DETAILED SOLUTIONS

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## ESE 2022 : Prelims Exam
## CLASSROOM TEST SERIES

## MECHANICAL ENGINEERING

## Test 20

### Full Syllabus Test 4 : Paper-II

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

## DETAILED EXPLANATIONS

**1. (c)**

Classification of energy storage technologies:

**1. Mechanical energy storage**

(a) Potential energy storage

(i) Compressed air storage

(ii) Pumped hydro storage

(b) Kinetic energy storage - Flywheels

**2. Electrical energy storage**

(a) Capacitors storage

(b) Super capacitors storage

(c) Inductor storage

(d) Superconducting magnetic energy storage (SMES)

**3. Thermal energy storage**

(a) Sensible heat storage

(b) Latent heat storage

**4. Chemical energy storage**

(a) Batteries

(b) Fuel cell

(c) Thermochemical energy storage

**Note :** Packed-bed storage comes under thermal energy storage mthod for passive space heating and cooling system.

**2. (d)**

There is almost complete absorption of short wave radiation (in range $\lambda$ < 0.29 μm) and infrared radiation (in range $\lambda$ > 2.3 μm) in the atmosphere. Thus, from the point of view of terrestrial applications of solar energy, the radiation only in the range of wavelength 0.29 to 2.3 μm is significant.

**3. (b)**

Solar radiation data are measured by following instruments :

(i) **Pyranometer :** A pyranometer is designed to measure global radiation, usually on a horizontal surface but can also be used on an inclined surface. When shaded from beam radiation by using a shading ring, it measures diffuse radiation only.

(ii) **Pyroheliometer :** It measures beam radiation by using a long and narrow tube to collect only beam radiation from the Sun at normal incidence.

(iii) A sunshine recorder measures the sunshine hours in a day.

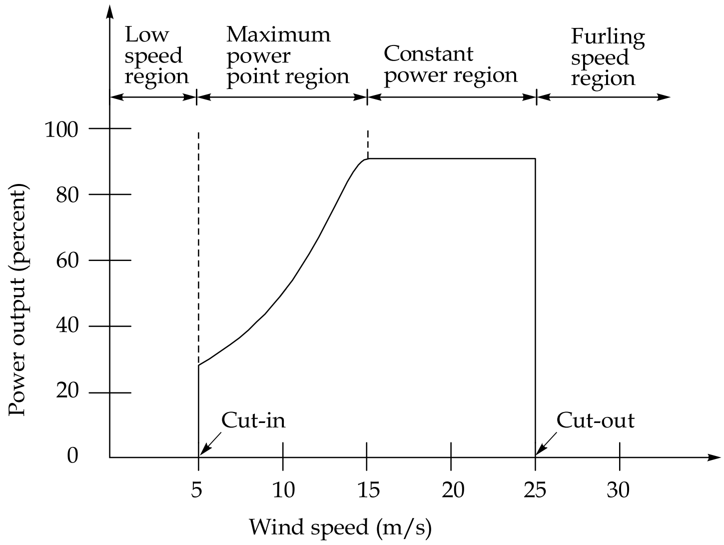
**4. (d)**

Adjusting the nacelle about the vertical axis to bring the rotor facing the wind is known as yaw control. The yaw-control system continuously orients the rotor in the direction of wind.

For localities with a wind prevailing in one direction only, the rotor can be in a fixed orientation, such a machine is said to be "yaw fixed". In large turbines, an active yaw control system (i.e. yaw active) with power steering and wind direction sensor is used to maintain the orieintation.

**5. (b)**

The power-speed characteristics of a wind turbine have four separate regions as shown in figure:




*Power versus wind speed characteristics*

Cut in speed is the minimum wind speed at which the blades will turn and generate usable power. This wind speed is typically about 5 m/s (i.e. 10 to 16 kmph).

**6. (c)**

Given : $\alpha = 45°$ (incidence angle)

$\therefore$ $\alpha + \theta_z = 90° \Rightarrow \theta_z = 45°$

**7. (d)**

Characteristics of various fuel cells are listed in the table below :

| S.No. | Fuel Cell | Operating Temperature | Fuel | Efficiency |
|---|---|---|---|---|
| 1. | PEMFC | 40 – 60°C | $H_2$ | 48 – 58% |
| 2. | AFC | 90°C | $H_2$ | 64% |
| 3. | PAFC | 150 – 200°C | $H_2$ | 42% |
| 4. | MCFC | 600 – 700°C | $H_2$ and CO | 50% |
| 5. | SOFC | 600 – 1000°C | $H_2$ and CO | 60 – 65% |

**8. (c)**

Given : $R = 15$ m, $r = 3$ m, $A = 4$ km$^2$, $\rho = 1025$ kg/m$^3$

Now, as we know that time between consecutive high and low tide is 6 hours and 12.5 minutes (= 25350 seconds).

$$\therefore \quad P_{avg} = \frac{1025 \times 9.81 \times A \times (R^2 - r^2)}{2 \times 22350}$$

$$P_{avg} = 0.225 \times A \times (R^2 - r^2)$$

$$P_{avg} = 0.225 \times 4 \times 10^6 \times (15^2 - 3^2)$$

$$P_{avg} = 194.4 \text{ MW}$$

**9.** **(c)**

Methane forming bacteria works best in temperature range of 20–55°C. Digestion at higher temperature proceeds, more rapidly than at lower temperature, with gas yield rates doubling at about every 5°C increase in temperature. The gas production decreases sharply below 20°C and almost stops at 10°C.

**10.** **(d)**

The causes of stress concentration are as follows:

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

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

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

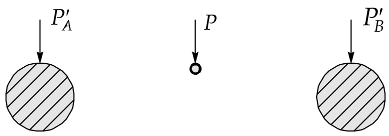
**(d) Discontinuities in the component :** Oil holes, grooves, keyways, splines, screw threads, etc.

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

**11.** **(b)**

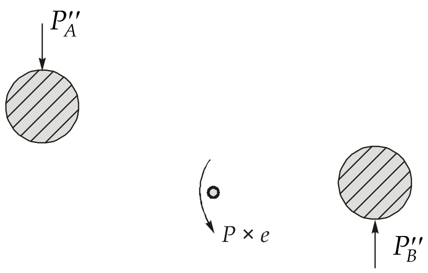
**12.** **(a)**

Primary shear force :




$$P'_A = P'_B = \frac{P}{2} = 7500 \text{ N}$$

Secondary shear force :




$$e = 50 \text{ mm}$$
$$r_1 = r_2 = 50 \text{ mm}$$
$$Pe = P''_A r_1 + P''_B r_2$$
$$Pe = K(r_1^2 + r_2^2)$$
$$K = \frac{15000 \times 50}{50^2 \times 2} = 150$$
$$P''_A = P''_B = Kr_1 = 150(50) = 7500 \text{ N}$$

Resultant shear forces:

$$P_A = P'_A + P''_A = 15000 \text{ N}$$
$$P_B = P'_A - P''_B = 0 \text{ N}$$

**13. (a)**

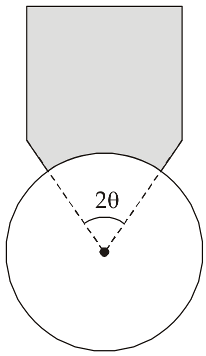
- Needle bearings have large load carrying capacity particularly at low peripheral speed.
- Needle bearings have a small outer diameter. It is due to this reason that they are often used to replace sleeve bearing. This allows replacement with little or no changes in design.

**14. (c)**

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

**15. (a)**

For long shoe,




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

**16. (d)**

$$\sigma_{b_1} = \frac{32M}{\pi d^3}$$
$$\tau_2 = \frac{16T}{\pi d^3}$$

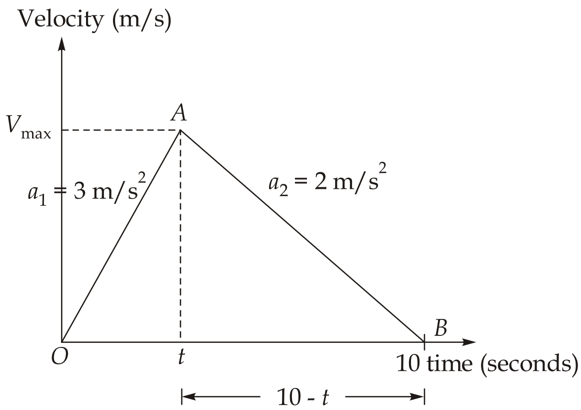
As, $\sigma_{b_1} = \frac{1}{2}\tau_2$

$\Rightarrow$ $\frac{32M}{\pi d^3} = \frac{1}{2}\cdot\frac{16T}{\pi d^3}$

$\Rightarrow$ $T = 4M = 40 \text{ N-m}$

**17. (d)**

The body undergoes constant acceleration motion between $OA$ and $AB$.

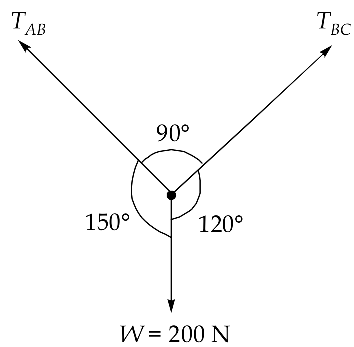



$$\Rightarrow \quad V_{max} = a_1 \times t = a_2 \times (10 - t)$$
$$\Rightarrow \quad 3 \times t = 2(10 - t)$$
$$\Rightarrow \quad t = 4 \text{ sec}$$
$$\Rightarrow \quad V_{max} = 3 \times 4 = 12 \text{ m/s}$$
$$\text{Distance travelled} = \text{Area } \Delta OAB$$
$$= \frac{1}{2} \times V_{max} \times \text{Total time}$$
$$= \frac{1}{2} \times 12 \times 10 = 60 \text{ m}$$

**18. (b)**

FBD of ball

By Lami's theorem,




$$\frac{W}{\sin 90°} = \frac{T_{AB}}{\sin 120°} = \frac{T_{BC}}{\sin 150°}$$
$$\Rightarrow \quad T_{AB} = \frac{W}{\sin 90°} \times \sin 120°$$
$$= \frac{200}{1} \times \frac{\sqrt{3}}{2} = 100\sqrt{3} \text{ N}$$

**19. (c)**

The volumetric compressive strain produced in the oil is given by

$$\frac{-dV}{V} = \frac{P}{K}$$
$$= \frac{1.4}{2800} = 500 \times 10^{-6}$$

**20. (c)**

Maximum shear stress is the radius of Mohr's circle and is equal to

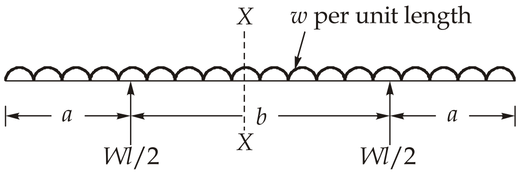
$$\tau_{max} = \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau_{xy}^2}$$

$$= \sqrt{10^2 + 20^2} = \sqrt{100+400}$$

$$\tau_{max} = 10\sqrt{5}\ \text{MPa}$$

**21. (d)**

The given condition of beam is




$$l = 2a + b$$

The bending moment at mid span shall be zero for

$$\frac{wl}{2} \times \frac{b}{2} - \frac{wl}{2}\left(\frac{a+\frac{b}{2}}{2}\right) = 0$$

$$\Rightarrow \quad \frac{b}{2} - \frac{a}{2} - \frac{b}{4} = 0$$

$$\Rightarrow \quad \frac{b}{a} = 2$$

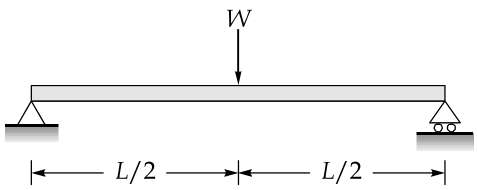
**22. (a)**

The maximum shear stress developed in the spring is related to the load as

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

which is independent of the number of turns or length.

**23. (d)**




The strain energy,

$$U = \frac{1}{2}\delta \times W$$

$$= \frac{1}{2} \times \frac{WL^3}{48EI} \times W$$

$$= \frac{W^2L^3}{96EI}$$

**24. (d)**

Given : $L = 1 \text{ m}, a = 0.04 \text{ m}$

The ratio of strain energy in the two cases is :

$$\frac{U_1}{U_2} = \frac{\frac{1}{2}\int_0^L \frac{(Wx)^2}{EI}dx}{\frac{W^2L}{2AE}}$$

$$\frac{U_1}{U_2} = \frac{W^2L^3}{6EI} \times \frac{2AE}{W^2L}$$

$$\frac{U_1}{U_2} = \frac{L^2 \times A}{3I} = \frac{a^2L^2}{3 \times \frac{a^4}{12}}$$

$$\frac{U_1}{U_2} = \frac{4L^2}{a^2} = \frac{4 \times 1^2}{(0.04)^2}$$

$$\frac{U_1}{U_2} = 2500$$

**25. (b)**

Given : $d = 10 \text{ m}, H = 100 \text{ m}, t = 0.010 \text{ m}$

Hence, the pressure at pipe will be

$$P = \rho g H$$

The hoop stress in the pipe is given by

$$\sigma_h = \frac{Pd}{2t}$$

$$= \frac{\rho g H \times d}{2t}$$

$$= \frac{10^3 \times 10 \times 100 \times 10}{2 \times 0.010} \text{ Pa}$$

$$\sigma_h = 500 \text{ MPa}$$

**26. (d)**

Since both the supports are fixed and both the bars are of same length, both bars will try to expand. So, rise in temperature will cause compressive stress in both the bars.

**27. (c)**

$$\text{Weight} = 500 \times 9.81 = 4905 \text{ N}$$

When weight is moving down with uniform velocity of 1 m/sec, then an initial tensile load of 4905 N is acting on two wire ropes.

Initial stress in each rope, $\sigma_i = \frac{1}{2} \times \frac{4905}{\left(\frac{\pi \times 8^2}{4}\right)} = 49.79 \text{ MPa}$

As a result of impact, $\sigma_2$ be the additional stress produced in each rope.

$$\frac{1}{2}\frac{W}{g}\times v^2 = \frac{\sigma_2^2}{2E}\times(\text{Volume})$$

$$\Rightarrow \quad \sigma_2^2 = \frac{Wv^2E}{g\times[\text{Volume}]} = \frac{\left(\frac{4905}{2}\right)\times(1000)^2\times 2\times 10^5}{9.81\times 10^3\times\frac{\pi}{4}\times 8^2\times 25\times 10^3}$$

$$\Rightarrow \quad \sigma_2^2 = 39788.74$$

$$\Rightarrow \quad \sigma_2 = 199.47\text{ MPa}$$

$\therefore$ Total stress in each rope $= \sigma_i + \sigma_2$

$$= 48.79 + 199.47 = 248.26\text{ MPa}$$

**28. (a)**

Given : $\tau_{max} = 100$ MPa

Strain energy per unit volume

$$U = \frac{\tau_{max}^2}{4G}$$

$$= \frac{100^2}{4\times 80\times 10^3}$$

$$= 0.03125\text{ N-mm/mm}^3$$

**29. (a)**

As we know that

$$E = \frac{9KG}{3K+G}$$

Now, $K_A = K_B$

$$\Rightarrow \quad \frac{E_AG_A}{3(3G_A - E_A)} = \frac{E_BG_B}{3(3G_B - E_B)}$$

$$\frac{E_AG_A}{3G_A - E_A} = \frac{1.01E_AG_B}{3G_B - 1.01E_A}$$

$$3G_AG_B - 1.01G_AE_A = 3.03G_AG_B - 1.01G_BE_A$$

$$1.01E_A(G_B - G_A) = 0.03G_AG_B$$

$$101E_A(G_B - G_A) = 3G_AG_B$$

$$G_B = \frac{1.01E_AG_A}{101E_A - 3G_A}$$

**30. (c)**

When $P_i \neq 0$, $P_o = 0$, then maximum hoop stress and corresponding shear stress at $r = r_i$ are

$$\sigma_{max} = \left(\frac{r_o^2 + r_i^2}{r_o^2 - r_i^2}\right)P_i$$

$$\tau_{max} = \left(\frac{r_o^2}{r_o^2 - r_i^2}\right) P_i$$

The maximum hoop stress occurs at inner circumference and hoop stress decreases towards the outer circumference.

**31. (a)**

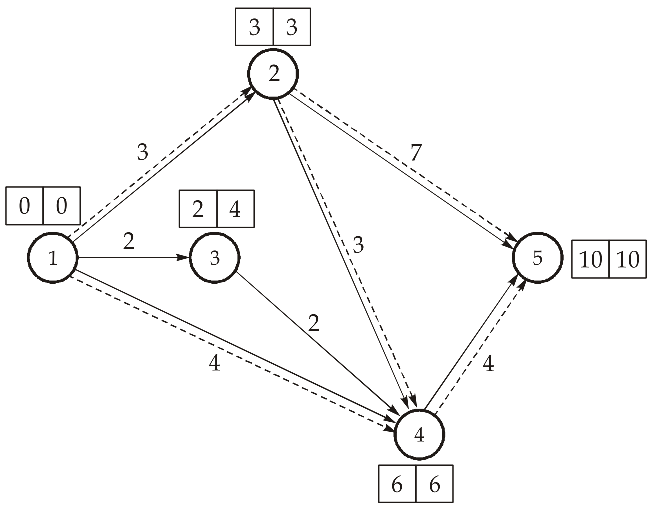
- Continuous casting is also known as strand casting. In this process, the liquid steel is poured into a double-walled, bottomless, water-cooled mould where a solid skin is quickly formed and a semifinished skin emeges from the open-mould bottom, which is further solidified by intensive cooling with water sprays as casting moves downwards.
- In squeeze casting, the solidification under pressure is claimed to be responsible for the reduction in the shrinkage cavities in the resulting castings.
- Slush casting is used to produce ornamental and decorative objects.
- Shell mould casting is a variation of sand mould casting.

**32. (d)**

Conventional screw and nut assembly is not suitable for CNC machine tools because of its lesser power transmitting capacity, lesser accuracy due to backlash and higher frictional forces. To avoid this, we use recirculating ball screw and nut assembly for transmitting energy in CNC machine tools.

**33. (c)**

Network diagram for given activities,




Critical paths:

(a) 1 - 2 - 5;

(b) 1 - 2 - 4 - 5;

(c) 1 - 4 - 5;

Project duration = 10 days

Total float for 1 - 3;

$$TF = L_j - \left(E_i + t_E^{ij}\right)$$
$$= 4 - (0 + 2)$$
$$= 4 - 2 = 2$$

**34. (d)**

- $$MS = \frac{\text{Total inventory cost any point}}{\text{Total inventory cost at EOQ}}$$
- Its minimum value is 1.

**35. (b)**

Given: $\lambda$ = 4 per hour, $\mu = \frac{60}{10}$ per hour = 6 per hour

then,
$$\rho = \frac{\lambda}{\mu} = \frac{4}{6} = \frac{2}{3}$$

$$L_q = \frac{\rho^2}{1-\rho} = \frac{\left(\frac{2}{3}\right)^2}{\left(1-\frac{2}{3}\right)^2} = \frac{4}{3}$$

and
$$L_S = \frac{\rho}{1-\rho} = \frac{\left(\frac{2}{3}\right)}{1-\frac{2}{3}} = 2$$

By little's law,
$$L_q = \lambda W_q$$
$$\Rightarrow \quad \frac{4}{3} = (4)(W_q)$$
$$\Rightarrow \quad W_q = \frac{1}{3}\text{hour} = 20 \text{ minutes}$$
and
$$L_s = \lambda W_s$$
$$\Rightarrow \quad 2 = 4(W_s)$$
$$\Rightarrow \quad W_s = \frac{1}{2}\text{hour} = 30 \text{ minutes}$$

Now, probability that waiting time in the queue is greater than 30 minutes is

$$P(W_q > 30) = \rho e^{-\frac{T}{W_s}} = \left(\frac{2}{3}\right) e^{-\frac{30}{30}}$$
$$= \left(\frac{2}{3}\right) e^{-1} = 0.245$$

**36. (d)**

Elements of preventive maintenance are:

1. Servicing
2. Inspection

3. Adjustment
4. Inspection
5. Testing
6. Installation

**37. (b)**

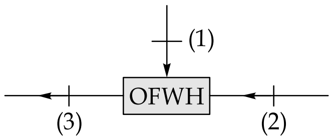
Given : $L$ = ±4 = 0.08; $Z$ = 1.96 [For 95% accuracy]

Now, confidence precision factor, $k = \frac{Z}{L} = \frac{1.96}{0.08} = 24.5$

**38. (d)**

$$\text{Tangential force, } F_t = \dot{m}\left(V_{w_1} + V_{w_2}\right)$$
$$= (1)(910) = 910 \text{ N}$$
$$\text{Axial force or thrust force } (F_a) = \dot{m}\left(V_{f_1} - V_{f_2}\right)$$
$$= 1(40) = 40 \text{ N}$$

**39. (b)**




$$(1)h_3 = xh_1 + (1 - x)h_2$$
$$700 = x(2700) + (1 - x)180$$
$$\Rightarrow \quad x = 0.20635 \text{ kg/kg of steam}$$

**40. (a)**

$$\text{Reheat factor, R.F.} = \frac{(h_1 - h_{2s}) + (h_2 - h_{3s}) + (h_3 - h_{4s}) + (h_4 - h_{5s}) + (h_5 - h_{6s})}{h_1 - h_{7s}}$$
$$\text{R.F.} = \frac{240 + 230 + 300 + 290 + 270}{1250}$$
$$= \frac{1330}{1250} = 1.064$$

**41. (d)**

Natural draught cooling towers are chosen

(i) When the wet bulbs temperature is low i.e. broad range and long approach is required.

(ii) In coal humid climates.

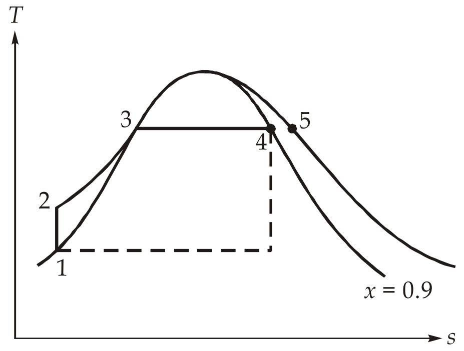
(iii) In heavy winter loads, however their initial capital cost is high and occupy more space.

**42. (d)**

- Condenser is a closed heat exchanger in which steam coming out of turbine is condensed by cooling water and vacuum is maintained, resulting in an increase in work done and efficiency of steam power plant.

- It helps to restore or recover feed water back to the boiler.
- Out of total heat supplied in the boiler 50 to 60% is rejected in the condenser.

**43. (c)**




$$Q_s = c_{p_w}(T_3 - T_2) + x(h_5 - h_3)$$
$$= 4(100 - 20) + 0.9(2500)$$
$$= 320 + 2250 = 2570 \text{ kJ/kg}$$

**44. (d)**

Given : $V_{w_2} = 165 \text{ m/s}, u_2 = 240 \text{ m/s}$

We know,
$$R_{CC} = 1 - \frac{V_{w_2}}{2u_2} = 1 - \frac{165}{2(240)}$$
$$R_{CC} = 0.6562$$

**45. (a)**

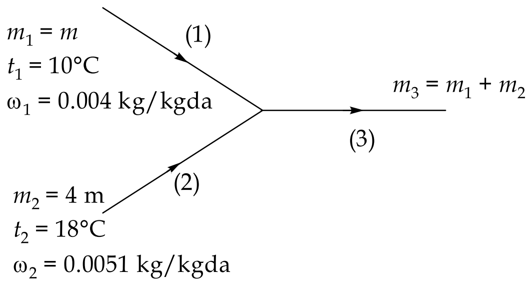
In electrolux refrigerator, two U-bends are provided as vapour-locks to prevent $H_2$ from getting into the high side or solution circuit.

**46. (d)**

There are some refrigerants which are fully miscible with oil like R11, R12 and some refrigerant which are fully immiscible like $NH_3$, $CO_2$ and dθ does not create any problem but the refrigerants like R22 creates problem which are partially miscible with oil.

**47. (b)**

From mass balance, for mixing process



$$m_1\omega_1 + m_2\omega_2 = m_3\omega_3$$

$$m \times 0.004 + 0.0051 \times 4m = (m + 4m) \times \omega_3$$

$$\therefore \quad \omega_3 = 0.00488 \text{ kg/kg d.a.}$$

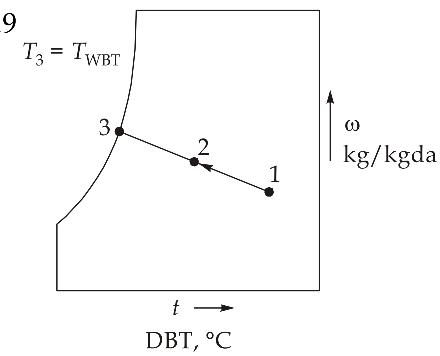
Now, degree of saturation

$$\mu = \frac{\omega_3}{\omega_s} = \frac{0.00488}{0.01} \times 100$$

$$\mu = 48.8$$

**48. (c)**

Given : $T_1 = 40°C,\ T_2 = 32°C,\ \eta = 0.9$




Now,

$$\eta = \frac{T_1 - T_2}{T_1 - T_{WBT}}$$

$$0.9 = \frac{40 - 32}{40 - T_{WBT}}$$

$$40 - T_{WBT} = \frac{8}{0.9}$$

$$T_{WBT} = 31.11 \simeq 31°C$$

**49. (c)**

Given : $\dot{Q}_1 = 140 \text{ kW},\ P = 60 \text{ kW}$

The loading on the condenser per unit of refrigeration is called Heat Rejection Ratio.

$$\therefore \quad HRR = \frac{\dot{Q}_1}{R.E}$$

$$\because \quad R.E = \dot{Q}_1 - P = 140 - 60 = 80 \text{ kW}$$

$$\therefore \quad HRR = \frac{140}{80} = 1.75$$

**50. (d)**

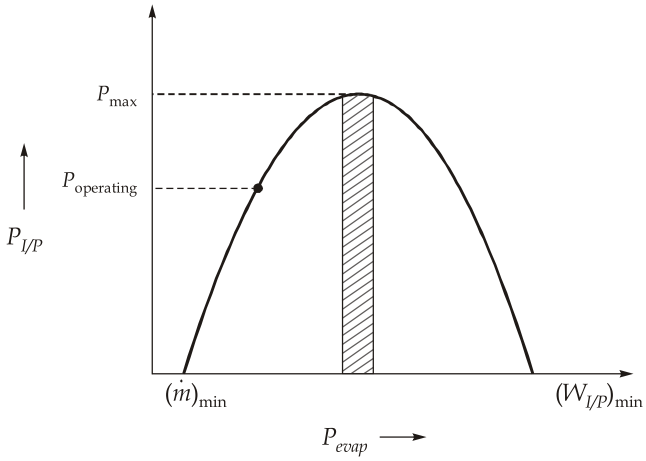
- A sling Psychrometer consists of dry bulb thermometer and wet bulb thermometer mounted side by side in a protective case that is attached to a handle by a swivel connection. The dry bulb thermometer is directly exposed to air and measures the actual temperature of the air. The bulb of wet bulb thermometer is covered by a wick thoroughly wetted by distilled water. The temperature measured by this wick covered bulb of a thermometer is the temperature of liquid water in the wick and is called WBT.
- DPT is the temperature of air recorded by a thermometer, when the moisture (water vapour) present in it begins to condense. It is a measure of latent heat of moist air.
- Degree of saturation is a measure of the capacity of air to absorb moisture.
- Evaporative air-cooler uses cooling and humidification process by water injection. The process will be effective when DBT is high and R.H. is low.

**51. (a)**

The weight of steam jet refrigeration system per ton of refrigeration is less. Hence, there are now a number of air-conditioning applications ranging upto 300 T.R. in capacity as well as many industrial applications of even larger size.

**52. (c)**

Pull down period is the time taken for the evaporator temperature to decrease to the design value from starting of the unit.




At very low evaporator pressure the mass flow rate is zero and hence the power input is also zero. When the refrigeration system is just starting at that moment also power is zero because evaporator and condenser pressures are same, hence work input is zero. The power requirement for all compressors initially increasess reaches its maximum value and again decreases operating pressure lies toward the left of maximum power condition. Hence, even though operating power is less but the compressor motor are designed for maximum power condition.

**53. (d)**

The following methods may be used to avoid cavitation:

(i) By selecting a runner of proper specific speed for given head.

(ii) By selecting matarials which resist better cavitation effect. Stainless steel or alloy steel is better than cast steel and cast steel is better than cast iron.

(iii) By polishing the blade surface, that is why stainless steel.

(iv) Runner or turbine may be kept under water.

(v) Cavitation free runner may be designed to fulfil the given conditions with extensive research.

**54. (d)**

Specific speed,

$$N_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{400\sqrt{1600}}{(16)^{5/4}} = \frac{400 \times 40}{32}$$

$$N_s = 500 \text{ (Kaplan turbine)}$$

**55. (a)**

$$\text{Total manometric head} = 12 + 8 = 20 \text{ m}$$

Pumping power,
$$P = \rho g Q H$$
$$= 1000 \times 10 \times 0.15 \times 20$$
$$= 30000 \text{ W}$$
$$= 30 \text{ kW}$$

**56. (b)**

$$h_{fs} = \frac{fLV_s^2}{2gD_s} = \frac{fL}{2gD_s}\left(\frac{A}{A_s}\omega r \sin\theta\right)^2$$

$h_{fs}$ is maximum at $\theta = \frac{\pi}{2} = 90°$.

**57. (d)**

In a Francis turbine, discharge leaves the runner radially at the exit, it means that the absolute velocity is radial at the outlet and whirl component of velocity at outlet is zero.
[i.e. $V_2 = V_{f2}$, $V_{w2} = 0$ and $\beta = 90°$]

**58. (b)**

Cavitation parameter (Thomas number)

$$\sigma = \frac{NPSH}{H_m}$$
$$= \frac{P - P_V}{\rho V^2/2}$$

**59. (d)**

The slip will be negative when there is a direct connection between the suction and delivery sides before the end of suction stroke. This happens if the momentum of liquid in the suction pipe is large enough to open the delivery valve before the begining of delivery storke. Slip is negative when delivery pipe is small and suction pipe is long and pump is running at very high speed.

**60. (d)**

Higher fuel consumption, lower thermal efficiency and higher exhaust temperatures are the disadvantages of 2-stroke engine. In 4-stroke engine, we will have high thermal efficiency as less mass flow rate of fuel is required than 2-stroke engine for same power output.

**61. (c)**

**Spark ignited concepts :** In opposition to traditional (near) stiochiometric homogeneous SI engines, the following combustion concepts with significant fuel-saving potential are developed:

**(i) Lean-burn combustion :** A homogeneous mix is used but, in opposition to conventional SI concept, a low fuel-air ratio is used, which provides advantages in terms of fuel efficiency (because of reduced throttling at part load, and of lower heat losses to cylinder walls).

**(ii) Stratified gasoline combustion :** Lean-burn combustion is limited by the inflammability of the mix, in order to operate the engine with a lower global fuel-air ratio, it is necessary to stratify the cylinder charge. This can be done with the high pressure in-cylinder injection of the fuel, which prepares a near stoichiometric mix in the immediacy of the spark plug, while the rest of the cylinder is filled with fresh air. Spray guided and multi-pulse strategies may be used for reducing spray penetration and for improving the homogeneity of the fuel-air mixture in the region of the spark plug gap.

**62. (d)**

Iso-octane ($C_8H_{18}$) has low boiling point and possesses a very good anti-knock quality. On the other hand, *n*-heptane ($n$–$C_7H_{16}$) has very poor antiknock qualities. Octane rating is used for fuels of SI engines. This is equivalent percentage of Iso-octane with *n*-heptane.

**63. (c)**

Given that brake power of engine is 12 kW.

Indicated power of individual cylinder is

$$P_{i1} = 12 - 5.25 = 6.75 \text{ kW}$$

$$P_{i2} = 12 - 5.75 = 6.25 \text{ kW}$$

Hence, mechanical efficiency is

$$\eta_m = \frac{12}{6.75+6.25} = \frac{12}{13} = 0.923$$

**64. (b)**

$$P = \frac{2\pi NT}{60000} = \frac{P_{bm}LAn}{60000} \quad \text{(For 4 stroke, } n = N/2\text{)}$$

$$P_{bm} = \frac{2\pi NT}{LAn} = \frac{2\pi NT}{L \times \frac{\pi}{4}D^2 \times \frac{N}{2}} = \frac{16T}{D^2 L}$$

$$P_{bm} = \frac{16 \times 24}{0.08^2 \times 0.12} \text{ bar} = 5 \text{ bar}$$

**65. (b)**

Prandtl number, $$\Pr = \frac{\nu}{\alpha} = \frac{\mu C_P}{K} = \left(\frac{\delta}{\delta_t}\right)^3$$

where, $\delta$ = Hydrodynamic boundary layer thickness

$\delta_t$ = Thermal boundary layer thickness

**66. (a)**

For two layers,

$$\frac{Q}{A} = \frac{T_1 - T_2}{\frac{L_1}{K_1} + \frac{L_2}{K_2}} = \frac{727 - 27}{\frac{0.5}{5} + \frac{0.5}{0.5}} = \frac{700}{\frac{11}{10}}$$

$$\frac{Q}{A} = \frac{7000}{11}\ \text{W/m}^2$$

For outer casing :

$$\frac{Q}{A} = \frac{27-10}{1/h}$$

$$\Rightarrow \quad \frac{7000}{11} = 17 \times h$$

$$h = \frac{7000}{11 \times 17} = \frac{7000}{187} = 37.43\ \text{W/m}^2\text{K}$$

**67. (b)**

As $C_{min} = C_{max}$, the effectiveness is :

$$\in = \frac{Q}{Q_{max}} = \frac{C_{min}(T_{hi} - T_{ho})}{C_{min}(T_{hi} - T_{ci})} = \frac{T_{hi} - T_{ho}}{T_{hi} - T_{ci}}$$

$$\in = \frac{76-47}{76-26} = \frac{29}{50} = 0.58$$

**68. (c)**

Rate of cooling of a body is the ratio of radiation power emitted by body and its heat capacity. As dimensions, surface material and temperature are equal, the radiation power of both spheres will be same but heat capacity of hollow sphere is less so it will cool at a faster rate.

**69. (b)**

Using Planck's distribution law,

$$\lambda_m T = \text{Constt.}$$

$$\Rightarrow \quad 5800 \times 0.5 = (307 + 273) \times \lambda_{m2}$$

$$\lambda_{m2} = \frac{2900}{580} = 5\ \mu\text{m}$$

**70. (d)**

- In nucleate pod boiling, the rate of heat transfer strongly depends on the nature of nucleation (i.e. liquid properties) and the type and the condition of the heated surface.
- There are no general theoretical relations available for heat transfer in nucleate boiling regime, so experimental based correlations are used.

**71. (d)**

- Statement 2 is correct for $3^{rd}$ generation robots.
- Statement 3 is correct for $2^{nd}$ generation robots.

**72. (c)**

The 90° rotation of $P$ about $x$-axis of frame {1} is

$$R_x(90) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos 90^\circ & -\sin 90^\circ \\ 0 & \sin 90^\circ & \cos 90^\circ \end{bmatrix}$$

$$R_x(90) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix}$$

The new position of point $P$ is

$$^1P' = R_x(90).^1P$$

$$^1P' = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix}\begin{bmatrix} 6 \\ 4 \\ 3 \end{bmatrix}$$

$$^1P' = [6 \quad -3 \quad 4]^T$$

**73. (c)**

SCARA assembly has one forward kinematic solution for given joint rotation and two inverse kinematic solutions for given end effector configuration.

**74. (d)**

**75. (a)**

Rotations are in order $X$-$Y$-$X$ about the fixed axis. Hence, it is a case of fixed angle representation. Therefore,

$$^1R_2 = R_x(45°)R_y(30°)R_x(60°)$$

**76. (b)**

In Carnot cycle,

$$\frac{Q_S}{Q_R} = \frac{T_H}{T_L}$$

$$\frac{Q}{0.4Q} = \frac{T_H}{27+273}$$

$$T_H = \frac{300}{0.4} = 750 \text{ K}$$

$$T_H = 477°\text{C}$$

**77. (d)**

The work done by the steady flow system is :

$$W = -\int_1^2 vdp = \int_2^1 vdp$$

**78. (c)**

The change in Gibbs free energy of the system provides a criterion for the spontaneity of a process at constant temperature and pressure. A change in the free energy of a system at constant temperature and pressure will be

$$(\Delta G)_{sys} = (\Delta H)_{sys} - T(\Delta S)_{sys}$$

If the Gibbs energy ($G$) of a mixture of reactants and products goes through a minimum value as the composition changes, then all net change will cease and the reaction system will be in a state of chemical equilibrium.

**79. (d)**

Given : $$\frac{dW}{dT} = 0.70 \text{ kNm/K} = 0.70 \text{ kJ/K}$$

Using first law of thermodynamics :

$$\frac{dQ}{dT} = \frac{dE}{dT} + \frac{dW}{dT}$$
$$= 0.30 + 0.70 = 1.00 \text{ kJ/K}$$

Heat interaction per degree temperature increase = 1.00 kJ.

**80. (a)**

Heat at constant pressure involves specific heat at constant pressure ($C_p$) :

$$Q = C_p dT$$

The percentage of heat supplied that goes to internal energy is

$$r = \frac{C_v dT}{C_p dT} = \frac{C_v}{C_p} = \frac{1}{\gamma}$$

For a monoatomic gas $\gamma$ = 1.67, while for a diatomic gas $\gamma$ = 1.4 and for a polyatomic gas $\gamma = \frac{4}{3}$.

$\Rightarrow \gamma = \frac{C_p}{C_v}$ is less for polyatomic gas than diatomic gas and $\gamma$ is less for diatomic gas than monoatomic gas.

So, $$r_{\text{poly}} > r_{\text{dia}} > r_{\text{mono}}$$

**81. (b)**

$$\eta_1 = 1 - \frac{T_2}{T_1} = \frac{T_1 - T_2}{T_1}$$

$$\eta_2 = 1 - \frac{T_1 - \Delta T}{T_1 - \Delta T} = \frac{(T_1 - \Delta T) - (T_2 - \Delta T)}{(T_1 - \Delta T)} = \frac{T_1 - T_2}{T_1 - \Delta T}$$

On comparision, we can see that

$$\eta_1 < \eta_2$$

**82. (b)**

$$\text{Loss of available energy} = T_o \Delta s$$
$$= 300 \times \left[\frac{1}{400} - \frac{1}{600}\right] \times 1000 \text{ kJ}$$
$$= 3 \times \left[\frac{6-4}{24}\right] \times 1000$$
$$= 250 \text{ kJ}$$

**83. (d)**

Gibbs theorem states that the total entropy of a mixture of gases is the sum of the partial entropies. The partial entropy of one of the gases of a mixture is the entropy that the gas would have if it occupied the whole volume alone at the same temperature and pressure.

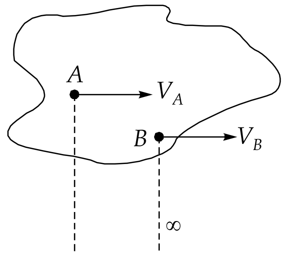
$$S_i = n_1 s_1 + n_2 s_2 + \ldots.. + n_c s_c = \sum n_k s_k$$

**84. (b)**

Oldham's coupling is an inversion of double slider crank mechanism and other inversions of double slider crank mechanism are elliptical trammel and scotch yoke mechanism.

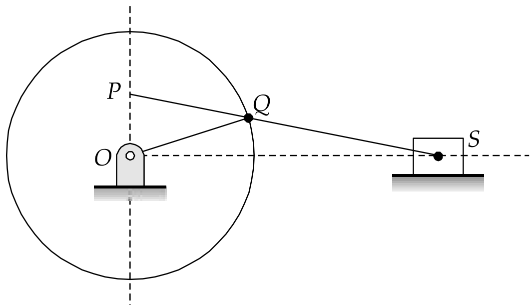
**85. (a)**

I-centre for body in pure translation lies at infinity.




**86. (b)**

Scott-Russel mechanism :




**87. (c)**

Number of pairs of teeth in contact,

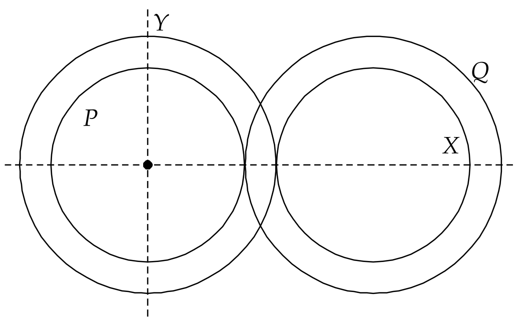
$$n = \frac{\text{Arc of contact}}{\text{Circular pitch}} = \frac{\text{Arc of contact}}{\pi m}$$

$$= \frac{35.2}{\pi \times 6} = 1.867$$

**88. (c)**

In cycloidal, teeth a convex flank is in contact with concave face resulting in less wear.

**90. (b)**



$$d_P + d_Q = d_X + d_Y$$
$$\Rightarrow \quad m_1(T_P + T_Q) = m_2(T_X + T_Y)$$
$$5(40 + 50) = 6(30 + T_Y)$$
$$\Rightarrow \quad T_Y = 45$$

**91. (b)**

Given : $m = 5 \text{ kg}; r = \frac{l}{2} = \frac{20}{2} = 10 \text{ cm} = 0.1 \text{ cm}, \omega = 10 \text{ rad/s}$

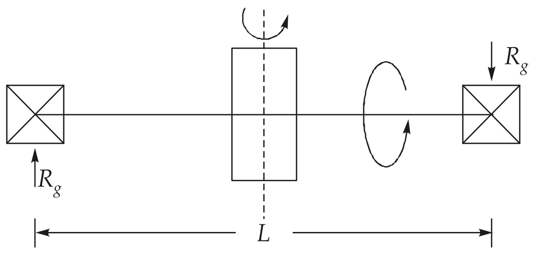
$$\text{Maximum tractive force} = \pm\sqrt{2}(1-c)mr\omega^2$$
$$= \pm\sqrt{2}\left(1-\frac{2}{3}\right) \times 5 \times 0.1 \times (10)^2$$
$$= \frac{50\sqrt{2}}{3} \text{ N}$$

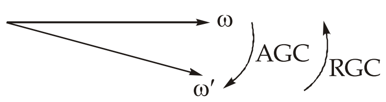
**92. (b)**

$$n = 6, j = 7, h = 0, F_r = 0$$
$$\text{DOF} = 3(n-1) - 2j - h - F_r$$
$$= 3(6-1) - 2 \times 7 - 0 - 0$$
$$= 15 - 14 = 1$$

**93. (c)**

$$m = 4 \text{ kg}$$
$$N = 560 \text{ rpm}$$
$$K = 100 \text{ mm} = 0.1 \text{ m}$$
$$N_P = 70 \text{ rpm}$$
$$I = mk^2 = 4 \times (0.1)^2 = 0.04 \text{ kg-m}^2$$




$$l = 200 \text{ mm} = 0.2 \text{ m}$$
$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 560}{60}$$
$$= 58.643 \text{ rad/s}$$
$$\omega_P = \frac{2\pi N_P}{60} = 7.33 \text{ rad/s}$$

$$C = I\omega\omega_p = 0.04 \times 58.643 \times 7.33 = 17.19 \text{ N-m}$$

Reaction at bearing due to gyroscopic effect

$$R_G = \frac{C}{l} = \frac{17.19}{0.2} = 85.95 \text{ N}$$

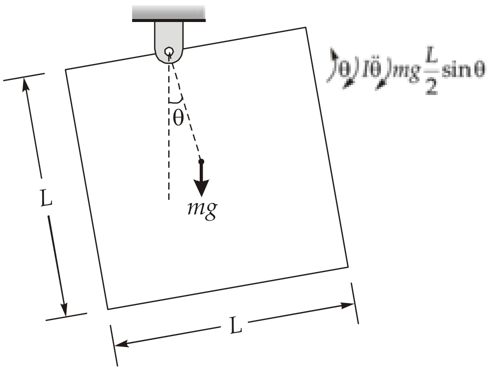
**94. (d)**

Mass moment of inertia of body about hinge point

$$= \left(\frac{mL^2}{12} + \frac{mL^2}{12}\right) + m\left(\frac{L}{2}\right)^2$$

$$I_o = \frac{5mL^2}{12}$$

Slightly disturbing body by angle θ




$$\Rightarrow \quad I_o\ddot{\theta} + mg\frac{L}{2}\sin\theta = 0$$

$$I_o\ddot{\theta} + mg\frac{L}{2}\theta = 0 \qquad (\because \sin\theta \approx \theta \text{ for small angle})$$

$$\Rightarrow \quad \omega_n = \sqrt{\frac{mg\frac{L}{2}}{I_o}} = \sqrt{\frac{mg\frac{L}{2}}{\frac{5mL^2}{12}}} = \sqrt{\frac{6g}{5L}}$$

**95. (d)**

For $\frac{\omega}{\omega_n} > \sqrt{2}$ or more for effective isolation, in vertical system it is difficult to get lower $\omega_n$ as for that require lower spring stiffness that cause large static deflection and generate large vibration in system even when transmitted force to support is reduced.

**96. (b)**

$$m = 10 \text{ kg}, K = 40 \text{ N/mm} = 40{,}000 \text{ N/m}, C = 0.1C_C, \xi = 0.1$$

$$\omega_n = \sqrt{\frac{K}{m}} = \sqrt{\frac{40000}{100}} = 20 \text{ rad/s}$$

$$\omega_d = \sqrt{1-\xi^2} \times \omega_n$$

$$= \sqrt{1-(0.1)^2} \times 20$$
$$= 19.899 \text{ rad/s}$$

**97. (c)**

$$\text{Sensitiveness} = \frac{\text{Range of speed}}{\text{Mean speed}} = \frac{N_2 - N_1}{N} = \frac{2(N_2 - N_1)}{(N_2 + N_1)}$$

where, $N$ = Mean speed

$N_2$ = Maximum at no load condition

$N_1$ = Minimum speed at full load condition

**98. (c)**

To check controllability, consider the matrix

$$[\phi_c] = [A°B \quad AB]_{2\times2}$$

if $|\phi_c| = 0$, system is uncontrollable.

Putting the values of matrices $A$ and $B$ in controllability matrix, we get

$$[\phi_c] = \begin{bmatrix} 1 & 17 \\ 3 & 1+3a \end{bmatrix}$$

For uncontrollable system,

$|\phi_c| = 0 \Rightarrow \quad (1 + 3a) - 17 \times 3 = 0$

$\therefore \quad a = \frac{50}{3}$

**99. (c)**

A tandem cylinder is used in applications where a large amount of force is required from a small diameter cylinder. Pressure is applied to both pistons, resulting in increased force because of larger area.

The drawback is that these cylinders must be longer than standard cylinder to achieve an equal speed because flow must go to both pistons.

**100. (b)**

- Proportional controllers may be faster than integral controller but steady state error will not be zero, i.e., it never reach the target.
- Integral controller is slower but the steady state error will be equal to zero.
- Statement 3 is correct.

**101. (a)**

Given : Temperature range = 0–100°C, $T_o$ = 0°C, $R_{T_o}$ = 50 Ω, α = 0.001/°C

For RTD, resistance at temperature $T$ is given by,

$$R_T = R_{T_o}\{1 + \alpha(T - T_o)\}$$

$\therefore$ At $T$ = 200°C, $\quad R_{T(200°C)} = 50\{1 + 0.001(200 - 0)\}$

$$R_{T(200°C)} = 60\ \Omega$$

$\therefore$ Change in resistance, $\quad \Delta R = R_{T(200°C)} - R_{T(0°C)}$

$$\Delta R = 60 - 50$$
$$\Delta R = 10\ \Omega$$

**102. (d)**

In a signal conditioning, a filter is a device or process that completely or partially supresses unwanted components or features from a signal. This usually means removing some frequencies to suppress interfering signal and to reduce background noise.

There are four main types of filters.

**(i) Low pass filter :** It is a circuit that can be designed to modify, reshape or reject all unwanted high frequencies of a electrical signal and accept or pass only those signal wanted by circuit designer.

**(ii) High pass filter :** They effectively cuts out the frequency response of a mic below a certain set point and allowing only the frequencies above this point to pass through as the audio signal.

**(iii) Band pass filter :** It limit the bandwidth of the output signal to the band allocated for the transmission.

**(iv) Band stop filter :** They eliminate a band of unwanted frequencies while at the same time enabling other frequencies to pass with minimum loss.

**103. (c)**

Programmable logic controller (PLC) is a specialized computer used to control machines and processes. It uses a programmable memory to store or save instructions and specific functions that include ON/OFF control, counting, arithmetic, timing, sequencing and data handling.

**104. (d)**

Key factors to be considered while selecting micro controller:

(i) Hardware architecture
(ii) Security
(iii) Memory requirements
(iv) Processing power and speed requirements
(v) Efficiency
(vi) Temperature tolerance
(vii) Software architecture
(viii) Hardware interface
(ix) Cost
(x) Number of inputs and output pins

**105. (a)**

For 8085, $n$ = 16, number of address lines.

∴ Maximum memory that can be connected,

$$M = 2^n$$
$$M = 2^{16} = 2^6.2^{10}$$
$$M = 64 \text{ kB}$$

**106. (d)**

In welding, size of heat affected zone (HAZ) is influenced by:

- Material with high thermal diffusivity are able to transfer variations of heat faster, meaning they cool faster, as a result HAZ size reduced.

- HAZ size increases with increase in thermal conductivity of the base metal, because the material passes heat rapidly to the adjacent molecules thus increasing HAZ size.
- HAZ size increases with increase in starting temperature as more amount of heat input to the material.
- HAZ size reduces with increase in welding speed because material comes in contact with welding torch lesser period of time thus transfering small heat energy.
- HAZ decreases with increase in base metal thickness.

**107. (c)**

RPM of lead screw, $$N_s = \frac{0.5 \times 2500}{2} = 625 \text{ rpm}$$

**108. (d)**

Hall-Petch equation gives yield strength of a polycrystalline material.

$$\sigma_y = \sigma_0 + \frac{k}{\sqrt{d}}$$

where $\sigma_0$ is the strength of single crystal, $d$ is the grain size and $k$ is constant. Thus, the yield strength increases with increase in grain size. But corrosion resistance decreases with decreased grain size as it offers more boundary of high energy available for chemical reaction.

**109. (d)**

In monotectic reaction, a liquid transforms into another liquid of different composition and a solid phase precipitates out.

**110. (b)**

Vanadium is a strong deoxidizer and promotes fine grain structure. It helps steel resist softening at elevated temperatures and seems to resist shock better than steel without it. So, vanadium is alloyed in steel to enhance endurance strength of steels.

**111. (b)**

If $A_i$ = Initial cross-section; $A_f$ = Final cross-section

then true strain $\varepsilon$ is given by

$$\varepsilon = \ln\left(\frac{A_i}{A_f}\right)$$

$$A_f = A_i e^{-\varepsilon}$$

The load which the material can bear is given by

$$F = \sigma A_f = \sigma A_i e^{-\varepsilon}$$

When necking begins,

$$\frac{dF}{d\varepsilon} = 0$$

$$A_i\left(\frac{d\sigma}{d\varepsilon} e^{-\varepsilon} - \sigma e^{-\varepsilon}\right) = 0$$

$$\Rightarrow \quad \frac{d\sigma}{d\varepsilon} = \sigma \text{ or } nK\varepsilon^{n-1} = K\varepsilon^n$$

$$\Rightarrow \quad \varepsilon = n$$

**112. (c)**

Resilience is defined as the ability of a material to absorb energy when deformed elastically. This property is important when material is subjected to shock loading.

**114. (b)**

Let fulcrum be at 0.5% carbon to apply lever rule,

$$\text{\% proeutectoid ferrite} = \frac{0.8-0.5}{0.8-0.0}\times 100$$

$$= \frac{300}{8} = 37.5\%$$

$$\text{\%pearlite} = 100 - 37.5 = 62.5\%$$

**116. (b)**

Nitriding is a case hardening process in which the components are exposed to the action of nascent nitrogen in a gaseous or liquid medium from 490°C to 590°C. In this process nitrogen is absorbed by the metal surface to get it hardened.

**117. (c)**

Nodular cast-iron is produced by making certain alloy additions such as Mg or Cr to molten-iron.

**118. (b)**

Mechanical and electrical properties of metals such as yield strength, fracture strength and electrical conductivity are adversely affected while physical and chemical properties such as melting point, specific heat, coefficient of thermal expansion are not sensitive to these effects.

**120. (c)**

Given : $W_P$ = 20 kJ/kg, $W_T$ = 1250 kJ/kg, $\dot{Q}_s$ = 3500 kJ/kg, $\eta_P = \eta_T = 0.8$, $\dot{m}_s = 20$ kg/s

$$\text{Actual pump work, } (W_P)_{act} = \frac{W_P}{\eta_P} = \frac{20}{0.8} = 25 \text{ kJ/kg}$$

$$\text{Actual turbine output, } (W_T)_{act} = 0.8 \times W_T = 0.8 \times 1250$$

$$(W_T)_{act} = 1000 \text{ kJ/kg}$$

$$\text{Net work output, } (W_{net}) = (W_T)_{act} - (W_P)_{act}$$

$$= 1000 - 25 = 975 \text{ kJ/kg}$$

$$\therefore \quad \text{Net power output, } \dot{P} = \dot{m} \times W_{net}$$

$$= 20 \times 975 = 19.5 \text{ MW}$$

$$\text{Thermal efficiency, } \eta = \frac{W_{net}}{\dot{Q}_s} = \frac{975}{3500} = 27.85\%$$

**121. (d)**

Characteristics of ideal working fluid in a vapour power cycle:

(i) Fluid should have a high critical temperature so that the saturation pressure at the maximum temperature should be less.

(ii) Fluid should have large enthalpy of vapourization so that less quantity of steam is required.

(iii) It should have steep saturated vapour line to reduce the moisture content in the lower stages.

(iv) Saturation pressure at the temperature of heat rejection should be above atmospheric pressure to avoid the need of maintaining vacuum in condenser.

**122. (d)**

- Steam trap, feed pump and economiser are boiler accessories.
- Safety valve is a boiler mounting which prevents the steam pressure from exceeding a limiting maximum pressure value. It operates automatically by releasing excess steam and bringing pressure down within safe limits.

**124. (d)**

Following are the factors on which selection of boiler is done.

(i) Working pressure and amount of steam needed.

(ii) Floor area required.

(iii) Operating and maintenance required.

(iv) Amount of fuel required.

(v) Water requirements.

(vi) Type of load-safety fluctuations etc.

**125. (c)**

For maximum work condition,

$$\eta_{cycle} = 1 - \sqrt{\frac{T_{min}}{T_{max}}}$$

$$\eta_{cycle} = 1 - \sqrt{\frac{300}{2700}}$$

$$\eta_{cycle} = 0.66 \text{ or } 66.66\%$$

**126. (c)**

$$\text{Propulsive power, } \dot{P} = \dot{m}_a [V_{exit} - V_{inlet}] \times V_{aircraft}$$

$$10 \times 10^6 = 50[V_{exit} - 300] \times 300$$

$$\therefore \quad V_{exit} = \frac{10 \times 10^6}{50 \times 300} + 300$$

$$= 966.66 \simeq 967 \text{ m/s}$$

**127. (d)**

Following are the major advantages of a condenser in a steam power plant:

1. Increase work done and efficiency due to low pressure of condenser.
2. It helps to restore high quality feed water back to boiler.
3. Due to increased work done, steam consumption rate for same power output decreases.
4. Reduces thermal stresses due to high temperature of feed water entering to boiler.
5. Cost saving as only make up water is to be treated instead of full water.

**128. (c)**

ID fan used in induced draught system maintains the tower at negative pressure thereby reducing leakage. ID for is installed at the top of tower and consumes more power because it drew out saturated air from draught.

**129. (d)**

Given : $F_c$ = 1000 N, $F_t$ = 600 N and $\phi$ = 30°

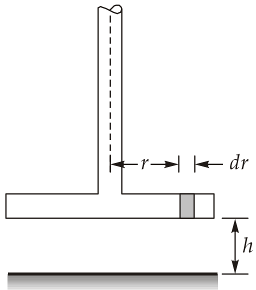
$$\text{Chip shear force, } F_s = F_c \cos\phi - F_t \sin\phi$$
$$= 1000 \cos 30° - 600 \sin 30°$$
$$= 566 \text{ N}$$

**130. (d)**

- Aneroid barometer and bourdon tube pressure gauges are mechanical pressure gauges.
- Aneroid barometer uses elastic diagraph to measure atmospheric pressure.
- Bourdon tube is used to measure high as well as low gauge pressure.

**131. (c)**

Consider an element at distance '$r$' and having width '$dr$' where linear velocity = $\omega R$




$$\tau = \mu \frac{du}{dy}$$

Assuming small gap '$h$' so the velocity distribution is linear

$$\frac{du}{dy} = \frac{V}{h}$$

$$\Rightarrow \quad \tau = \mu \frac{V}{h}$$

$$\text{Torque, } dT = \text{Shear stress} \times \text{Area} \times r$$

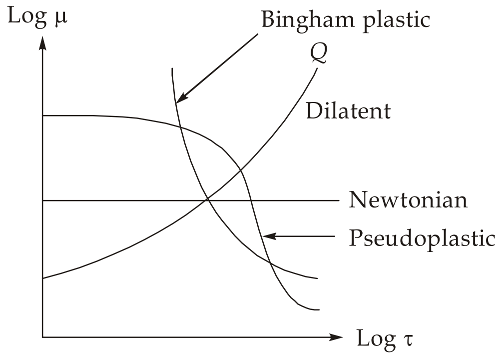
$$dT = \mu \frac{V}{h} \times 2\pi r dr \times r$$

$$dT = \frac{2\pi\mu\omega}{h} \cdot r^3 dr$$

$$T = \int_0^R \frac{2\pi\mu\omega}{h} \cdot r^3 dr = \frac{2\pi\mu\omega}{h} \cdot \frac{r}{4}\bigg|_0^R$$

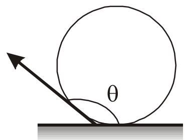
$$= \frac{\pi\mu\omega R^4}{2h}$$

**132. (b)**




**133. (b)**

Non wetting liquid




- $\theta > 90°$
- Cohesion is more than adhesion
- Example-mercury glass

**134. (b)**

Let pressure difference be $\Delta P$

$$\text{So, in terms of water column} = h = \frac{\Delta P}{\rho g}$$

$$\text{When use manometric fluid, } \frac{\Delta P}{\rho g} = \left(\frac{\rho m}{\rho} - 1\right)h' = (1.25 - 1)h'$$

$$\therefore \quad \text{Differential head, } h' = \frac{h}{0.25} = 4h$$

[Note : Such manometric fluid is used when small pressure difference]

**135. (b)**

Uniform flow,

- Velocity vector's magnitude as well as direction remains constant.
- $\frac{dv}{ds} = 0$

**136. (c)**

Bernoulli's equation between A and B

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + z_B + h_L$$

⇒ Piezometric head at $B$

$$\Rightarrow \quad \frac{P_B}{\rho g} + z_B = \frac{P_A}{\rho g} + \frac{V_A^2}{2g} + z_A - \frac{V_B^2}{2g} - h_L$$

$$= 2.5 + 0.4 + 3.5 - 0.4 - 0.3 = 5.7 \text{ m}$$

**137. (b)**

$$\text{Displacement thickness, } \delta^* = \int_0^\delta \left(1 - \frac{u}{u_\infty}\right) dy = \int_0^\delta \left(1 - \frac{y}{\delta}\right) dy$$

$$= y - \frac{y^2}{2\delta}\bigg|_0^\delta = \delta - \frac{\delta^2}{2\delta} = \frac{\delta}{2}$$

**138. (c)**

In turbulent flow maximum velocity $V$ is given by

$$\frac{V_{\max}}{u} = 1.43\sqrt{f} + 1 \qquad \{f = 0.02, \bar{u} = 5 \text{ m/s}\}$$

$$V_{\max} = (1.43 \times \sqrt{0.02} + 1)5 = 6 \text{ m/s}$$

**139. (d)**

- Hydraulic gradient line (HGL) represents the sum of pressure head and datum head.
- For a pipe of constant diameter, the HGL is always sloping down in the flow direction and is parallel to total gradient line (TGL). The difference between TGL and HGL represents the velocity head.
- Due to the frictional head loss in the pipe, HGL is always sloping down.

**140. (b)**

Ratio of head loss in pipes,

$$\frac{(h_L)_A}{(h_L)_B} = \frac{\left(\frac{fLQ^2}{12.1D^5}\right)_A}{\left(\frac{fLQ^2}{12.1D^5}\right)_B}$$

∵ Pipes in series, $Q = Q_A = Q_B$ and as $f_A = f_B$, $L_A = L_B$

$$\frac{(h_L)_A}{(h_L)_B} = \left(\frac{D_B}{D_A}\right)^5$$

$$= \left(\frac{D_B}{D_A}\right)^5 = \left(\frac{D}{1.2D}\right)^5 = \frac{1}{(1.2)^5} = 0.402$$

**141. (c)**

- In tensile test, actual area is smaller than original area. Therefore true stress will be more than original.
- During experiment in laboratory, strain is measured that is why it is called fundamental quantity while stress is derived from strain.
- The modulus of elasticity and poisson's ratio are assumed to be same in tension as well as in compression.

**142. (d)**

- Pull-in torque is the maximum torque against which a motor will start for a given pulse rate and reach synchronism without losing a step.
- Pull-out torque is the maximum torque that can be applied to a motor running at a given stepping rate, without losing synchronism.
- Pull-in rate is the maximum switching rate at which a loaded motor can start without losing steps.
- Slew range is the range of switching rates between pull-in and pull-out in which a motor will run in synchronism but cannot start or reverse.

**143. (a)**

**144. (a)**

In fixed dome type biogas plant, there is no bifurcation in the digester chamber and therefore, gas production is somewhat less as compared to floating point design.

**145. (a)**

In pre-loading, the clamped material under the bolt is a compressive stress and when an external (separating) force which is less than the preload force is applied then it tends to decrease the compressive stress in the clamped material because both the preload and separating forces are opposite in direction that's why the portion below the bolt, i.e., holes is safer than the gross plate section where there is no preloading effect.

**146. (a)**

**147. (c)**

At higher speed, extreme pressure additives can't get enough time to react with manganese and produce low shear strength film, so water emulsion are used to decrease the viscosity of cutting fluid so that takes away the heat from the machining area.

**148. (a)**

Above a certain pressure ratio the addition of regenerator causes a loss in cycle efficiency when compared to the original brayton cycle.

In this situation, the compressor discharge temperature is higher than the turbine exhaust gas temperature. The compressed air will thus be cooled in the regenerator and the exhaust gas will be heated. As a result both the heat supply and heat rejected are increased. However, the compressor and turbine work remain unchanged so, the cycle efficiency decreases.

**149. (b)**

Reaction turbine works above the atmospheric pressure greater than the impulse turbine pressure due to this reaction blading is commonly used in intermediate and low pressure parts of steam turbine.

**150. (c)**

- Value differs from both price and cost in sense, that it is cost proportional to function,

  i.e. $$\text{value} = \frac{\text{Function (or utility)}}{\text{Cost}}$$

- It can be seen that the value of a product can be increased either by increasing its utility with the same cost or decreasing its cost for the same function.

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