_2^{3/2}}$$

$$\frac{150}{D_1^2 (16)^{3/2}} = \frac{900}{D_2^2 (25)^{3/2}}$$

$$D_r = \frac{D_2}{D_1} = \sqrt{\frac{900}{150} \times \frac{64}{125}} = \sqrt{3.072}$$

$$D_r \simeq 1.75$$

14. (c)

Given : V = 20 m/s; u = 5 m/s; ρ = 1000 kg/m^3; A = 0.02 m^2

Force acting on plate = Change in momentum in x-direction

$$= \rho A(V-u)[(V-u)-0]$$

$$= 1000 \times 0.02 \times (20 - 5)^2$$

$$= 1000 \times 0.02 \times 15^2$$

$$= 4.5 \text{ kN}$$

15. (b)

$$\text{Radial velocity at exit} = \frac{Q_2}{\pi D_2 B_2} = \frac{80 \times 10^{-3}}{\pi \times 40 \times 10^{-2} \times 2.5 \times 10^{-2}}$$

$$= 2.55 \text{ m/s}$$

16. (b)

$$\sigma_c = \frac{(NPSH)_{min}}{H}$$

$$0.12 = \frac{(NPSH)_{min}}{30}$$

$$(\text{NPSH})_{\text{min}} = 3.6 \text{ m}$$

$$\text{NPSH} = \frac{(P_{atm})_{abs}}{\gamma} - \frac{P_v}{\gamma} - Z_s - h_L$$

where, $\gamma = \rho g$; Z_s = Elevation of the pump above the sump water surface; $(Z_s)_{\text{max}}$ corresponds to σ_c

$$(Z_s)_{\text{max}} = \frac{(P_{atm})_{abs}}{\gamma} - \frac{P_v}{\gamma} - h_L - (NPSH)_{min}$$

$$= \left(\frac{96}{10} - \frac{3.0}{10} - 0.3 - 3.6\right) \times \frac{10^3}{10^3}$$

$$= 5.4 \text{ m}$$

17. (b)

When a piping system is primarily made up of vertical lift and very little pipe friction, the pump characteristics should be steep and when a piping system is primarily made up of friction head and very little of vertical lift, the pump characteristics should be near horizontal.

18. (c)

Operation of NC machine tools is based on prepared programmes which consists of block or series of numbers in a coded language.

20. (c)

The dead band or dead space of a transducer is the range of input values for which there is no output. It is basically range of input values for which output is zero. Dead zone is also known as dead band, dead space or neutral zone.

21. (b)

Under normal condition, slider is at centre,

$\therefore$ Resistance at normal position, $R_T = \dfrac{15000}{2} = 7500\,\Omega$

Change in resistance, from normal position,

$$R_p = 7500 - 4000 = 3500\ \Omega$$

Now, Sensitivity, $k = \dfrac{15000}{100} = 150\ \Omega/\text{mm}$

$\therefore$ Displacement $= \dfrac{3500}{150} = 23.33$ mm

22. (c)

Full scale output from sensor,

$$V_{FS} = 256 \times 2 = 512 \text{ mV}$$

For a resolution of 0.5°C, we must be able to detect a signal from sensor = 0.5 × 2 = 1 mV

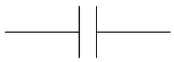
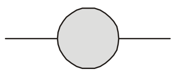
Now, with a word length of 'n' bits, for ADC resolution = $\dfrac{V_{FS}}{2^n}$

$\therefore$ $1 = \dfrac{512}{2^n}$

$\therefore$ $2^n = 512$

$\Rightarrow$ $n = 9$ bits

23. (d)

Ladder symbols	Instruction
1. 	Input as contacts not closed until input
2. 	Input as contacts which are closed until input
3. 	Output
4. 	Special instructions

24. (c)

For derivative mode of control,

$$I_{out} - I_o = k_D \frac{de}{dt}$$

where, I_o = Set point output value; I_{out} = Output value when error is changing at the rate $\frac{de}{dt}$ i.e. controller output; k_D = Proportionality constant

Now, substituting the values,

$$I_{out} = 60 + 0.5 \times 2$$
$$= 61\%$$

25. (d)

PID controller is also known as universal controller. It provides a continuous variation of output within a control loop feedback mechanism to accurately control the process, removing oscillation and increasing process efficiency.

26. (c)

- Micro-controller contains ALU, control unit and registers.
- It has internal memory.
- It has interfacing circuit, timers and counters.

28. (c)

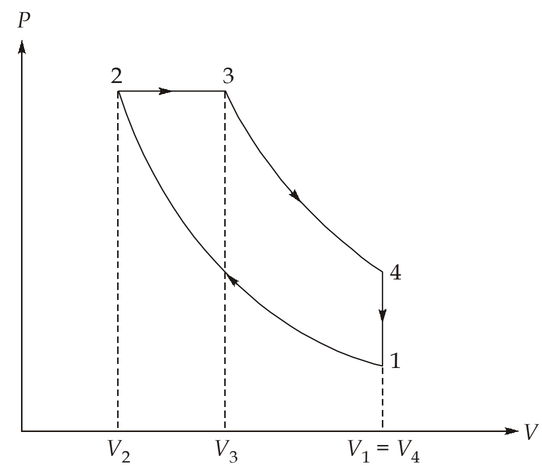
Interrupts which cannot be ignored when triggered are known as non-maskable interrupt e.g. TRAP.

29. (b)

η_v (at full throttle for CI engines) = 90%

η_v (at full throttle for SI engines) = 85%

30. (b)



$$\frac{V_3}{V_2} = \text{Cut off ratio}$$

$$\frac{V_1}{V_2} = r = \text{Compression ratio} = 17$$

$$V_1 = 17V_2$$

$$V_3 - V_2 = 0.06\,(V_1 - V_2)$$

$$V_3 - V_2 = 0.06 \times 16V_2$$

$$V_3 - V_2 = 0.96\,V_2$$

$$\frac{V_3}{V_2} = 1.96$$

31. (d)

For the same engine speed and cylinder volume, the power developed by a 4 stroke engine is half the power output from a 2 stroke engine.

32. (c)

The anti-knock value of diesel fuel is rated in terms of the cetane number. Cetane is a straight chain paraffin, has very good ignitability and is arbitarily assigned a rating of 100 cetane number. For observation of knock intensity, blend consisting of 60% cetane and 40% α-methyl naphthalene, then we will say that the commercial fuel has a cetane rating of 60.

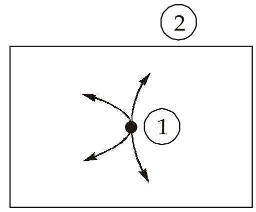
33. (b)

For heat flow at same rate in both the rods:

$$Q = \frac{K_a A_a (T_1 - T_2)}{l} = \frac{K_b A_b (T_1 - T_2)}{l}$$

or
$$\frac{K_a}{K_b} = \frac{A_b}{A_a}$$

34. (d)



$$(F_g)_{1\text{-}2} = \frac{1}{\frac{1-\varepsilon_1}{\varepsilon_1} + \frac{1}{F_{12}} + \left(\frac{1-\varepsilon_2}{\varepsilon_2}\right)\frac{A_1}{A_2}}$$

The configuration corresponds to a completely enclosed body, which is small compared with the enclosing body. That is

$A_1 <<< A_2$ and $F_{12} = 1$

Hence,
$$(F_g)_{1\text{-}2} = \frac{1}{\frac{1-\varepsilon_1}{\varepsilon_1}+1} = \frac{1}{\frac{0.6}{0.4}+1}$$

$$(F_g)_{1\text{-}2} = 0.4$$

35. (b)

The prescribed relation can be rewritten as:

$$\frac{hd}{k} = 0.53\left[\frac{\Delta t g d^3 \beta}{\nu^2}\right]^{0.25}$$

Using identical operating conditions,

$$\frac{h_1}{h_2} = \left(\frac{d_2}{d_1}\right)^{0.25} = \left(\frac{16}{4}\right)^{0.25} = \sqrt{2}$$

$$h_2 = \frac{h_1}{\sqrt{2}} = \frac{1412}{\sqrt{2}} = 1000 \text{ kcal/m}^2\text{-hr-°C}$$

36. (b)

$$\bar{h} = \frac{4}{3}h_x \text{ i.e.}$$

the average heat transfer coefficient is four-third of the local heat transfer coefficient at the lower edge of the plate.

37. (b)

For parallel flow,
$$\in = \frac{1-e^{-(1+C)NTU}}{1+C}$$

For counter flow, $\in = \dfrac{1-e^{-(1-C)NTU}}{1+Ce^{-(1-C)NTU}}$

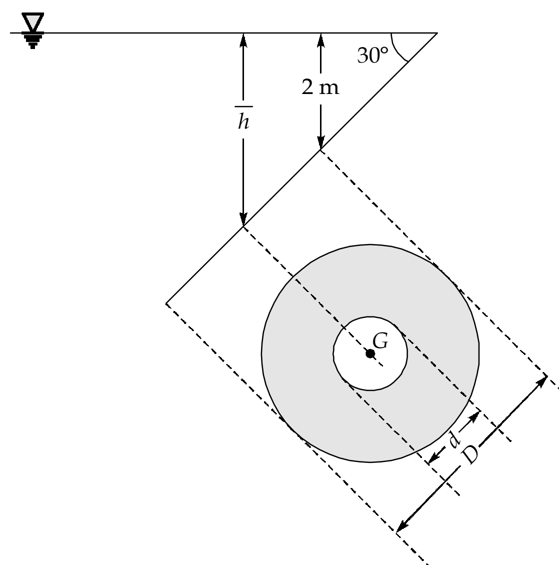
For phase change process, $C = 0$

$\therefore$ $\in_{\text{parallel flow}} = \in_{\text{counter flow}} = 1 - e^{-NTU}$

38. (b)

For a spherical drop, $\Delta P = \dfrac{4\sigma}{D} = \dfrac{4\times0.073}{3\times10^{-3}} = 97.33$ Pa

39. (c)



Given : D = 4 m; d = 2 m; ρ = 0.8 × 1000 = 800 kg/m^3; $\bar{h} = 2 + \dfrac{D}{2}\sin 30° = 2 + \dfrac{4}{2}\times\dfrac{1}{2} = 3$ m

The force on one side of plate (F) $= \rho g\bar{h}A$

$$= 800\times9.81\times3\times\frac{\pi}{4}\left(4^2-2^2\right)$$

$$= 221.89 \text{ kN}$$

40. (d)

Reynolds number, Re $= \dfrac{\rho VD}{\mu} = \dfrac{4\rho Q}{\pi D\mu}$ $\quad\left[\because V = \dfrac{Q}{A} = \dfrac{4Q}{\pi D^2}\right]$

$$= \frac{4\times(1.25\times1000)\times180\times10^{-3}}{\pi\times0.01\times0.9\times60} = 530.51$$

Re < 2000, flow is laminar in pipe

41. (b)

Rate of flow per unit width, (W = 1)

$$Q = \left(\frac{2}{3}b\times 1\right)\times\left(\frac{V_{max}}{2}\right)-\left(\frac{b}{3}\times 1\right)\left(\frac{V_{max}}{2\times 2}\right)$$

$$= b\times V_{max}\left(\frac{1}{3}-\frac{1}{12}\right)$$

$$= \frac{b\times V_{max}}{4}$$

Also, Flow rate, $Q = V_{avg} \times b \times 1$

$$\Rightarrow \quad \frac{b\times V_{max}}{4} = \frac{V_{avg}\times b}{1}$$

$$\Rightarrow \quad \frac{V_{avg}}{V_{max}} = \frac{1}{4}$$

[Note : For linear velocity profile, the average velocity for a particular section is mean of extreme point velocities]

42. (c)

- The terms creeping flow or stokes flow or low Reynolds number hydrodynamics are used synonymously to refer to the flow in which inertia force is negligible compared to viscous and pressure forces.
- In practice the low Reynolds number approximation often remains satisfactory for Reynolds number of order of unity [Re ~ 1].
- The basic equations for creeping flows:

$$\Delta P = \mu \nabla^2 V \qquad \text{[Linear equation]}$$

43. (c)

The force resisting the motion of sphere (drag force) as per stokes experiment

$$F_D = 3\pi\mu v d$$

where, v = velocity of sphere relative to undisturbed fluid, μ = dynamic viscosity of fluid, d = diameter of sphere

For terminal velocity,

Submerged weight = Resisting force

$$\Rightarrow \quad \frac{\pi d^3}{6}(\gamma_s-\gamma) = 3\pi\mu v d$$

$$\Rightarrow \quad V_{terminal} = \frac{d^2}{18\mu}(\gamma_s-\gamma)$$

44. (d)

$P_A - \rho_w \times g \times 0.5 - \rho_{oil} \times g \times 1 + \rho_w \times g \times 1.5 = P_B$

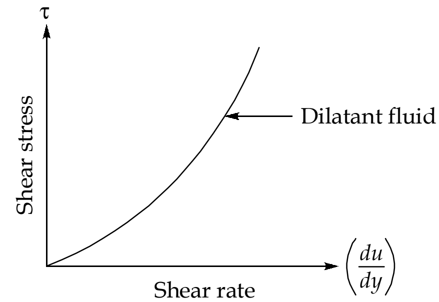
$$\Rightarrow \quad P_A - P_B = \rho_{oil}\times g\times 1 - \rho_w \times g \times 1$$

$$= 800 \times 9.81 - 1000 \times 9.81$$

$$= -1962.0 \text{ N/m}^2$$

45. (a)

Dilatant fluid,



$$\tau = \mu\left(\frac{du}{dy}\right)^n, n > 1$$

e.g. Starch suspension, sugar solution etc.

46. (b)

In orifice meter discharge Q,

$$Q \propto \sqrt{\Delta h}$$

where, Δh is differential manometric reading

$$\Rightarrow \quad Q = k\sqrt{\Delta h}$$

Taking natural log both sides

$$\Rightarrow \quad lnQ = ln\left(k\sqrt{\Delta h}\right)$$

$$\Rightarrow \quad lnQ = ln\,k + \frac{1}{2}ln\Delta h$$

Differentiating,

$$\Rightarrow \quad \frac{dQ}{Q} = 0 + \frac{1}{2}\frac{(\Delta h)}{\Delta h}$$

$$\Rightarrow \quad \%\text{error in } Q = \frac{1}{2}\times(0.02)\times 100 \qquad \left[\because \frac{d(\Delta h)}{\Delta h}\times 100 = 2\%\text{ error}\right]$$

$$= 1\%$$

47. (b)

	Minor losses		**Losses in terms of head**
1.	Sudden expansion	–	$\frac{(V_1 - V_2)^2}{2g}$
2.	Sudden contraction	–	$\left(\frac{1}{C_C} - 1\right)\frac{V_2^2}{2g}$
3.	Exit losses	–	$\frac{0.5V^2}{2g}$

4. Bend losses – $\frac{V^2}{2g}$

5. Bend and fitting losses – $\frac{kV^2}{2g}$

48. (d)

Darcy-Weisbach friction factor,

$$f = \frac{1.325}{\left[ln\left[\frac{e}{3.7 \times D} + \frac{5.74}{(\text{Re})^{0.9}}\right]\right]^2}$$

where, Re = Reynolds number = $\frac{V \cdot D}{\nu}$; e = Pipe roughness; D = Pipe diameter; ν = Kinematic viscosity; V = Velocity

49. (d)

By first law,

$$\dot{Q}_{out} = \dot{W}_{in} - \dot{W}_{out}$$

$$\dot{W}_{in} = 10 \times 200 = 2000 \text{ Watts}$$

$$\dot{W}_{out} = \text{Torque} \times \text{Angular velocity} = 10 \times \left(\frac{1200 \times 2\pi}{60}\right) \text{W}$$

$$= 400\pi \text{ Watts}$$

$$\dot{Q}_{out} = 2000 - 400\pi$$

$$= 2000 - 1256.6 = 743.4 \text{ W}$$

Given

$$\dot{Q}_{out} = 15(T_s - T_o)$$

$$743.4 = 15(T_s - T_o)$$

$$T_s = \frac{743.4}{15} + 27 = 76.56°\text{C}$$

50. (b)

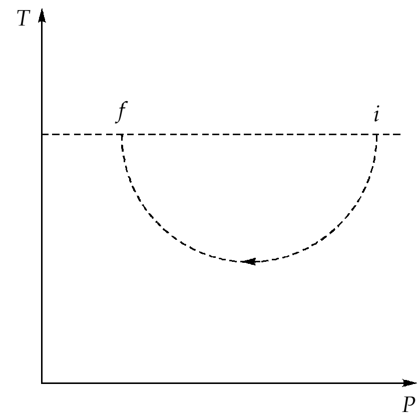
$$\eta_{th} = \frac{W_{in}}{Q_{\text{Supplied}}} = \frac{Q_{\text{Supplied}} - Q_{\text{Rejected}}}{Q_{\text{Supplied}}}$$

$$= \frac{20000 - (2000 + 6000)}{20000}$$

$$\eta_{th} = \frac{12000}{20000} = 0.6 = 60\%$$

51. (c)

In free expansion process, pressure drops, no heat loss or gain, zero work done and no change in initial and final temperature takes place.



Note : Free expansion process is not an isothermal process.

52. (c)

For reversible adiabatic process, $\Delta s = 0$

$$\Rightarrow \quad h_1 - h_2 = -\int_1^2 v dp$$

53. (b)

$$\left(p + \frac{a}{v^2}\right)(v - b) = RT \quad \text{(Van der Waals equation)}$$

Here '$\frac{a}{v^2}$' represents attraction force between molecules and 'b' represents the finite volume occupied by the gas molecules.

54. (d)

Critical temperature of the gas is the temperature at or above which there is no liquification of gas no matter how much pressure is applied.

55. (c)

$$\bar{R} = 8314 \text{ J/mole/K}$$

or

$$\bar{R} = \frac{8314}{9.81} \text{ mkgf/kg mole/K}$$

$$\simeq 848 \text{ mkgf/kg mole/K}$$

56. (b)

As work done by the gas can be determined by area under the curve *AB* in both cases and we can see that

Area of diagram 1 under curve > Area of diagram 2 under the curve

$$W_1 > W_2$$

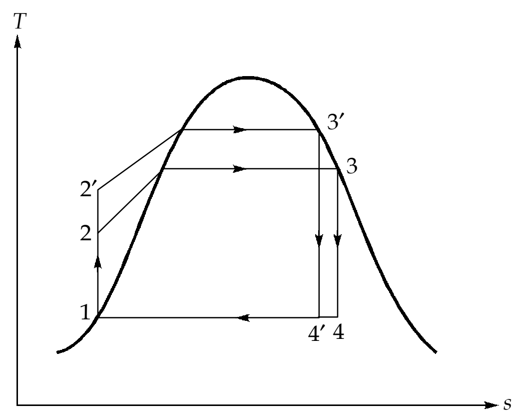
57. (b)

Due to steam extraction at several places loss of work output increases and steam rate increases which requires bigger size boiler.

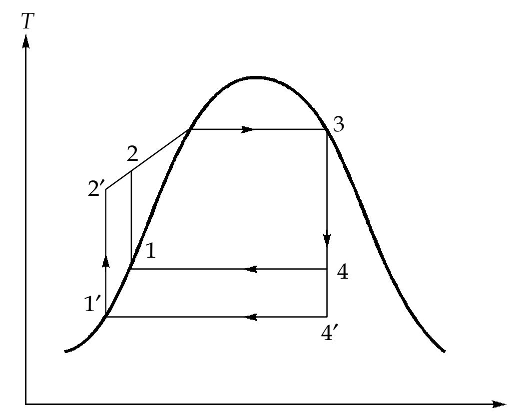
58. (d)

An increase in the pressure of working fluid increases the mean temperature of heat addition and hence increases the cycle efficiency.

A decrease in the temperature of the working fluid at which heat is rejected decreases the mean temperature of heat rejection thus increasing cycle efficiency.



T_{mA} = increases



T_{mR} = decreases

59. (c)

$$\eta_{\text{ideal regeneration}} = \frac{T_H - T_L}{T_H} = \frac{327-27}{327+273}$$

$$= \frac{300}{600} = 50\%$$

60. (b)

Fusible plug is a safety device used for preventing the level of water from going down below a critical point and thus avoid heating. Body of fusible plug is made of gun metal, bronze or brass and it is threaded cylindrical with a tapered core of low melting point fusible material like lead based alloys.

62. (a)

The time taken to complete one stroke by a double acting steam engine turning N revolutions is given by

$$t = \frac{1}{2N} = \frac{1}{2 \times 225} \times 60$$
$$= \frac{1}{7.5} \text{sec}$$

63. (d)

The enthalpy difference (H_d – H_c) represents the heating of steam due to random molecular energy resulting from friction in the divergent section of the nozzle.

64. (b)

At stall conditions, i.e. when $\frac{c_b}{c_{a_1}} = 0,$ the torque on the blades is maximum. However no work is done as the distance through which the torque acts is zero.

65. (a)

$$\text{Corrected vacuum} = 76 - (H_b - H_g)$$
$$= 76 - (76.5 - 71)$$
$$= 70.5 \text{ cm of Hg}$$

66. (a)

The work input to compressor,

$$W_c = \left(\frac{n}{n-1}\right)[P_1V_1 - P_2V_2]$$
$$W_c = \uparrow\left(\frac{1}{\left(1 - \frac{1}{\uparrow n}\right)\downarrow}\right)[P_1V_1 - P_2V_2]$$

67. (b)

$$\frac{P_2}{P_1} = \frac{\text{Critical pressure at throat}}{\text{Inlet pressure}}$$
$$= \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}$$

68. (a)

$$h_3 = 0.2h_1 + 0.8h_2$$
$$= 0.2 \times 2800 + 0.8 \times 200$$
$$= 720 \text{ kJ/kg}$$

69. (b)

Since nozzle efficiency,
$$\eta_N \propto C_V^2$$
$$C_V \propto \sqrt{\eta_N}$$
$$\frac{C_{V_1}}{C_{V_2}} = \sqrt{\frac{\eta_N}{\left(\frac{\eta_N}{2}\right)}} = \sqrt{2}$$
$$C_{V_2} = \frac{C_{V_1}}{1.414}$$

70. (c)

Maintaining constant temperature requires large quantity of coolant water. Use of large coolant water makes compressor bulky and decreases the engine speed.

71. (c)

$$\text{Degree of reaction, } R = \frac{(\Delta h)_{rotor}}{\Delta h_{rotor} + (\Delta h)_{stator}}$$
$$= \frac{(\Delta h)_{rotor}}{(\Delta h)_{stage}}$$

72. (d)

- Intercooling : $W_C \downarrow, W_T = \text{Same} \Rightarrow W_{net} \uparrow$
- Reheating : $W_C = \text{Same}, W_T \uparrow \Rightarrow W_{net} \uparrow$
- Regeneration : $W_C = \text{Same}, W_T = \text{Same}, \Rightarrow W_{net} = \text{Same}$

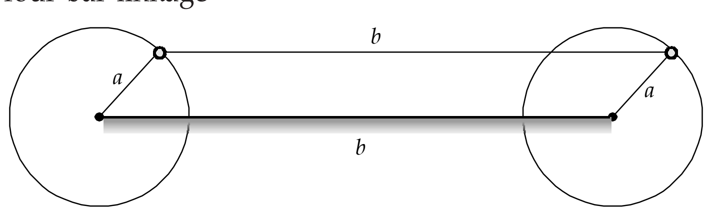
73. (c)

The burning causes rapid decomposition and heat release. This heat is conducted back to the propellant and thus the process is self sustaining, such a process is called burning by deflagration. To obtain maximum thrust whole of the combustion space is filled with propellant and it is allowed to burn.

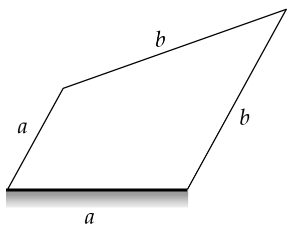
74. (c)

For double crank mechanism

- Sum of shortest and longest links is less than other two links and smallest link is the fixed link.
- Parallel-crank four bar linkage



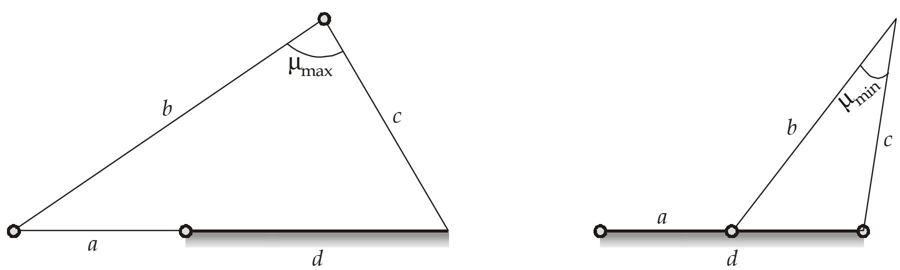
- Deltoid linkage



In this mechanism also pair of links have same length but are adjacent to each other.
For double crank, any of the two shortest links can be fixed.

75. (c)

Transmission angle (μ),



Transmission angle is maximum (μ_{max}) and minimum (μ_{min}), when crank angle with fixed link is 180° and 0°, respectively.

77. (c)

$$\text{Friction coefficient, } \mu = \tan\phi = 0.75 = \frac{3}{4}$$

$$\Rightarrow \quad \sin\phi = \frac{3}{5} = 0.6$$

$$\eta_{max} = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-0.6}{1+0.6}$$

$$= \frac{0.4}{1.6} = 0.25 = 25\%$$

78. (c)

- Mating of two non-conjugate teeth is known as interference because the two teeth do not properly slide and thus rough action and binding occurs.
- Interference occurs when the number of teeth on the smaller of the two meshing gears is less than a required minimum.
- In an involute tenth, convex surfaces are in contact so there is more wear.

79. (d)

Correct steering equation:

$$\cot\phi - \cot\theta = \frac{W}{L}$$

where, ϕ = angle turned by outer front wheel, θ = angle turned by inner front wheel

$$\Rightarrow \quad \cot\phi - \cot(26.56) = \frac{250}{400}$$

$$\Rightarrow \quad \cot\phi = 2.625 \qquad [\because \tan 26.56° = 0.5]$$

$$\Rightarrow \quad \phi = \cot^{-1}(2.625)$$

80. (a)

The maximum value of addendum of pinion to avoid interference

$$(a_p)_{max} = r\sqrt{1+\frac{R}{r}\left(\frac{R}{r}+2\right)\sin^2\phi} - r$$

$$(a_p)_{max} = \frac{mt}{2}\left[\sqrt{1+G(G+2)\sin^2\phi} - 1\right]$$

$$(a_p)_{max} = \frac{20}{2}\left[\sqrt{1+2(2+2)\sin^2 30°} - 1\right]m$$

$$= \left[10\times\left(\sqrt{3}-1\right)\right]m$$

$$= 7.32\ m$$

81. (c)

$$\text{Coefficient of insensitiveness} = \frac{N_1^2 - N_2^2}{2N_2^2} = \frac{f}{(M+m)g}$$

where, f = friction force at sleeve, m = mass of sleeve, M = mass of ball

$$\Rightarrow \quad \text{Coefficient of insensitiveness} = \frac{20}{(18+2)\times 9.81} = 0.1019 = 10.19\%$$

82. (c)

$$\text{Gyroscopic couple, } C = I\omega\omega_p$$

$$\text{Mass moment of inertia, } I = \frac{M}{2}\left(R^2+r^2\right) = \frac{100}{2}\left(5^2+2^2\right) = 1450 \text{ kg-m}^2$$

$$\text{Angular velocity of engine, } \omega = \frac{2\pi N}{60} = 2\times\frac{22}{7}\times\frac{420}{60} = 44 \text{ rad/s}$$

$$\text{Angular velocity of precession, } \omega_p = 10 \text{ rad/s}$$

$$\Rightarrow \quad C = 1450 \times 44 \times 10$$

$$= 638000 \text{ N-m}$$

$$= 638 \text{ kN-m}$$

83. (c)

Given : mass, m = 10 kg, spring stiffness, k = 4 N/mm = 4000 N/m

$$\therefore \quad \omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{4000}{10}} = 20 \text{ rad/s}$$

Damping is 50% of critical,

$$\text{i.e. } \xi = \frac{C}{C_C} = 0.5$$

⇒ Damping frequency or natural frequency of damped vibration

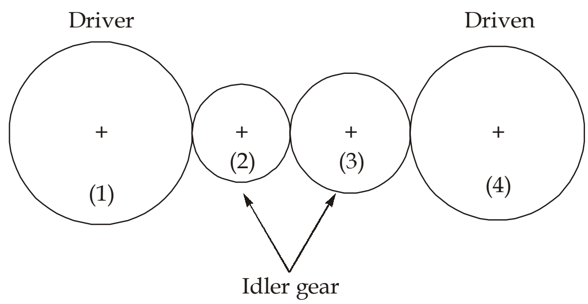
$$\omega_d = \left(\sqrt{1-\xi^2}\right)\omega_n$$

$$= \left(\sqrt{1-(0.5)^2}\right)\times 20$$

$$= 17.32 \text{ rad/s}$$

84. (a)

Simple gear train : Every shaft is having only one gear in use and module of each gear is same i.e. $[m_1 = m_2 = m_3 \text{ .... } m_n = m]$



If the number of idler gear is odd, then direction of motion of driven gear will be same as that of driver gear.

86. (b)

Angle made by solar beam with the horizontal is called solar altitude angle (α_a) and it is complement of zenith angle (θ_z).

$$\alpha_a = 90° - \theta_z$$

$$\Rightarrow \quad \theta_z = 90° - 30° = 60°$$

$$\text{Air mass ratio (AMR)} = \frac{1}{\cos\theta_z} = \frac{1}{\cos 60°} = 2$$

87. (d)

For horizontal surface, $\beta = 0$

So collector equation is reduced to $\cos\theta = \sin\phi\sin\delta + \cos\phi\cos\delta\cos\omega$

We can solve this question by simply observing that, for horizontal surface (β = 0), there should not be any β term in collector equation which indicates option (d) as correct answer.

88. (c)

- Solid gas and liquid gas transformations are not employed inspite of large latent heats as large changes in volume makes the system complex and impracticable.
- In solid-solid transition, heat is stored as the material is transformed from one crystalline form to another. These transitions involve small volume changes, however, most of them have small latent heats.

89. (c)

Given: $E = 2.42$ eV and we know that

$$E = \frac{1.24}{\lambda} eV$$

$$\Rightarrow \quad \lambda = \frac{1.24}{2.42} \mu m = 0.512 \text{ μm}$$

90. (c)

$$\text{Solidity } (\gamma) = \frac{A_{blade}}{A_{swept}}$$

$$\text{For horizontal machine, } \gamma = \frac{NC}{\pi R}$$

$$\text{For vertical machine, } \gamma = \frac{NC}{R} \quad \text{For Darrieus type rotor}$$

$$\text{otherwise, } \gamma = \frac{NC}{2R}$$

91. (a)

Given : $\omega = 4.5$ rad/s, $\rho = 1.2$ kg/m^3

$$\text{Area of rotor} = \pi R^2 = \pi \times 40^2 = 1600\,\pi\text{m}^2$$

$$\text{For maximum output, } C_p = 0.593$$

$$\text{Tip speed ratio, } \lambda = \frac{\omega R}{V_{up}} = \frac{4.5 \times 40}{20} = 9$$

$$(P_{\text{wind}})_{\text{available}} = \frac{1}{2} \rho A V_{up}^3$$

$$= \frac{1}{2} \times 1.2 \times 1600\,\pi \times 20^3 = 7.68\,\pi \text{ MN}$$

$$T_{\max} = \frac{(P_{wind})_a}{V_{up}} \times R = 15.36\,\pi \text{MJ}$$

$$\text{Torque coefficient, } C_{T,\,\max} = \frac{C_{P\max}}{\lambda} = \frac{0.593}{9}$$

Torque produced at the shaft at maximum output,

$$T_{\text{sh, max}} = \frac{0.593}{9} \times 15.36\,\pi \text{MJ}$$

$$= 3.18 \text{ MJ}$$

92. (c)

Stall regulated machines require speed regulation and a suitable torque speed characteristic intrinsic in the aerodynamic design of the rotor. Stall regulation can be used without much problem upto about a 25 m diameter rotor. Above this size, severe vibration problems associated with the stalled flow in high wind speeds have been encountered.

93. (b)

- Liquefaction of biomass mainly takes place through two routes : (i) Liquefaction through pyrolysis process without any gasification medium and (ii) liquefaction through methanol synthesis with gasification medium.
- Liquefaction through gasification medium involves the production of methanol from mixture of H_2 and CO (Producer gas). The reaction takes place at 330°C and 150 atm pressure.

94. (a)

A compact AFC (alkaline fuel cell) with hydrazine fuel and hydrogen peroxide/oxygen as oxidant is proposed for vehicle propulsion. Oxygen is obtained either by catalytic decomposition of hydrogen peroxide or from ambient air.

96. (b)

As
$$\tau_{max} = \frac{1}{2}\left[\sqrt{(\sigma_T)^2 + 4\tau^2}\right]$$
$$= \frac{1}{2}\left[\sqrt{(40)^2 + 4\times 20^2}\right]$$
$$= \frac{40\sqrt{2}}{2} = 20\sqrt{2} = 28.28 \text{ MPa}$$

97. (a)

Compressive residual stress at the surface of a component tends to increase fatigue strength and fatigue life, slow crack propagation and increase resistance to environmentally assisted cracking such as stress corrosion cracking, hydrogen induced cracking.

98. (c)

- In the design of friction clutch, the torque carrying capacity is decided by condition of uniform wear rate theory of friction plate because they give lower frictional torque, the intensity of pressure is maximum at the inner radius and minimum at the outer radius.
- Centrifugal clutches are used to automate and smoothen the engagement process.

99. (a)

$$\text{Sommerfeld number} = \left(\frac{r}{c}\right)^2 \frac{zn}{P}$$
$$0.04 = \left(\frac{1}{0.005}\right)^2 \times \frac{0.03\times 3000}{10^6 \times P\times 60}$$
$$\Rightarrow \quad P = 1.5 \text{ MPa}$$

100. (b)

As $$\delta = \frac{8WD^3N}{Gd^4}$$

$$D = d \times c = 8 \times 6 = 48 \text{ mm}$$

$$\Rightarrow \quad 30 = \frac{8 \times 1200 \times 48^3 \times N}{69120 \times 8^4}$$

$\Rightarrow$ Active number of coils $N = 8$

101. (b)

Line shaft consist of a number of shafts, which are connected axially by means of couplings. Commercial shafts are made of low carbon steels.

102. (d)

The speed of machine spindle are usually designed to follow geometric progression as it is easier to achieve speeds in geometric progression through gearing.

103. (c)

$$\text{Shear strain} = \cot\phi + \tan(\phi - \alpha)$$
$$= \cot 30° + \tan(30° - 0)$$
$$= \sqrt{3} + \frac{1}{\sqrt{3}} = 2.309$$

104. (a)

- In case of edge dislocation burger's vector will be perpendicular to dislocation line.
- Shear stress in the direction normal to the edge dislocation line is called resolved shear stress.
- Motion of edge dislocations within the material is called climb.

105. (c)

Selective leaching is nothing but the loss of one chemical element from alloy. Dezincification, where Zn element is depleted from yellow brass consequently, it will be turned into red. It is because Zn is very active metal compared to Cu (mobile metal) therefore Zn will be oxidized.

107. (b)

Bainite cannot be produced by continuous cooling, so austenite is cooled at rate equal to or greater than critical cooling rate to a temperature below the nose of TTT-diagram but above the martensite start line. This temperature is maintained for substantial period of time till cooling curve enters into the TTT diagram. This will produce bainite structure and process is known as austempering.

108. (d)

Nanomaterial synthesis methods :

(A) Physical method:

(1) Mechanical method (Mechanical grinding)

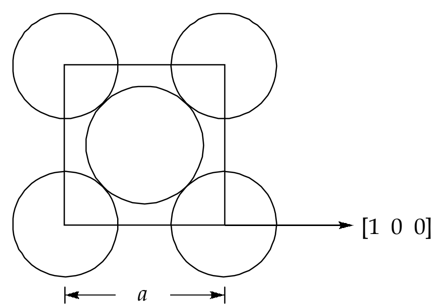
(2) Vapour method
  (a) Sputtering
  (b) Laser ablation
  (c) Laser pyrolysis

(B) Chemical method:
  (a) Sol-gel technique
  (b) Chemical vapour deposition
  (c) Colloidal method
  (d) Spray pyrolysis

(C) Biological method: Green Synthesis

109. (c)

For FCC structure,



$$\text{Linear density} = \frac{\text{Number of atoms appeared in that direction}}{\text{Length of the direction vector}}$$

Since, one complete atom appeared along [1 0 0]

$$\text{Linear density} = \frac{1}{a} = \frac{1}{2\sqrt{2}R} \qquad [\because \text{ For FCC } a = 2\sqrt{2}R\,]$$

110. (b)

Hexagonal	$a = b \neq c,$	$\alpha = \beta = 90°, \gamma = 120°$
Tetragonal	$a = b \neq c,$	$\alpha = \beta = \gamma = 90°$
Rhombohedral	$a = b = c,$	$\alpha = \beta = \gamma \neq 90°$
Monoclinic	$a \neq b \neq c,$	$\alpha = \gamma = 90° \neq \beta$

111. (c)

- Martensite has a metastable phase.
- It does not appear on Fe-C phase diagram.
- It has BCT (body centered-tetragonal) microstructure.

112. (b)

- Twinning deformation occurs when slip system are less than 5.
- HCP material deform predominantly by twin deformation.

113. (b)

Given : $(h\ k\ l) = (1\ 2\ 2)$

$a = 0.286$ nm

So, interplaner spacing, $d_{hkl} = \dfrac{a}{\sqrt{h^2+k^2+l^2}}$

$\Rightarrow \quad d_{122} = \dfrac{0.286}{\sqrt{1^2+2^2+2^2}}$

$\Rightarrow \quad d_{122} = \dfrac{0.286}{\sqrt{9}} = 0.0953 \text{ nm}$

114. (c)

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

$$= 0\times 5 + \frac{1}{2}\times 10\times 5^2$$

$$= 125 \text{ m}$$

$\therefore$ Tower height = 125 m

Distance covered in 2 second = $s_1 = 0\times 2 + \frac{1}{2}\times 10\times 2^2 = 20$ m

Remaining distance to cover = $s - s_1 = 125 - 20 = 105$ m

$\therefore$ Time to cover remaining distance

$\Rightarrow \quad 105 = 0\times t + \frac{1}{2}\times 10\times t^2$

$\Rightarrow \quad t = \sqrt{21} = 4.58$ sec

115. (c)

The force of friction always opposes the relative motion between the two bodies in contact irrespective of direction of motion.

116. (b)

Force, $F = 20 + 50t$

$\therefore \quad a = \dfrac{F}{m} = \dfrac{20+50t}{2}$

$\therefore \quad a = 10 + 25t = \dfrac{d^2x}{dt^2}$

Integrating, we get

$$v = \frac{dx}{dt} = 10t + 12.5t^2 + c_1$$

At $t = 0$, $v = 0$

$\therefore \quad c_1 = 0$

Again integrating, we get

$$x = 10\frac{t^2}{2} + 12.5\frac{t^3}{3} + c_2$$

At, $t = 0$, $x = 0$

$$c_2 = 0$$

$$\therefore \quad x = 5t^2 + 12.5\frac{t^3}{3}$$

Now, at $t = 10$ seconds,

$$x = 4666.66 \simeq 4667 \text{ m}$$

117. (b)

By applying Lami's theorem at point 'A'

$$\frac{500}{\sin 45°} = \frac{F_{AB}}{\sin 270°}$$

$$\therefore \quad F_{AB} = \frac{500}{\sin 45°} \times \sin 270°$$

$$F_{AB} = 707 \text{ kN}$$

118. (c)

Hot cracking is a welding defect that occurs due to hydrogen embrittlement, high temperature gradients and large heat affected zone. It can be avoided by preheating the base metal.

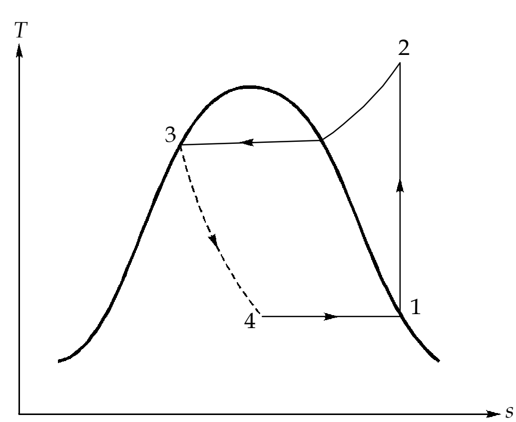
119. (d)

$$\text{Hole tolerance} = (UL)_{hole} - (LL)_{hole} = 0.05 \text{ mm}$$

$$\text{Allowance} = (LL)_{hole} - (UL)_{shaft} = 0.03 \text{ mm}$$

$$\text{Type of fit, clearance} = (LL)_{hole} - (UL)_{shaft} = 0.03 \text{ mm}$$

120. (b)



Given:

$$h_1 = 160 \text{ kJ/kg}, h_2 = 200 \text{ kJ/kg}$$

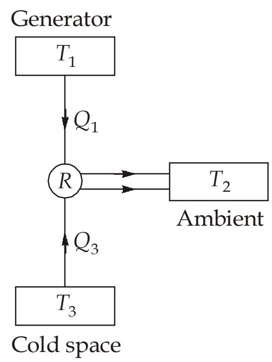
$$h_3 = h_4 = 60 \text{ kJ/kg, R.C.} = 10 \text{ Ton} = 10 \times 3.5 = 35 \text{ kW}$$

Now,
$$\dot{m} \times R.E. = R.C.$$
$$\dot{m} \times (h_1 - h_4) = R.C.$$
$$\dot{m} \times (160 - 60) = 35$$
$$\dot{m} = \frac{35}{100} = 0.35 \text{ kg/s}$$

121. (c)

Given: Q_1 = 2000 kJ/kg, T_1 = 900 K, T_3 = 200 K, T_2 = 300 K

For VARS system,



$$\text{COP} = \frac{Q_3}{Q_1} = \frac{T_3 \times (T_1 - T_2)}{T_1 \times (T_2 - T_3)}$$

$$\therefore \quad \frac{Q_3}{2000} = \frac{200(900 - 300)}{900(300 - 200)}$$
$$Q_3 = 2666.67 \text{ kJ/kg}$$
$$Q_3 \simeq 2667 \text{ kJ/kg}$$

122. (c)

The pressure reduction in a capillary tube occurs due to the following two factors :

1. The refrigerant has to overcome the frictional resistance offered by tube walls, this leads to same pressure drop.
2. The liquid refrigerant flashes (evaporates) into mixture of liquid and vapour as its pressure reduces.

123. (c)

Refrigeration capacity, $R.C. = \dot{m}c_p\Delta T + mL$
$$R.C. = 10 \times 4.2 \times 20 + 10 \times 335$$
$$R.C. = 4190 \text{ kW/min}$$
or
$$R.C. = 69.83 \text{ kW}$$
$$R.C. \simeq 70 \text{ kW}$$

124. (b)

$$\text{Relative humidity, } \phi = \frac{P_V}{P_{VS}} \times 100$$

$$\phi = \frac{2.33}{5.628} \times 100$$

$$\phi = 41.4\%$$

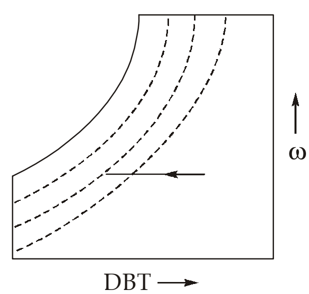
125. (b)

$$\text{Specific humidity, } \omega = 0.622 \frac{P_V}{P - P_V}$$

$$0.016 = \frac{0.622 P_V}{101.325 - P_V}$$

$$\therefore \quad P_V = 2.541 \text{ kPa}$$

126. (b)



During sensible cooling of moist air, DBT ↓; R.H. ↑; ω = same, h ↓; v ↓

127. (b)

For repairman (A),

$$\text{Wages} = \text{Rs. } 8/\text{hr}$$

$$\lambda = 8/\text{hr}$$

$$\mu = 10/\text{hr}$$

$$\rho = \frac{\lambda}{\mu} = \frac{8}{10} = 0.8$$

So, $$L_s = \frac{\rho}{1-\rho} = \frac{0.8}{1-0.8} = 4 \text{ [i.e. on an average four machines are idle]}$$

$$\text{Cost involved} = 4 \times 12 \times 8 + 8 \times 8$$

$$= \text{Rs. } 448$$

For repairman (B),

$$\text{Wages} = \text{Rs. } 12/\text{hr}$$

$$\lambda = 8/\text{hr}$$

$$\mu = 12/\text{hr}$$

$$\rho = \frac{\lambda}{\mu} = \frac{8}{12} = 0.67$$

So, $L_s = \frac{\rho}{1-\rho} = \frac{0.67}{1-0.67} = 2$ [i.e. two machines are idle]

Cost involved = $2 \times 12 \times 8 + 12 \times 8$
= Rs. 288

⇒ Total cost would be minimum for repairman 'B'.

128. (a)

Opportunity loss due to potential profit because of not meeting the demand,

$$P = S_p - C - C_b$$
$$= 6 - 5 = 1$$

Opportunity loss due to unsold item,

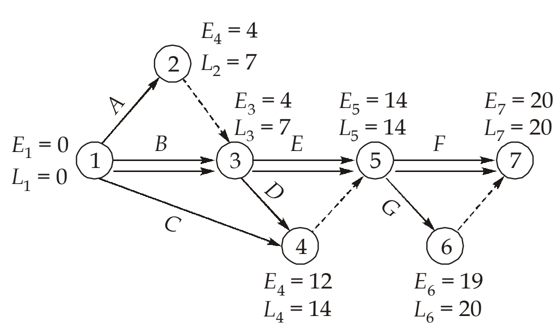
$$l = C - C_s + C_h$$
$$= 5$$

$$\frac{P}{P+l} = \frac{1}{1+5} = \frac{1}{6} = 0.167$$

X	$P(X)$	Cumulative Probability
25	0.05	0.05
30	0.15	0.20
35	0.35	0.55
40	0.30	0.85
45	0.15	1.00

Now, 0.167 lies between 0.05 and 0.20, of these 0.20 is greater so he should purchase 30 papers daily to get maximum profit.

129. (b)



For activity 'D', $TF = \left(L_j - t_{ij}\right) - E_i$

$= (L_4 - 5) - E_3 = (14 - 5) - 7 = 2$

130. (c)

Given : $TR = 95Q - 0.001Q^2$

$TC = 0.004Q^2 + 5Q + 16000$

So, profit $(P) = TR - TC = 90Q - 0.005Q^2 - 16000$

For maximum profit, $\frac{dP}{dQ} = 0$

$\Rightarrow \quad Q = \frac{90}{2 \times 0.005} = 9000$ units

Now, average unit cost $(C) = \frac{TC}{Q}$

$$C = 0.004Q + 5 + \frac{16000}{Q}$$

For minimum cost, $\frac{dC}{dQ} = 0$

$\Rightarrow \quad 0.004 - \frac{16000}{Q^2} = 0$

$\Rightarrow \quad Q = \sqrt{\frac{16000}{0.004}} = 2000$ units

131. (a)

$$\alpha = 0.4,$$

$$F_{i+1} = F_i + \alpha(e_i)$$

D_i	F_i	$e_i = D_i - F_i$
82	67	+15
68	73	–5
76	71	+5
93	73	+20
71	81	–10

So, $\text{RFSE} = \sum_{i=1}^{n} e_i = 25$

$$\text{MAD} = \frac{\sum_{i=1}^{n} |e_i|}{n} = \frac{55}{5}$$

Now, Tracking signal $(TS) = \frac{RSFE}{MAD} = \frac{25}{\left(\frac{55}{5}\right)} = \frac{25}{11}$

132. (d)

- 70% of the cases of machinery condition measurements and monitoring are done through vibration measurements and monitoring because it is difficult (hazardous) to do analysis (monitoring) on running machine with accuracy.
- Vibration monitoring can be done by both online and offline mode depending upon the external environment of machine.

- Laser vibrometer are used to measure both linear as well as rotational vibrations of a component or machine.
- Laser vibrometer works on the doppler's effect.
- Laser vibrometers are also used to measure vibrations from large distances for example vibration monitoring of large towers, wind mills etc.

133. (c)

Modular ratio of two materials is the ratio of their modulii of elasticity. It is an unit-less quantity. The concept of modular ratio is very important in the computation of properties of reinforced, prestressed, jacketed, encased and composite cross-sections.

134. (b)

Usually, ratio of ultimate stress to working stress is called F.O.S. In elastic theory of design, material F.O.S. is only considered and the ratio of yield stress to working stress is called F.O.S.

135. (c)

Firing interval of any engine is equal to 720/n where n equals the number of cylinders.

So for six cylinder engine, firing interval = $\frac{720°}{6} = 120°$

136. (c)

Robot configuration	**Symbol**
1. Cartesian	LLL
2. Cylindrical	TLL, LTL, LVL
3. POLAR/Spherical	TRL
4. Revolute or jointed arm/ Articulated arm	TRR, VVR

137. (b)

- 6 DOF is required for an arbitrary task in 3D.
- Painting and welding can be done by 5 DOF robot.
- Electronics assembly is usually done by 4 DOF, SCARA robot.

138. (c)

In this case, motions alternate relative to the reference frame and current frame. Pre or past multiplying each motion's matrix accordingly, we will get

$$T = \text{Trans}(4, 0, 0) \times R_x(60°) \times R_o(30°) \times \text{Trans}(10, 0, 0)$$

139. (b)

Homogeneous transformation matrix is given by,

$${}^1T_2 = \left[\begin{array}{c|c} {}^1R_2 & {}^1D_2 \\ \hline 0\ 0\ 0 & 1 \end{array}\right]$$

Substituting the respective values, we get

$$^{1}T_2 = \begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & \cos 90° & -\sin 90° & 4 \\ 0 & \sin 90° & \cos 90° & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

On solving, we get

$$^{1}T_2 = \begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 0 & -1 & 4 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Now,

$$^{1}P = {}^{1}T_2 \times {}^{2}P$$

$$\therefore \quad ^{1}P = \begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 0 & -1 & 4 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 2 \\ 5 \\ -4 \\ 1 \end{bmatrix}$$

On solving, we get

$$^{1}P = [5, 8, 6]^T$$

140. (b)

Asimov's three laws of robotics are:

1. First law (Human safety) : A robot may not injure a human being or through inaction allow a human being to come to harm.
2. Second law (Robots are slaves) : A robot must obey the orders given to it by human beings except where such orders would conflict with the first law.
3. Third law (Robot survival) : A robot must protect its own existence as long as protection does not conflict with first or second law.

141. (a)

The volume of air handled by the compressor and expander are smaller as compared to an open air refrigeration system because it can work at a suction pressure higher than that of atmospheric pressure.

142. (a)

Fluidity of pure material and alloy having eutectic composition will be maximum because there is no mushy zone. Larger is the extent of mushy zone lesser will be fluidity of liquid metal and more variation will be there in the properties of alloy.

144. (b)

- Welded assemblies are tight and leak proof as compared with riveted assemblies.
- Production time is less for welded assemblies.
- The inspection of the welded joint is more specialized and costly compared with the inspection of riveted structure.

145. (d)

TOF provides relationship between strength of machine component subjected to complex state of stresses with mechanical properties obtained in tensile test.

146. (c)

Crank effort is the net effort applied at the crank pin perpendicular to crank which gives the required turning moment on the crank shaft.

149. (a)

Derivative controllers do not respond to steady-state error signals, since with a steady error the rate of change of error with time is zero. Because of this derivative control is always combined with proportional control; the proportional part gives response to all error signals, including steady signals, while the derivative part responds to rate of change.

150. (c)

For pelton turbine, $\alpha = 0°$ and $\theta = 0°$