DETAILED SOLUTIONS

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ESE 2020 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 18

Full Syllabus Test-2 (Paper-II)

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

DETAILED EXPLANATIONS

1. (a)

Given: N = 840 rpm,

$$\Rightarrow \quad \omega = \frac{2\pi N}{60} = \frac{2}{60}\times\frac{22}{7}\times 840 = 88 \text{ rad/s}$$

$$r = 5 \text{ cm}$$

$$l = 25 \text{ cm} \Rightarrow n = \frac{l}{r} = \frac{25}{5} = 5$$

$$m = 2 \text{ kg}$$

$$F_I = mr\omega^2\left(\cos\theta + \frac{\cos 2\theta}{n}\right)$$

Maximum value will be at $\theta = 0°$.

$$\Rightarrow \quad (F_I)_{max} = 2\times 0.05\times(88)^2\times\left(1+\frac{1}{5}\right)$$

$$= 2 \times 0.01 \times 7744 \times 6$$

$$= 12 \times 77.44 = 929.28 \text{ N}$$

2. (c)

In space, there are 6 degrees of freedom for a link and revolute joint constraint 5 degrees of freedom in 3D space. So,

$$f = 2 \times 6 - 5$$

$$= 12 - 5 = 7$$

Please note that there is no fixed link here.

3. (c)

There are four links including the fixed one. There are two revolute and two swivel trunnion joints. Please note that swivel trunnion allow two motion and constrain only one.

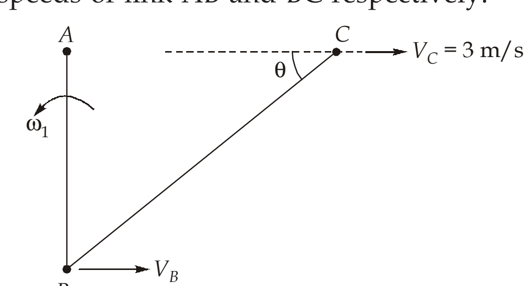
$$F = 3(4-1) - 2 \times 2 - 2 \times 1 - 1$$

$$F = 2$$

There is one redundant degree of freedom as the coupler link can translate without causing any change in remaining mechanism.

4. (d)

Let ω_1 and ω_2 be angular speeds of link AB and BC respectively.



As velocity of B and C are parallel the angular speed of link BC will be zero.

5. (b)

$$\text{Pitch angle} = \frac{360°}{30} = 12°$$

$$\text{Contact ratio} = \frac{\text{Angle of action}}{\text{Pitch angle}} = \frac{30°}{12°} = 2.5$$

6. (c)

For a flat face follower trace point is at the point of contact between the follower and the cam surface when the contact is along the base circle of the cam. Point C will be point of contact when the base circle will be in contact with follower.

7. (d)

A governor is stable if its controlling force diagram satisfy following condition:

$$\frac{dF}{dr} > \frac{F}{r}$$

Check this condition for all options

For option (d)

$$\frac{dF}{dr} = a$$

and

$$\frac{F}{r} = a - \frac{b}{r}$$

As $\frac{dF}{dr} > \frac{F}{r}$ option (d) is correct.

8. (b)

$$(\omega_o)_{avg} = \omega_i$$

ω_{mean} of the driven shaft is equal to the angular velocity, ω_i of the driving shaft, as both the shafts complete one revolution in the same period of time.

The mean speed ω_{mean} is not equal to $\left(\frac{\omega_{2max} + \omega_{2min}}{2}\right)$. As the variation of speed is not linear throughout the rotation of the driven shaft.

$$(\omega_o)_{max} = \frac{\omega_i}{\cos\alpha}$$

$$(\omega_o)_{min} = \omega_i \cos\alpha$$

$$\text{Coefficient of fluctuation} = \frac{(\omega_o)_{max} - (\omega_o)_{min}}{(\omega_o)_{avg}}$$

$$= \frac{\frac{1}{\cos\alpha} - \cos\alpha}{1} = \frac{1-\cos^2\alpha}{\cos\alpha} = \frac{\sin^2\alpha}{\cos\alpha}$$
$$= \tan\alpha \sin\alpha$$

10. (d)

Overall efficiency of three cycles coupled in series,

$$\eta_0 = 1 - (1 - \eta_1)(1 - \eta_2)(1 - \eta_3)$$
$$= 1 - (1 - 0.5)(1 - 0.4)(1 - 0.4)$$
$$= 1 - 0.5 \times 0.6 \times 0.6$$
$$\eta_0 = 0.82$$

11. (c)

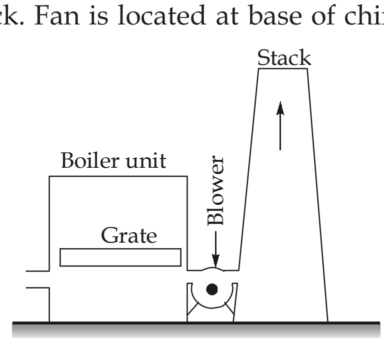
$$v_f = 0.00101 \text{ m}^3/\text{kg}$$
$$P_1 = 8000 \text{ kPa}$$
$$P_2 = 9.6 \text{ kPa}$$
$$\text{Work input} = v_f(P_1 - P_2) = 0.00101\,(8000 - 9.6)$$
$$= 0.00101\,(7990.4)$$
$$= 1.01 \times 7.99 = 8.069 \text{ kJ/kg}$$

12. (c)

- In a drum boiler, the circulation of water is produced through the density difference of water in the downcast pipe and the water/steam mixture in the furnace water-wall. The type that circulates water using only the density difference is known as a natural circulation boiler, while the type that includes an installed pump is known as a forced circulation boiler.
- A drum-type boiler can be either the natural circulation type or forced/assisted circulation type.
- Drum-type boilers are essentially subcritical boilers; they operate below the critical pressure of the working fluid. The economic design pressure limit of fluid in a drum-type boiler is around 18 MPa.
- All natural circularion boiler is used upto steam pressure of approximately 180 bar with separation of steam from water takes place in boiler drum.

13. (b)

Induced draught in which the suction created on furnace side draws flue gases and throws them out through small chimney/stack. Fan is located at base of chimney in induced draught.



Induced draught

14. **(d)**

It can operate economically at low speed and uneconomical at high speed about 800 km/h.

15. **(a)**

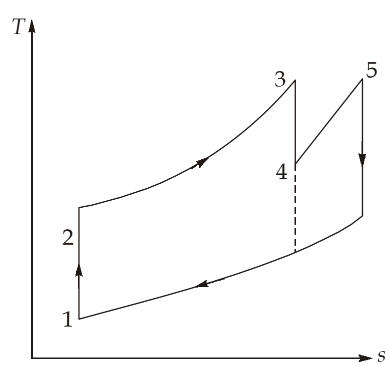
Air leakage causes the reduction in work done per kg of steam as it increases the back pressure. The quantity of water required for condensation of steam is increased due to presence of the air, air being non-condensable, forms an air film around the condensate film. Since air has a low thermal conductivity, the heat transfer is greatly reduced. Hence, leakage of air reduces the condenser efficiency.

16. **(b)**

- Francis Turbine is a reaction Turbine. The principal feature of a reaction turbine that distinguishes it from an impulse turbine is that only a part of the total head available at the inlet to the turbine is converted to velocity head, before the runner is reached.
- In the reaction turbine the working fluid completely fills the passage in the runner. The pressure or static head of the fluid changes gradually as it passes through the runner along with the change in its kinetic energy based on absolute velocity due to the impulse action between the fluid and the runner. A reaction turbine is usually well suited for low heads.

17. **(c)**

Reheat gas turbine cycle:



The specific work output is given by,

$$= C_p\,(T_3 - T_4) + C_p\,(T_5 - T_6) - C_p\,(T_2 - T_1)$$

The heat supplied to the cycle is

$$= C_p\,(T_3 - T_2) + C_p\,(T_5 - T_4)$$

Thus, the cycle efficiency, $$\eta = \left[1 - \left(\frac{T_{mR}\uparrow\uparrow}{T_{mA}\uparrow}\right)\uparrow\right]\downarrow$$

Therefore, a reheat cycle is used to increase the work output.

A common method of increasing the mean temperature of heat reception is to reheat the gas after it has expanded in a part of the gas turbine. By doing so the mean temperature of heat rejection is also increased, resulting in a decrease in the thermal efficiency of the plant. However, the specific output of the plant increases due to reheat

18. (d)

Functions and feature of volute casing in centrifugal Pump :

1. It is of spiral type in which area of flow increase gradually.
2. The increase in area of flow decrease the velocity of flow.
3. The decrease in velocity increase the pressure of the water flowing through the casing.
4. The efficiency of the pump increase slightly as a large amount of energy is lost due to the formation of eddies.

Therefore Option (d) is most appropriate and correct answer

19. (b)

In axial flow compressor in single stage pressure rise is low but efficiency is high due to aerofoil blades.

20. (c)

As per given data:

In centrifugal impeller,

Blade velocity at eye tip, U_1 = 200 m/s

Axial velocity at inlet, V_1 = 150 m/s

Sonic velocity, C = 300 m/s

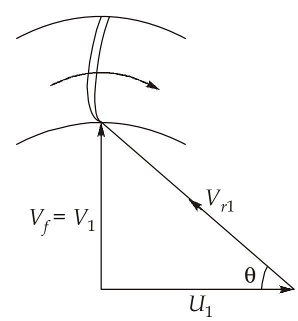
From inlet velocity triangle, $V_{r1}^2 = U_1^2 + V_1^2$

$= 200^2 + 150^2 = 62500$

$= 62500$

$V_{r1} = 250$ m/s

Mach number, $Ma = \frac{V_{r1}}{C} = \frac{250}{300} = 0.833$

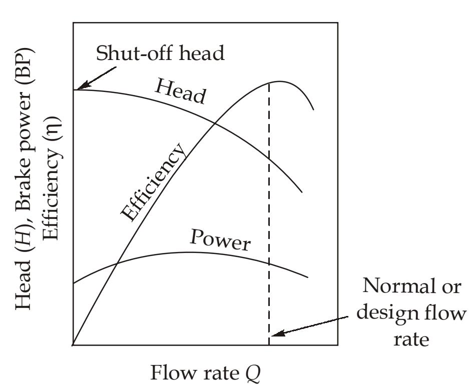


Inlet velocity triangle

21. (b)

The straight and radial blades are usually employed to avoid any undesirable bending stress to be set up in the blades. The choice of radial blades also ensures that the total pressure rise is divided equally between impeller and diffuser.

22. (d)



23. (c)

Its power coefficient is considerably more than that of an S-rotor (Savonius rotor).

24. (b)

- As a consequence of this geometry of the sun and the earth, large seasonal variations occur in the amount of solar radiation received at different latitudes of the earth.
- The largest annual variations occur near the two poles and the smallest near the equator. The mean distance is 1.496×10^8 km, which is known as 1 Astronomical Unit.
- Due to the variations in the sun-earth distance, the solar radiation intercepted by the earth varies by ±3.3 per cent around the mean value.

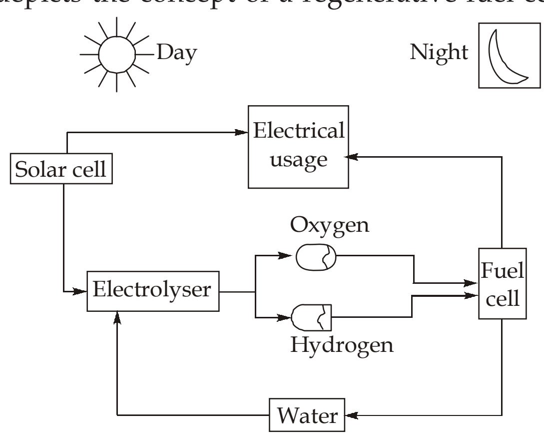
25. (a)

$$\eta_{Gas} = \frac{\text{Calorific value of gas/ kg of fuel}}{\text{Average calorific value of gas/ kg of fuel}}$$

$$= \frac{2.5 \times 5.4}{19.80 \times 1} \times 100 = \frac{13.5}{19.8} \times 100 = 68.18\%$$

27. (b)

Regenerative Fuel Cells (RFC) are actually not fuel cells by principle. The reverse technique of fuel cell is used for RFC. In this type of fuel cells, water is electrolyzed with the help of electricity from solar photovoltaic cell to produce hydrogen and oxygen gases and these gases are utilized in the proton exchange membrane (PEM) fuel cell to generate electricity. This technology is useful in space application. Further, using this technology, solar energy can be stored in the form of hydrogen energy and it will be of use in the night when solar photovoltaic would not work. The figure shown below depicts the concept of a regenerative fuel cell.



28. (c)

$$\text{LST (hrs)} = \text{LT(hrs)} + \frac{\text{TC}}{60}\text{(hrs)}$$

The time correction factor comes into picture due to eccentricity of Earth's orbit and time zone,

TC = Time correction

TC = 4 × [Longitude – LSTM] + EOT

LSTM = 15° (LT – GMT)

LSTM = Local standard time meridian

LT = Local time

GMT = Greenwich mean time

EOT = Equation of time

29. (c)

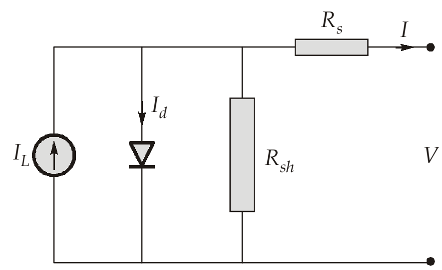
Fill factor of a photovoltaic device is $FF = \frac{V_m I_m}{V_{oc} I_{sc}}$.

In practical cells, I_{sc} is no longer equal to the light generated current, I_L, but is less by shunt current through R_{sh}. Further, an internal voltage drop of IR_s is also included in the terminal voltage. Thus, for a practical cell, the characteristic is modified as

$$I = I_L - I_o\left[\exp\left\{\frac{(V+IR_s)}{V_T}\right\}-1\right]-\frac{(V+IR_s)}{R_{sh}}$$

I_o = Dark current

V_T = Voltage at temperature, T



Hence, by increasing shunt resistance, reducing series resistance and reducing the dark current, fill factor of photovoltaic device increases.

30. (a)

The difference between F_{BD} and F_{AC} would give the weight of the oil in the tank.

$$W = F_{BD} - F_{AC}$$

$$F_{AC} = (F_{BD} - W) = \text{Required force}$$

$$F_{AC} = P_{AC} \times A = 0.9 \times 1000 \times 10 \times 3.5 \times (8 + 0.1) \times 6$$

$$= 9000 \times 21 \times 8.1 = 1530900 \text{ N}$$

$$F_{AC} = 1.53 \text{ MN}$$

31. (b)

Given: $A = 5 \text{ cm}^2 = 5 \times 10^{-4} \text{ m}^2$, $H = 7.2$ m

$$Q_a = 3.6 \text{ L/s} = 3.6 \times 10^{-3} \text{ m}^3\text{/s},\ C_V = 0.95$$

$$Q_a = C_d \times A\sqrt{2gH}$$

$$3.6 \times 10^{-3} = C_d \times 5 \times 10^{-4}\sqrt{2 \times 10 \times 7.2}$$

$$= C_d \times 5 \times 10^{-4} \times 12 = C_d \times 6 \times 10^{-3}$$

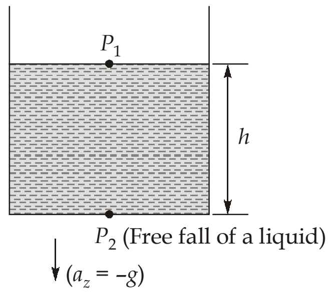
$$C_d = 0.6$$

$$C_d = C_c \times C_v \quad [\text{Where } C_c = \text{Coefficient of contraction}]$$

$$C_c = \frac{C_d}{C_v} = \frac{0.6}{0.95} = \frac{60}{95} = 0.631$$

32. (d)

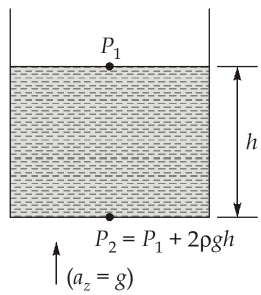
1.



$$P_2 = P_1$$

$$\left(\frac{\partial P}{\partial Z}\right)_1 = 0$$

2.



$$\left(\frac{\partial P}{\partial Z}\right)_2 = -2\rho g$$

$$\left(\frac{\partial P}{\partial Z}\right)_1 - \left(\frac{\partial P}{\partial Z}\right)_2 = 0 - (-2\rho g) = 2\rho g$$

33. (c)

We take plate as control volume. So final velocity of water w.r.t. plate is zero.

Let V_r = Relative velocity between plate and the jet.

- When plate is stationary $V_r = V$
- When plate is moving with velocity $\frac{V}{2}$ towards the jet.

$$V_r = V + \frac{V}{2} = 1.5V$$

The momentum equation for steady flow in horizontal direction is given as

$$\Sigma \vec{F} = \sum_{\text{out}} \beta \dot{m} \vec{V} - \sum_{\text{in}} \beta \dot{m} \vec{V}$$

$$-F_R = -\dot{m}_i V_i, \qquad F_r = \dot{m}_i V_i$$

- Stationary plate: ($V_i = V$ and $\dot{m}_i = \rho A V_i = \rho A V$) $\rightarrow F_R = \rho A V^2 = F$
- Moving plate: [$V_i = 1.5V$ and $\dot{m}_i = \rho A(1.5V)$]

$\Rightarrow$ $F_R = \rho A\ (1.5V)^2 = 2.25\ \rho A V^2 = 2.25F$

34. (c)

Given: $\frac{\partial u}{\partial y} = \frac{\partial v}{\partial x}$

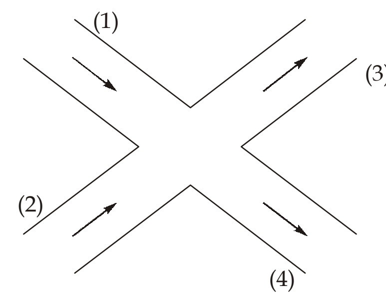
$$\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) = 0$$

Now,
$$\omega_z = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$$
$$\omega_z = 0$$

So, flow is irrotational.

35. (a)

Let's assume direction of flow in pipe 4 is outward.



$$\text{Total discharge, } Q_1 + Q_2 = Q_3 + Q_4$$
$$A_1V_1 + A_2V_2 = A_3V_3 + A_4V_4$$
$$A_1 + A_2 = A_3 + A_4$$
$$\frac{\pi}{4}D_1^2 + \frac{\pi}{4}D_2^2 = \frac{\pi}{4}D_3^2 + \frac{\pi}{4}D_4^2$$
$$D_1^2 + D_2^2 = D_3^2 + D_4^2 \quad \text{... (i)}$$

Putting the values,
$$1^2 + 2^2 = 4^2 + D_4^2$$
$$D_4^2 = 5 - 16 = -11 \text{ (Not possible)}$$

∴ Direction of flow should be inward.

36. (d)

Average of u is given by

$$\bar{u} = \frac{5 + 10 - 8 - 7}{4} = 0$$

Similarly,
$$\bar{v} = \frac{4 - 5 - 7 + 8}{4} = 0$$

Fluctuating components are found to be

$$u' = u - \bar{u} = u$$
$$v' = v - \bar{v} = v$$

∴
$$\overline{u'v'} = \overline{uv} = \frac{20 - 50 + 56 - 56}{4} = -\frac{30}{4}$$
$$\overline{u'v'} = -7.5$$

37. (b)

$$P = \rho RT \text{ (Ideal gas equation)}$$

So,
$$P \propto \rho$$

As P decreases, ρ will decrease.

Now,
$$\rho AV = \text{Constant (continuity equation)}$$

$$\therefore \qquad \rho \propto \frac{1}{V} \text{ (Area is constant)}$$

So, then ρ decreases, velocity will increase

38. (c)

$$\phi = x^2 - y^2$$

$$u = \frac{\partial \phi}{\partial x} = 2x, \qquad v = \frac{\partial \phi}{\partial y} = -2y$$

$$u = \frac{\partial \psi}{\partial y}$$

$$\psi = \int u\,dy = \int 2x\,dy = 2xy + f(x)$$

$$\psi = 2xy + f(x) \qquad \text{... (i)}$$

Now,

$$v = -\frac{\partial \psi}{\partial x}$$

$$\psi = -\int v\,dx = -\int(-2y)\,dx = 2xy + g(y)$$

$$\psi = 2xy + g(y) \qquad \text{... (ii)}$$

It is also given, at $x = 0$ and $y = 0$, $\psi = 0$ ... (iii)

From (i), (ii) and (iii)

$$\psi = 2xy \qquad [g(y) = 0, f(x) = 0]$$

39. (a)

$$V_{max} = 1.5 \text{ m/s},$$
$$B = 100 \text{ mm} = 0.1 \text{ m}$$

For laminar flow between two parallel plates, average velocity is given by:

$$V = \frac{2}{3}V_m = \frac{2}{3} \times 1.5 = 1 \text{ m/s}$$

$$\text{Dischrage, } q = BV = 0.1 \times 1 = 0.1 \text{ m}^3\text{/s per unit width}$$

40. (b)

At any distance x, according to Fourier's law, $q_x = -kA_x \frac{dT}{dx}$

Since q_x and k both are constant, it follows that $A_x \frac{dT}{dx} = \text{Constant}$

$$\frac{dT}{dx} = \frac{C}{A_x}$$

$$\frac{dT}{dx} = \text{Slope of the temperature distribution}$$

As 'A_x' increases with x, then $\frac{dT}{dx}$ must decrease with increasing x. T-x is hyperbolic profile.

41. (c)

We know the effectiveness for fin, $\varepsilon = \sqrt{\frac{kP}{hA}}$

Now, $$\varepsilon = \sqrt{\frac{kP}{hA}} = \sqrt{\frac{hP}{kA}} \times \frac{k}{h} = \frac{mk}{h}$$

$\therefore$ $$\varepsilon = \frac{mk}{h}$$

So, when $\varepsilon < 1$, $h > mk \rightarrow$ adding a secondary surface (fin) will reduces the heat transfer and the added surface will act as an insulation.

42. (c)

The characteristic length, $L_c = \frac{V}{A_s}$

$$L_c = \frac{\frac{\pi D^3}{6}}{\pi D^2} = \frac{D}{6} = \frac{0.001}{6}$$

Biot number, $$\text{Bi} = \frac{hL_c}{k} = \frac{210 \times 0.001}{35 \times 6} = \frac{210 \times 0.001}{210} = 0.001$$

$$\text{Bi} = 0.001$$

43. (a)

Liquid metals are a special class of fluids with very low Prandtl number. The very low Prandtl number is due to high thermal conductivity of these fluid. Hence they are suitable fluid for coolants.

44. (d)

$$J = 24 \text{ W/m}^2$$
$$E = 22 \text{ W/m}^2$$
$$G = 32 \text{ W/m}^2$$
$$J = \varepsilon E + (1 - \varepsilon)G \text{ (for opaque surface)}$$
$$24 = \varepsilon \times 22 + (1 - \varepsilon) \times 32$$
$$24 = 22\varepsilon + 32 - 32\varepsilon$$
$$\varepsilon = \frac{32 - 24}{32 - 22} = 0.8$$

45. (d)

For Black body,

$$E_b = \pi \times I_b$$

$$I_b = \frac{E_b}{\pi} = \frac{\sigma T^4}{\pi} = \frac{5.67 \times 10^{-8} \times (100)^4}{\pi} = 1.804 \text{ W/m}^2.\text{Sr}$$

46. (c)

$$D_o = 2\text{ cm}, \quad r_o = 1\text{ cm}$$

Critical radius of insulation, $r_c = \dfrac{k}{h_a} = \dfrac{0.3}{15} = 0.02\text{ m} = 2\text{ cm}$

Critical thickness of insulation $= 2 - 1 = 1$ cm

47. (a)

$$h_{fg} = 2300\text{ kJ/kg}, \qquad A = 0.5\text{ m}^2$$
$$T_s = 60°\text{C}, \qquad T_w = 80°\text{C}$$
$$\bar{h}_L = 5000\text{ W/m}^2\text{K} = 5\text{ kW/m}^2\text{K}$$

∵ Rate of heat transfer through convection = Rate of heat transfer in condensation

$\Rightarrow \quad \bar{h}_L A(T_w - T_s) = \dot{m}h_{fg}$

$\Rightarrow \quad 5 \times 0.5\ (80 - 60) = \dot{m} \times 2300$

$\therefore \quad \dot{m} = \dfrac{5 \times 0.5 \times 20}{2300} = \dfrac{50}{2300}$

$$\dot{m} = 0.0217 \approx 0.022\text{ kg/s}$$

48. (b)

- Baffles are commonly placed in the shell to force the shell side fluid to flow across the shell to enhance heat transfer and to maintain unifrom spacing between the tubes.
- Baffles disrupt the flow of fluid and hence increased pumping power will be needed to maintain flow.
- Baffles physically support the tubes, reducing flow induced tube vibration.

49. (a)

Given: $m_h = m_c = 0.5$ kg/s and both the fluids are air so have same specific heats

$\therefore \quad C_h = C_c$

So, it is a balanced heat exchanger.

For a balanced counter flow heat exchanger, $\varepsilon = \dfrac{\text{NTU}}{1+\text{NTU}}$

Now, $\quad \text{NTU} = \dfrac{UA}{C} = \dfrac{25 \times 30}{0.5 \times 1000} = 1.5$

Hence, $\quad \varepsilon = \dfrac{\text{NTU}}{1+\text{NTU}} = \dfrac{1.5}{1+1.5} = \dfrac{1.5}{2.5} = 0.6$

50. (c)

$$\text{Nu} \propto \text{Gr}^{0.25}$$

$\Rightarrow \quad \dfrac{hl_c}{k} \propto \left(\dfrac{g\beta\Delta T l_c^3}{v^2}\right)^{0.25}$ [Keeping all other term constant except l_c]

$$h \propto \frac{1}{l_c^{1-0.75}} \propto \frac{1}{l_c^{0.25}}$$

Here l_c is characteristic length which is the diameter of horizontal cylinder.

$$\frac{h_1}{h_2} = \left(\frac{D_2}{D_1}\right)^{0.25} = (14)^{0.25}$$

$$h_2 = \frac{h_1}{14^{0.25}} = \frac{100}{14^{0.25}}\ \text{W/m}^2\text{K}$$

$$\therefore \quad h_2 < 100$$

Hence option (c) is correct.

51. (b)

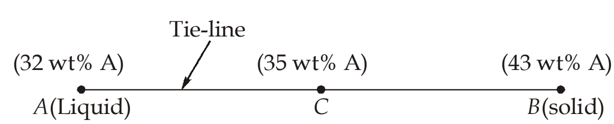
$$\text{Time constant, } \tau = \frac{\rho VC}{hA_s}$$

$$\text{Biot number, Bi} = \frac{h \times r_o / 3}{k_s} = \frac{hr_o}{3k_s}$$

$$\text{Fourier number, } F_o = \frac{\alpha t}{L^2}$$

$$\text{Prandtl number, Pr} = \frac{\mu c_p}{k_f}$$

52. (a)



$$\text{Weight fraction, } (w_{\text{solid}}) = \frac{AC}{AB} = \frac{35-32}{43-32} = \frac{3}{11} = 0.272$$

$$w_{\text{solid}} = 0.272$$

54. (a)

The microstructure of dual phase steel consisting of soft ferrite and hard martensite. The amount of ferrite in this steel is around 70-80% and the balance being martensite.

Unlike most low carbon steel it does not exhibit yield point phenomenon.

55. (b)

Given: D = 10 mm, $d = \sqrt{3.96}$ mm, P = 550 kg

We know that,

$$\text{BHN} = \frac{P}{\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right)} = \frac{550}{\pi \times \frac{10}{2}\left[10 - \sqrt{10^2 - \left(\sqrt{3.96}\right)^2}\right]}$$

$$= \frac{550}{\frac{22}{7}\times 5\left(10-\sqrt{100-3.96}\right)} = \frac{5\times 7}{\left(10-\sqrt{96.04}\right)}$$

$$= \frac{35}{10-9.8} = \frac{35}{0.2} = 175$$

$$\text{BHN} = 175$$

56. (c)

German silver is an alloy of Ni, Cu and Zn. It does not has any silver content.

57. (d)

Crevice corrosion generally occurs in poorly gasketed pipe flanges, under bolt heads and attachments immersed in liquids. The area within the crevice becomes anodic. Because of localized damage, crevice corrosion is very destructive. Good gasketing must be done to avoid crevice corrossion.

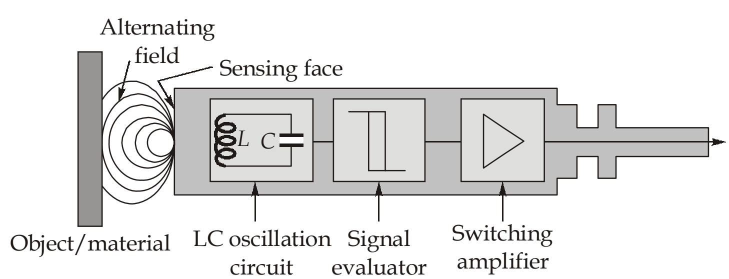
59. (b)

Large grains produce the ORANGE-PEEL effect, resulting in a rough surface appearance, such as when sheet metal is streched to form a part or when bulk metal is subjected to compression, such as in forging operation.

61. (b)

A wire of Constantan alloy (copper-nickel 55-45% alloy) can be called as a sensor because variation in mechanical displacement (tension or compression) can be sensed as change in electric résistance. This wire becomes a transducer with appropriate electrodes and input-output mechanism attached to it. Stepper motor is an example of actuator.

62. (b)



Schematic of Inductive Proximity switch

Inductive proximity switches are basically used for detection of metallic objects. An inductive proximity sensor has four components; the coil, oscillator, detection circuit and output circuit. An alternating current is supplied to the coil which generates a magnetic field. When, a metal object comes closer to the end of the coil, inductance of the coil changes. This is continuously monitored by a circuit which triggers a switch when a preset value of inductance change is occurred.

Applications of inductive proximity switches:

- **Industrial automation:** counting of products during production or transfer.
- **Security:** detection of metal objects, arms, land mines.

63. (a)

Common bit-lengths of binary numbers include bits, nibbles, and bytes. Each 1 or 0 in a binary number is called a bit. From there, a group of 4 bits is called a nibble, and 8-bits makes a byte. A microprocessor is a multipurpose, programmable logic device that reads binary instructions from a storage device called memory accepts binary data.

64. (d)

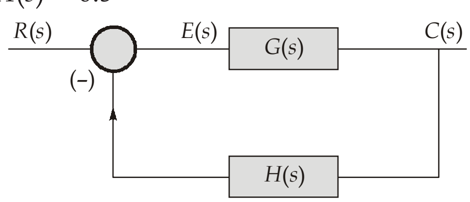
Assembly language programming is generally written by using hexadecimal codes. Programs can be written by using special keyboard equipped with using hex keys. Programs also have instructions to translate these keys into their equivalent binary patterns. The data and instructions are stored in prescribed locations in memory. An operation code is written which accomplishes the intended task(s). These tasks are carried out on 'operand(s)' by the operation code. 8085 is a typical general purpose microprocessor and has 8-bit word length.

65. (d)

The reciprocating pump is a positive plunger pump. It is also known as positive displacement pump or piston pump. It is often used where relatively small quantity is to be handled and the delivery pressure is quite large. Depending on the area of cylinder the pump delivers constant volume of fluid in each cycle independent to the pressure at the output port.

66. (b)

Given: $R(s)$ = 10 V, $G(s)$ = 2, $H(s)$ = 0.5



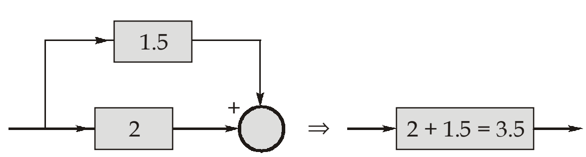
$$\frac{E(s)}{R(s)} = \frac{1}{1+G(s)H(s)}$$

$$E(s) = \frac{R(s)}{1+G(s)H(s)} = \frac{10V}{1+2\times 0.5} = 5\text{ V}$$

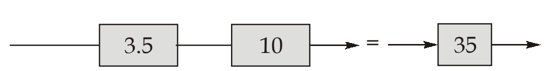
NOTE: $G(s)$ = Forward gain, $H(s)$ = Feedback gain.

67. (c)

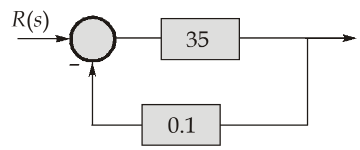
Gains are in parallel



Gains are in series



Equivalent circuit:



It is a negative feedback closed loop system

$$\text{Closed loop transfer function (CLTF)} = \frac{G(s)}{1+G(s)H(s)}$$

$$G(s) = 35$$
$$H(s) = 0.1$$
$$= \frac{35}{1+35\times 0.1} = 7.7$$

68. (c)

Derivative controller is used for fast response and good stability. The major advantage of derivative controller is that it improves the transient response of the system.

69. (c)

As we know,
$$\text{Power} = VI = \frac{V^2}{R}$$
$$V_{max}^2 = \text{Power} \times R$$
$$V_{max}^2 = 50 \times 10^{-3} \times 8 \times 10^3$$
$$V_{max}^2 = 400$$
$$V_{max} = 20 \text{ volts}$$
$$\text{Output voltage, } V = \frac{V_{max}\times x}{x_{total}} = \frac{20\times 2}{5} = 8 \text{ Volt}$$

70. (a)

$C_xH_{2x} + z(O_2 + 3.76\ N_2) \Rightarrow aCO_2 + bH_2O + 3.76\ z\ N_2$

By comparing,
$$a = x$$
$$b = x$$
$$a + \frac{b}{2} = z$$
$$x + \frac{x}{2} = z$$
$$1.5x = z$$

So, Mass of oxygen required $= 1.5x \times 32$

$$\text{Mass of air required} = \frac{1.5x\times 32}{0.232}$$
$$\text{Mass of fuel} = (12 \times x + 1 \times 2 \times x) = 14x$$
$$\text{Air fuel ratio, A/F} = \frac{1.5x\times 32}{0.232\times 14x} = 14.8:1$$

72. (a)

For 4-stroke engine, $iP_1 = \frac{P_{mi}L_1A_1N_1n_1}{120}$

For 2-stroke engine, $iP_2 = \frac{P_{mi}L_1A_1N_1n_2}{60}$

Average piston speed, $\bar{u}_p = 2\,LN$

So, $LN = \frac{u_P}{2}$

$$iP_1 = P_{m_i} \times A_1 \times \frac{u_{P_1}}{2} \times \frac{6}{120}$$

$$iP_2 = P_{m_i} \times A_2 \times \frac{u_{P_2}}{2} \times \frac{2}{60}$$

$$\frac{iP_1}{iP_2} = \frac{A_1 \times u_{P_1} \times 6 \times 60}{A_2 \times u_{P_2} \times 2 \times 120} = \left(\frac{D_1}{D_2}\right)^2 \times \frac{u_{P_1}}{u_{P_2}} \times \frac{6}{2} \times \frac{60}{120}$$

$$\frac{60}{12} = (2)^2 \times \frac{12}{u_{P_2}} \times \frac{3}{2}$$

$$u_{P_2} = (2)^2 \times 12 \times \frac{3}{2} \times \frac{12}{60} = 14.4 \text{ m/s}$$

73. (b)

Let, bp at full load $= x$ kW

bp at 80% full load $= 0.8x$

ip at 80% full load $= 0.8x + fp$

$$\eta_m(\text{at 80\% load}) = \frac{bp}{ip}$$

$$0.75 = \frac{0.8x}{0.8x + fp}$$

$$0.6x + 0.75fp = 0.8x$$

$$fp = \frac{0.2x}{0.75}$$

At full load, $ip = bp + fp$

$$50 = x + \frac{0.2x}{0.75} = x\left(\frac{0.95}{0.75}\right)$$

$$x = \frac{50 \times 0.75}{0.95}$$

$$fp = \frac{0.2}{0.75} \times \frac{50 \times 0.75}{0.95} = 10.52 \text{ kW}$$

74. (c)

$$\text{Angular velocity, } \omega = \frac{\theta}{t}$$

$$\frac{2\pi N}{60} = \frac{45\times\pi}{180\times 0.005}$$

$$N = 1500 \text{ rpm}$$

75. (d)

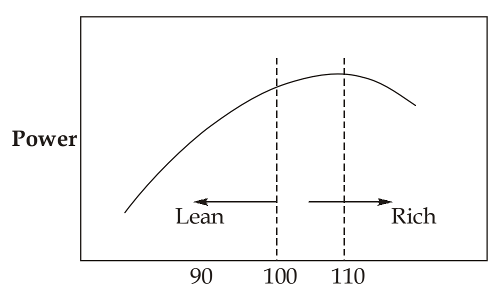
1. Maximum NO_x is formed at a slightly lean equivalence ratio of about $\phi = 0.95$. At this condition flame temperature is still very high and in addition, there is an excess of oxygen that can combine with the nitrogen to form various oxides.
2. If spark is advanced, the cylinder temperature will be increased and more NO_x will be created.
3. Because CI engines have higher compression ratios and higher temperature and pressure, with divided combustion chambers and indirect injection (IDI), they tend to generate higher levels of NO_x.

76. (a)

Knock limited compression ratio is obtained by increasing the compression ratio on a variable compression ratio engine until incipient knocking is observed. Any change in operating conditions such as fuel-air ratio or the engine design that increases the knock limited compression ratio is said to reduce the tendency towards knocking.

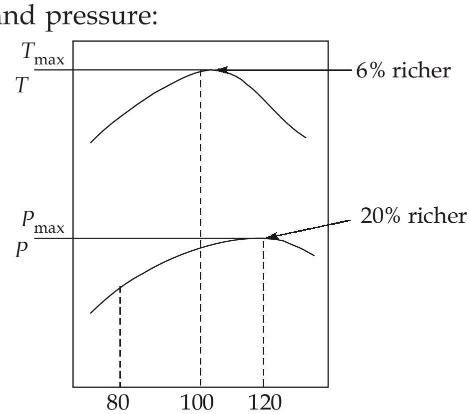
77. (d)

1. For maximum power:



Mixture strength expresses as a %age of stoichiometric mixture

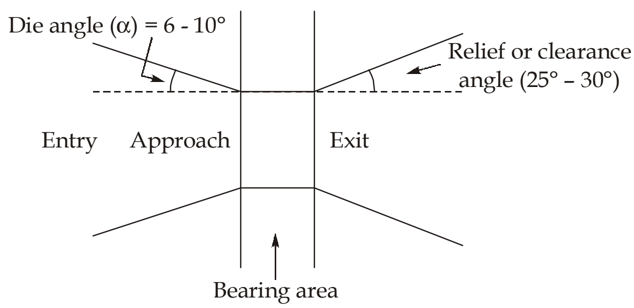
2. Maximum temperature and pressure:



Mixture strength expressed as a %age of stiochiometric mixture.

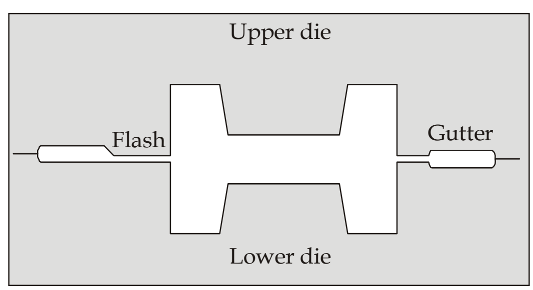
At a given compression ratio the temperature after combustion reaches a maximum when the mixture is slightly rich i.e. around 6% or so (F/A = 0.072 or A/F =14 : 1).
The pressure of a gas in a given space depends upon its temperature and the number of molecules. The curve of pressure therefore follows temperature, but because of the increasing number of molecules, pressure does not start to decrease until the mixture is somewhat richer than that for maximum i.e. about 20 percent rich.

78. **(d)**

- 

- The lime neutralises any amount of acid left on the surface and absorbs the lubricant for carrying it to the die.

79. **(b)**
Without gutter, flash may become excessively thick, not allowing the dies to close completely. The gutter should be more than the flash provided.



81. **(d)**
The compression failure of the skin of the mould cavity because of excessive heat in the molten metal is known as rat tails. Under the influence of the heat the sand expands, thereby moving the mould wall backwards and in the process when the wall gives away, the casting surface may have this marked as a small line.

82. **(d)**

$$\text{Diameter, } d_1 = 3 \text{ mm}$$
$$r_1 = 1.5 \text{ mm}$$
$$t \propto \left(\frac{V}{SA}\right)^2$$
$$t = k\left(\frac{V}{SA}\right)^2 = k\left(\frac{R}{3}\right)^2$$

$$\frac{t_2}{t_1} = \left(\frac{R_2}{R_1}\right)^2$$

$$t_2 = t_1 \times (2)^2 [\because \text{ Where, } R_2 = 2R_1]$$

$$= 10 \times 2^2$$

$$t_2 = 40 \text{ s}$$

83. (b)

Taylor's tool life exponent, n = 0.4

Machining cost, C_m = ₹5 per min

Total tooling cost, C_T = 60 × 2 = ₹120

Optimum tool life for minimum cost,

$$T_o = \frac{C_T}{C_m}\left(\frac{1-n}{n}\right) = \frac{120}{5} \times \left(\frac{1-0.4}{0.4}\right)$$

$$T_o = 36 \text{ minutes}$$

84. (d)

Mechanical comminution or pulverization involves crushing, milling in a ball mill or grinding brittle or less ductile metals into small particles.

Comminution is the oldest mechanical operation for the size reduction of solid materials and is an important step in many processes where raw materials are converted into intermediate or final products. It is the most widely used method of powder production for hard metals and oxide powders.

85. (c)

Given: V = 30 + 60L

We know that,
$$V = V_o - \frac{I}{I_o} \times V_o$$

$$V = 90 - \frac{90 \times I}{1000}$$

$$30 + 60L = 90 - \frac{90 \times I}{1000}$$

$$\frac{90I}{1000} = 60 - 60L$$

$$I = (60 - 60L) \times \frac{1000}{90}$$

Power, $P = V \times I$

$$= (30 + 60L) \times (60 - 60L) \times \frac{1000}{90}$$

$$= (1 + 2L) \times (2 - 2L) \times 30 \times 30 \times \frac{1000}{90}$$

For optimum arc length, power should be maximum, so $\frac{\partial P}{\partial L} = 0$

$$\Rightarrow \quad \frac{\partial}{\partial L}(1+2L)(2-2L) = 0$$

$$\frac{\partial}{\partial L}\left(2+4L-2L-4L^2\right) = 0$$

$$2 - 8L = 0$$

$$L = \frac{2}{8} = \frac{1}{4} = 0.25 \text{ cm}$$

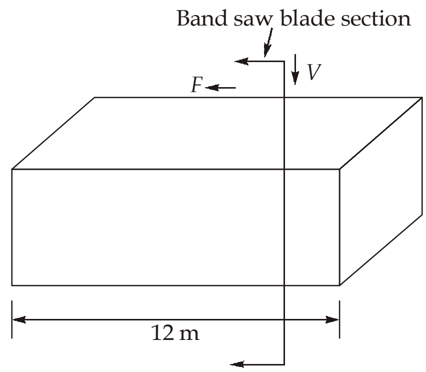
$$L = 2.5 \text{ mm}$$

86. (c)

As dew point temperature is lower than dry bulb temperature of air so cooling will happen. As specific humidity remains same at dew point there will be no humidification or dehumidification.

87. (c)

$$\text{Saw speed} = 120 \text{ m/min}$$



$$\text{So, number of teeth engaging per minute} = 10 \times \left(\frac{\text{Teeth}}{\text{Meter}}\right) \times 120 \times \left(\frac{\text{Meter}}{\text{Minute}}\right)$$

$$= 1200 \text{ Teeth/minute}$$

$$\text{Feed per tooth} = 0.003 \text{ meter}$$

$$\text{Feed per minute} = 1200 \times 0.003$$

$$= 3.6 \text{ m/min}$$

$$\text{Time taken to cut 10 m} = \frac{10}{3.6} = 2.8 \text{ minute}$$

88. (c)

$$\text{Average uncut chip thickness, } t_{avg} = \frac{v_w}{m \times V_g}\sqrt{\frac{d}{D}}$$

89. (c)

Advantages

Reduced fixturing: NC requires fixtures which are simpler and less costly to fabricate because the positioning is done by the NC tape rather than the jig or fixture.

Improved quality control: NC is ideal for complicated workparts where the chances of human mistakes are high. Numerical control produces parts with greater accuracy, reduced scrap, and lower inspection requirements.

Reduced floor space requirement: Since one NC machining center can often accomplish the production of several conventional machines, the amount of floor space required in an NC shop is usually less than in a conventional shop.

Disadvantages

Non-optimal speeds and feeds: In conventional numerical control, the control system does not provide the opportunity to make changes in speeds and feeds during the cutting process. As a consequence, the programmer must set the speeds and feeds for worst-case conditions. The result is lower than optimum productivity.

90. (b)

Change in diameter, $\Delta d = d_f - d_i = 50.025 - 50 = 0.025$ mm

Initial length, $l_i = 600$ mm

As we know, Poisson's ratio,
$$\mu = -\frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \frac{-\dfrac{\Delta d}{d_i}}{\dfrac{\Delta l}{l_i}}$$

$$0.3 = -\frac{0.025/50}{\Delta l/600}$$

$$\Delta l = \frac{-0.025}{50} \times \frac{600}{0.3} = -1 \text{ mm}$$

91. (b)

Yield strength, $S_{yt} = 280$ MPa

Factor of safety, $N = 2$

Permissible stress, $\sigma_{per} = \dfrac{S_{yt}}{N} = \dfrac{280}{2} = 140$ MPa

From strength criterion, $\sigma_{max} < \sigma_{per}$

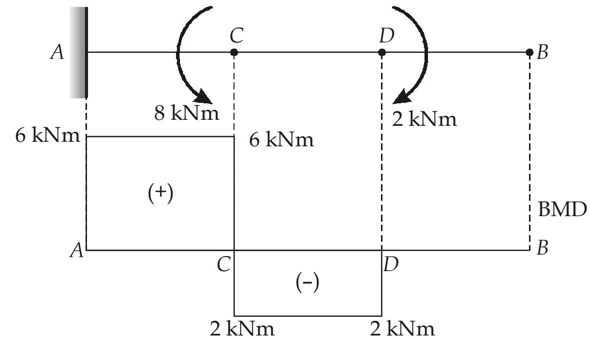
$$\Rightarrow \quad \frac{\gamma AL}{A} \le \sigma_{per}$$

$$\Rightarrow \quad 77 \times 10^3 L \le 140 \times 10^6$$

$$L \le \frac{140 \times 10^6}{77 \times 10^3}$$

$$L \le 1818.18 \text{ m}$$

92. (c)



$$\text{Maximum bending moment, } M_{max} = 6 \text{ kN-m}$$

$$\text{Allowable stress, } \sigma_{per} = 120 \text{ MPa}$$

$$\text{For safe design, } \sigma_{max} \le \sigma_{per}$$

$$\frac{M_{max}}{I} y_{max} \le \sigma_{per}$$

$$\frac{I}{y_{max}} \ge \frac{M_{max}}{\sigma_{per}}$$

$$Z \ge \frac{6 \times 10^6}{120}$$

$$\ge 50000 \text{ mm}^3$$

$$\text{So, } Z_{min} = 50000 \text{ mm}^3$$

93. (b)

In case of simply supported beam with uniformly distributed load, 'w',

$$\text{Deflection at the centre, } \delta = \frac{5}{384}\frac{wL^4}{EI}$$

$$w = \frac{384}{5}\frac{EI\delta}{L^4} = \frac{384 \times 200 \times 10^3 \times \frac{100 \times 240^3}{12} \times 4}{5 \times (4000)^4}$$

$$= \frac{384 \times 2 \times 24^3 \times 4}{5 \times 4^4 \times 12 \times 100} = \frac{48 \times (8 \times 2) \times 24^3 \times 4}{5 \times 16 \times 16 \times 12 \times 100}$$

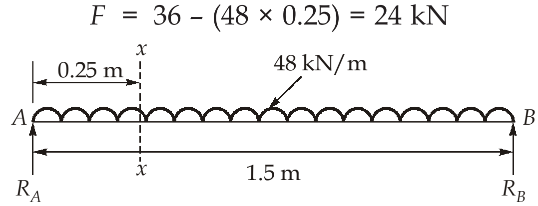
$$w = \frac{24^3}{500} = 27.65 \text{ kN/m}$$

94. (c)

$$\text{By symmetry, } R_A = R_B = \frac{48 \times 1.5}{2} = 36 \text{ kN}$$

Shear force at cross-section at distance of 0.25 m,

$$F = 36 - (48 \times 0.25) = 24 \text{ kN}$$



$$\text{Maximum shear stress, } \tau_{max} = \frac{3}{2}\tau_{avg} = \frac{3}{2} \times \frac{F}{bh} = \frac{3}{2} \times \frac{24 \times 1000}{75 \times 20} = 24 \text{ MPa}$$

95. **(b)**

$$^2D_1 = -^1R_2^T\ ^1D_2 = -\begin{bmatrix} 1 & 0 & 0 \\ 0 & 0.500 & 0.866 \\ 0 & -0.866 & 0.500 \end{bmatrix}\begin{bmatrix} 7.0 \\ 5.0 \\ 7.0 \end{bmatrix}$$

$$^2D_1 = \begin{bmatrix} -7.00 \\ -8.56 \\ 0.83 \end{bmatrix} = [-7.00 \quad -8.56 \quad 0.83]^T$$

97. **(c)**

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

$$^1R_2 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos 90° & -\sin 90° \\ 0 & \sin 90° & \cos 90° \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix}$$

$$\therefore \quad ^1T_2 = \left[\begin{array}{ccc|c} 1 & 0 & 0 & 7 \\ 0 & 0 & -1 & 5 \\ 0 & 1 & 0 & 6 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

98. **(b)**

$$\text{Total deformation} = 0$$

$$\Delta_a + \Delta_{th} = 0$$

$$\Rightarrow \quad \frac{P \times 0.4}{AE} + 1 \times \alpha \times \Delta T = 0$$

$$\Rightarrow \frac{P \times 0.4}{200 \times 70 \times 10^3} + 2.4 \times 10^{-5} \times (-50) = 0$$

$$\Rightarrow \quad \frac{P \times 0.4}{14 \times 10^6} = 12 \times 10^{-4}$$

$$\Rightarrow \quad P = \frac{14 \times 12 \times 100}{0.4} = 42 \text{ kN}$$

99. **(c)**

$$\text{Total angle of twist} = 1° = \frac{\pi}{180}$$

$$\frac{Tl_A}{JG_A} + \frac{Tl_B}{JG_B} = \frac{\pi}{180}$$

$$\Rightarrow \quad \frac{T}{\frac{\pi}{32} \times 20^4}\left[\frac{300}{30 \times 10^3} + \frac{700}{35 \times 10^3}\right] = \frac{\pi}{180}$$

$$T\left[\frac{1}{100}+\frac{1}{50}\right] = \frac{\pi^2}{32}\times\frac{20^4}{180}$$

$$T = \frac{\pi^2}{32}\times\frac{100\times16\times10^4}{180\times3} = 9138.52\text{ N-mm} = 9.138\text{ N-m}$$

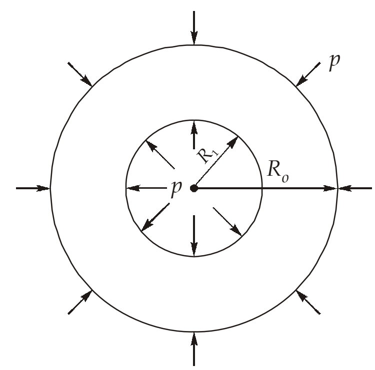
100. (b)

In case of thick cylinder subjected to both internal and external pressure,

$$p_x = p_o + p$$

At $x = R_i$, $p_x = p$

At $x = R_o$, $p_x = p$



So, $$p_x = -a+\frac{b}{x^2}$$

$\Rightarrow$ $$p = -a+\frac{b}{R_i^2}$$

$$p = -a+\frac{b}{R_o^2}$$

By subtracting, $$0 = 0+b\left[\frac{1}{R_i^2}-\frac{1}{R_o^2}\right]$$

$\Rightarrow$ $$b = 0$$

So, $$a = -p$$

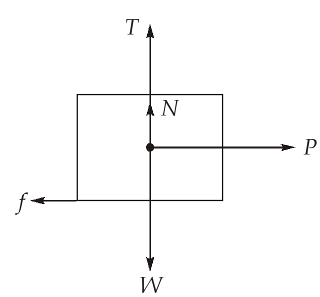
Thus, $$\sigma_h = a+\frac{b}{x^2} = a$$

$$(\sigma_h)_{R_i} = -p = (\sigma_h)_{R_o}$$

$$(\sigma_h)_{R_o} = -6\text{ MPa}$$

$$= 6\text{ MPa (Compressive)}$$

101. (a)



Force equilibrium in vertical direction,

$$T + N = W$$

Normal reaction, $N = W - T$

$$N = 1000 - T$$

Force equilibrium in horizontal direction,

$$P = f$$

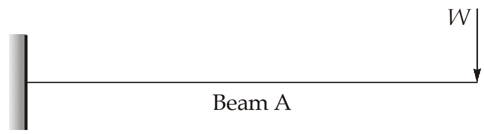
$$150 = \mu N = 0.2\,(1000 - T)$$

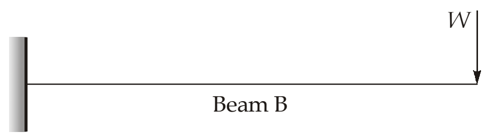
$$\frac{150}{0.2} = 1000 - T$$

$$T = 1000 - 750 = 250\text{ N}$$

102. **(b)**

Shear force in beam A, $F_A = W$





Maximum shear stress in beam A,

$$\tau_{\text{max, A}} = \frac{3}{2}\frac{F_A}{A_A} = \frac{3}{2} \times \frac{W}{A} \qquad (\because \text{ rectangular cross-section})$$

Shear force in beam B, $F_B = W$

Maximum shear stress in beam B,

$$\tau_{\text{max, B}} = \frac{4}{3}\frac{F_B}{A_B} = \frac{4}{3} \times \frac{W}{A} \qquad (\because \text{ circular cross-section})$$

Now,

$$\frac{\tau_{\max A}}{\tau_{\max B}} = \frac{\frac{3}{2}\frac{W}{A}}{\frac{4}{3}\frac{W}{A}} = \frac{9}{8}$$

103. **(c)**

From symmetry,

$$R_B = R_C = \frac{1}{2}w\left(L + \frac{2L}{3}\right) = \frac{1}{2}w\left(\frac{5L}{3}\right) = \frac{5wL}{6}$$

Bending moment at mid point,

$$M = -\frac{w}{2}\left(\frac{L}{3} + \frac{L}{2}\right)^2 + \frac{5wL}{6} \times \frac{L}{2}$$

$$= -\frac{w}{2}\left(\frac{5L}{6}\right)^2 + \frac{5wL^2}{12} = \left[\frac{5}{12} - \frac{1}{2} \times \frac{25}{36}\right]wL^2$$

$$M = \frac{30-25}{72}wL^2 = \frac{5}{72}wL^2$$

104. **(c)**

As we know,

$$\eta = 1 - \frac{T_2}{T_1}$$

$\Rightarrow$

$$0.3 = 1 - \frac{T_2}{T_1}$$

$$1 - 0.3 = \frac{T_2}{T_1} \Rightarrow T_2 = 0.7T_1$$

Now, $$\eta' = 1 - \frac{T_2'}{T_1}$$

$\Rightarrow$ $$0.4 = 1 - \frac{T_2'}{T_1}$$

$$1 - 0.4 = \frac{T_2'}{T_1} \Rightarrow T_2' = 0.6T_1$$

$$\%\text{change} = \frac{T_2' - T_2}{T_2} \times 100 = \frac{0.6T_1 - 0.7T_1}{0.7T_1} \times 100$$

$$= -14.28\%$$

105. (b)

As we know,

$$\text{Work, } W = \int p\,dv = 10^5 \times \int_{0.5}^{1} (5 - 2V)\,dv \ J$$

$$= 10^5 \left[5V - \frac{2V^2}{2}\right]_{0.5}^{1} J$$

$$= 10^5 [5(1 - 0.5) - (1^2 - 0.5^2)] \text{ J}$$

$$= 10^5 (2.5 - 0.75) = 1.75 \times 10^5 \text{ J}$$

$$= 175 \text{ kJ}$$

106. (b)

As we know,

$$\text{Polytropic specific heat, } c_{poly} = -c_v \frac{\gamma - n}{n - 1} = -\frac{R}{(\gamma - 1)} \frac{\gamma - n}{n - 1}$$

$$= -\frac{\bar{R}}{M(\gamma - 1)} \frac{\gamma - n}{n - 1} = -\frac{8.314}{4 \times \left(\frac{5}{3} - 1\right)} \frac{\left(\frac{5}{3} - \frac{4}{3}\right)}{\left(\frac{4}{3} - 1\right)}$$

$$= -\frac{8.314}{4 \times \frac{2}{3}} \times \frac{1/3}{1/3} = -\frac{8.314 \times 3}{8}$$

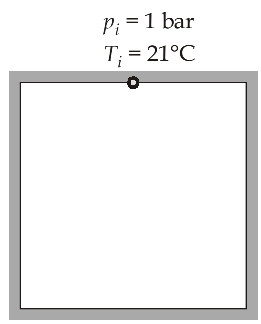
$$c_{poly} = -3.117 \text{ kJ/kgK}$$

Here polytropic specific heat for the process is negative because, to execute such a process with $n \in (1, \gamma)$, more work should be done by the system than the heat added or more work should be done on the system than the heat removed.

107. (c)

Mass conservation, $m_i - m_e = m_2 - m_1$

$m_i = m_2$ $[\because m_1 = 0, m_e = 0]$



Energy conservation, $\Delta U = m_i h_i - m_e h_e + Q - W$

$$m_2u_2 - m_1u_1 = m_ih_i \quad [\because Q = 0 \text{ (insulated)}, W = 0 \text{ (rigid)}, m_e = 0]$$

$$m_2u_2 = m_ih_i \quad [\because m_1 = 0]$$

$$u_2 = h_i \quad [\because m_i = m_2]$$

$$c_vT_2 = c_pT_i$$

$$T_2 = \frac{c_p}{c_v}T_i = \gamma T_i$$

$$= 1.4 \times (21 + 273)$$

$$= 411.6 \text{ K} = 138.6°\text{C}$$

108. (d)

As we know,

Maximum work obtainable for two finite bodies,

$$W_{max} = c_p\left(\sqrt{T_1} - \sqrt{T_2}\right)^2 = c_p\left(T_1 + T_2 - 2\sqrt{T_1T_2}\right)$$

$$= 20\left[1200 + 300 - 2\sqrt{1200 \times 300}\right]$$

$$= 20\left[1500 - 200 \times 6\right] = 20 \times 300$$

$$= 6000 \text{ kJ} = 6 \text{ MJ}$$

109. (c)

In practice, all of the kinetic energy in the wind cannot be converted to shaft power.

The Betz criterion, derived by using the principle of conservation of momentum and energy, suggests a maximum possible turbine efficiency (or power coefficient) of 59% or $\left(\frac{16}{27} \times 100\right)\%$.

i.e. 59% of the available kinetic energy can be converted into useful power.

110. (b)

Amplitude, $R = 15$ m

$r = 4$ m

Basin area, $A = 3 \text{ km}^2$

$$\text{Density } (\rho) = 1025 \text{ kg/m}^3$$

$$\begin{aligned}\text{Average power potential available} &= \text{Average power of generated}\\ &= 0.225 \times A(R^2 - r^2) \text{ Watts}\\ &= 0.225 \times 3 \times 10^6 \times (15^2 - 4^2)\\ &= 0.675 \times 10^6 (225 - 16)\\ &= 0.675 \times 10^6 \times 209\\ &= 141.075 \text{ MW}\end{aligned}$$

111. **(b)**

For real gas, during throttling process, pressure decreases and temperature increases initially, reaches to maximum and then decreases. Throtlling is an isenthalpic process.

112. **(a)**

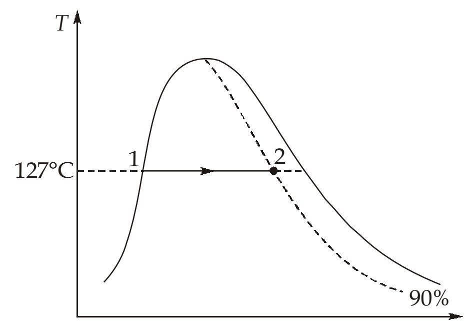
$$h_{fg} = 2000 \text{ kJ/kg}$$

Change in entropy, $\Delta S = \dfrac{\Delta h}{T} = \dfrac{(h_2 - h_1)}{T}$

As we know, $h_2 = h_1 + xh_{fg}$

$$\begin{aligned}h_2 - h_1 &= 0.9 \times 2000\\ &= 1800 \text{ kJ/kg}\end{aligned}$$

$$\Delta S = \frac{1800}{400} = 4.5 \text{ kJ/ kgK}$$



113. **(c)**

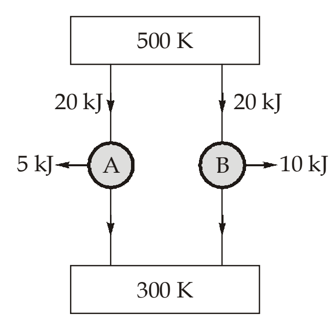
Irreversibility associated with a process,

$$I = T_o \, \Delta S$$

where, ΔS = Entropy change of universe

T_o = Surrounding temperature

114. **(b)**



Efficiency of Carnot engine, $\eta_{max} = 1 - \dfrac{T_2}{T_1} = 1 - \dfrac{300}{500} = 0.4$

Efficiency of heat engine A, $\eta_A = \dfrac{W_A}{Q_A} = \dfrac{5}{20} = 0.25$

$$\eta_A < \eta_{max}$$

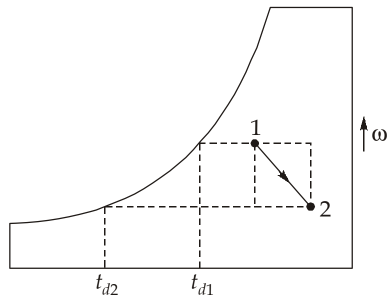
So, engine A is possible and irreversible.

Efficiency of heat engine B, $\eta_B = \dfrac{W_B}{Q_B} = \dfrac{10}{20} = 0.5$

$$\eta_B > \eta_{max}$$

So, engine B is impossible.

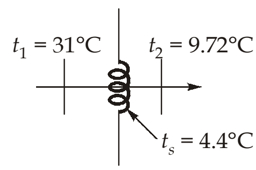
115. (c)



Since, $t_{d1} > t_{d2}$

∴ DPT of air decreases

116. (d)



$$\text{Coil bypass factor} = \frac{t_2 - t_s}{t_1 - t_s} = \frac{9.72 - 4.4}{31 - 4.4} = \frac{5.32}{26.6} = 0.2$$

117. (b)

Excessive liquid line pressure drop can cause the liquid refrigerant to flash, resulting in faulty expansion value operation.

118. (b)

For a saturated hydrocarbon denoted by $C_mH_nF_pCl_q$, the designation is

$$R(m - 1)(n + 1)p$$

In case of inorganic refrigerants designations have been given according to their moleclar weight added to 700.

120. (c)

SDE is based on the availability of the items:

1. Scarce
2. Difficult
3. Easily available

121. (c)

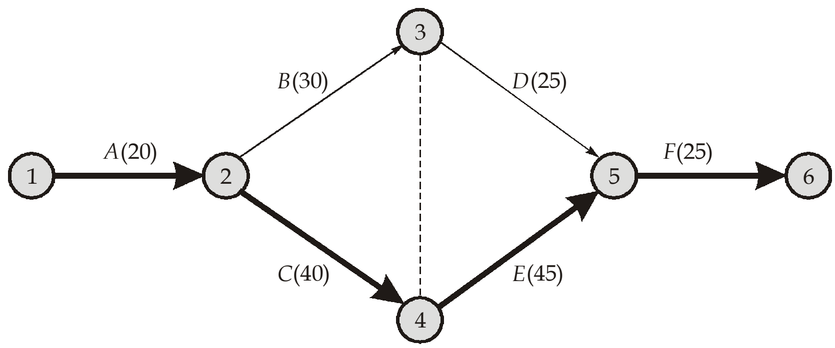
$$\text{EOQ} = \sqrt{\frac{2DC_o}{C_h}} \times \sqrt{\frac{C_h + C_b}{C_b}}$$

$$Q^* = \sqrt{\frac{2 \times 1000 \times 128}{5} \times \frac{5 + 40}{40}}$$

$$= \sqrt{\frac{2 \times 1000 \times 128}{5} \times \frac{9}{8}} = 240 \text{ units}$$

$$\text{Maximum stockout level, } Q_2 = Q^* \times \frac{C_h}{C_h + C_b} = 240 \times \frac{5}{5 + 40} = 26.67 \text{ units}$$

122. (d)



Critical path is A - C - E - F

Total project completion time = 20 + 40 + 45 + 25 = 130 days

123. (c)

Note that 148 – 135 = 13 and 161 – 148 = 13. Demand is following linear curve, so demand in 2021 will be 161 + 13 = 174.

124. (b)

PERT is a probabilistic model and used for new activities.

CPM is deterministic model.

125. (a)

Balance mass can be given as:

$$M_b = \frac{V_o}{V_t} \times m_t = \frac{12}{14} \times 6.2 = 5.3 \text{ gm}$$

126. (d)

As we know,

Endurance limit in reversed bending,

$$S_e' = 0.5 \times S_{ut} = 0.5 \times 500 = 250 \text{ MPa}$$

$k_a = 0.8$, $k_b = 0.866$, $k_c = 0.9$, $k_d = 1$

So, corrected endurance limit of component in reversed bending,

$$S_e = k_a k_b k_c k_d S_e'$$

$$= 0.8 \times 0.866 \times 0.9 \times 1 \times 250$$

Endurance limit in fluctuating torsion

$$S_{se} = \frac{1}{\sqrt{3}} S_e = \frac{1}{\sqrt{3}} \times 0.8 \times \frac{\sqrt{3}}{2} \times 0.9 \times 250 = 90 \text{ MPa}$$

127. (a)

$$\text{Tangential force, } F_t = \frac{2T}{d} = \frac{2 \times 60000}{90} = \frac{4000}{3} \text{ N}$$

$$\text{Velocity factor, } C_v = \frac{3}{3+v} = \frac{3}{3+7} = 0.3$$

Service factor, $C_s = 1.5$

Effective load between two meshing gears,

$$P_{eff} = \frac{C_s}{C_v} F_t = \frac{1.5}{0.3} \times \frac{4000}{3} = 6666.67 \text{ N}$$

128. (b)

Destructive pitting is a surface fatigue failure, which occurs when the load on the gear tooth exceeds the surface endurance strength of the material.

Initial or corrective pitting is a localized phenomenon, characterized by small pits at high spots.

129. (d)

Last two terms in the designation of anti-friction bearing represent shaft diameter.

Multiplying last two terms by 5 gives shaft diameter.

Here, Shaft diameter, $d = 40$ mm

So, $\frac{40}{5} = 08$

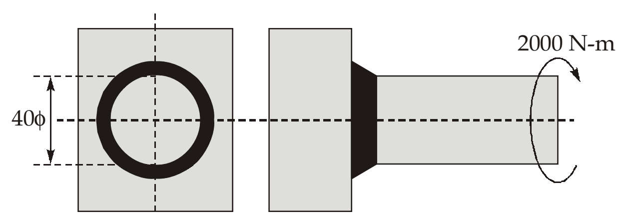
$X = 0$

$Y = 8$

130. (c)

Throat size, $h = 5$ mm

Torque equation:



$$\frac{T}{J} = \frac{\tau_{max}}{R}$$

$$\frac{T}{2\pi R^3 h} = \frac{\tau_{max}}{R}$$

$\Rightarrow$
$$\tau_{max} = \frac{T}{2\pi R^3 h}$$

Here, $R = \frac{D}{2} = \frac{40}{2} = 20$ mm

$$\tau_{max} = \frac{2000 \times 1000}{2\pi \times (20)^2 \times 5} = \frac{2000 \times 1000}{4000 \times \pi} = 159.15 \text{ MPa}$$

131. (a)

In deep groove ball bearing, the radius of the ball is slightly less than the radii of curvature of the grooves in the races.Kinematically, this gives a point contact between the balls and the races. Therefore, the balls and the races may roll freely without any slidings.

132. (c)

IR are calibrated to black bodies but practically real bodies temperature are measured. So measurement will depends on some factors like:

1. Emissivity
2. Reflected temperature
3. Atmospheric temperature
4. Relative humidity

For emissivity field calibration is done generally in two ways:

1. If we know that temperature of the body by some other means then we set. The emissivity in IR camera according that is match the readings (known temperature).
2. Attached black dull tape to the measuring body and point the IR camera to that tape and find the measurement. In this case set the emissivity to 1.

133. (c)

Capital investment requirement is less in fixed position layout.

134. (c)

When the sun earth and moon are aligned in conjunction. The lunar and solar tides are in phase, producing net tides of maximum range. These are spring tides.

135. (d)

Slope of constant volume line on T-s diagram,

$$\left(\frac{dT}{ds}\right)_v = \frac{T}{c_v}$$

Slope of constant pressure line on T-s diagram,

$$\left(\frac{dT}{ds}\right)_p = \frac{T}{c_p}$$

Since $c_p > c_v$

$$\left(\frac{dT}{ds}\right)_v > \left(\frac{dT}{ds}\right)_p$$

137. (b)

To decrease inertia, diameter is reduced but to obtain desired output, length of armature is increased.

138. (a)

One of the drawback of the simple vapour-absorption cycle is low temperature of the rich solution entering the generator and high temperature of the poor solution entering the absorber. By adding heat exchanger between poor and rich solutions, the amount of heat added in the generator is reduced and hence increases the COP

139. (a)

The clearance is necessary in reciprocating compressors to provide for thermal expansion and machining tolerances.

141. (b)

Since Poisson's ratio is zero, normal strain in z-direction will be zero, i.e. $\varepsilon_z = 0$. So, every plane stress element is also in plane strain.

142. (d)

In case of cycloidal teeth, the pressure angle varies from the maximum at the beginning of engagement to zero when the point of contact coincides with pitch point P and then again increases to maximum in the reverse direction.

143. (d)

Statement 2 is correct as the tension in wire is mg, i.e.

$$\Delta x_1 = \frac{mg}{k_1}, \quad \Delta x_2 = \frac{2mg}{k_2}$$

$$\text{Deflection of mass} = \Delta x_1 + 2\Delta x_2 = \frac{mg}{k_1} + \frac{4mg}{k_2}$$

$$\text{Natural frequency, } \omega_n = \sqrt{\frac{g}{\Delta}} = \sqrt{\frac{1}{\frac{m}{k_1} + \frac{4m}{k_2}}} = \sqrt{\frac{k_1 k_2}{m(k_2 + 4k_1)}}$$

144. (b)

Balancing of rotating mass is easy as compared to balancing of reciprocating mass.

145. (b)

The minimum temperature differences between two fluids is called pinch point which causes a lower thermal irreversibility and an increase in surface area resulting in a large expensive steam generator with a improved plant efficiency.

147. (d)

A 2.0 L car engine will at like a 1.7L car engine at 1500 m altitude (unless it is turbo charged) because of 15 percent drop in pressure and thus 15 percent drop in density of air.

A fan or compressor will displace 15 percent less air at the altitude for the same volume displacement rate.

Therefore, larger cooling fans may need to be selected for operation at high altitude to ensure the specified mass flow rate.

148. (a)

When silicon content is low ($< 1\%$) in combination with faster cooling rates, there is no time for cementite to get decomposed, thus most of the brittle cementite retains. Because of prescence of cementite, fractured surface appear white, hence the name as white cast iron. They are very brittle and extremely difficult to machine.

149. (c)

The thermal efficiency of the CI engine is higher than SI engine because of higher compression ratio used.

150. (c)

During the preparation of the cope, no follow board is necessary because the sand that is already compacted in drag will support the fragile pattern.

