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# ESE 2017

## Prelims Exam
## Detailed Solution

**MECHANICAL ENGINEERING**

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# Explanation of Mechanical Engg. Prelims Paper (ESE - 2017)

**Directions:**

Each of the following **thirty (30)** items consists of two statements, one labelled as 'Statement (I)' and the other as 'Statement (II)'. Examine these two statements carefully and select the answers to these items using the code given below:

**Code:**

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is **not** the correct explanation of Statement (I)

(c) Statement (I) is true but Statement (II) is false

(d) Statement (I) is false but Statement (II) is true

**1.** **Statement (I):** Depth of centre of pressure of any immersed surface is independent of the density of the liquid.

**Statement (II):** Centre of area of the immersed body lies below the centre of pressure.

**Ans.** **(c)**

**Sol.** The depth of centre of pressure of immersed surface in liquid,

$$\text{Depth of centre of area} + \frac{I_{CG}\sin^2\theta}{A\bar{x}}$$

$$h_{cp} = \bar{x} + \frac{I_{CG}\sin^2\theta}{A\bar{x}}$$

Hence depth of centre of pressure is independent on density of fluid.

- Centre of area lies above the centre of pressure

**2.** **Statement (I):** In flow through a pipeline, the nature of the fluid flow depends on the velocity of the fluid.

**Statement (II):** Reynolds number of the depends on the velocity, the diameter of the pipe and the kinematic viscosity of the fluid.

**Ans.** **(a)**

**Sol.** The nature of flow means the flow is laminar or turbulent. Hence this nature is ascertained by Reynold number defined as,

$$Re = \frac{vD}{\nu}$$

where 'v' is flow velocity, 'D' is pipe diameter and '$\nu$' is kinematic viscosity.

**3.** **Statement (I):** The specific heat at constant pressure for an ideal gas is always greater than the specific heat at constant volume.

**Statement (II):** Heat added at constant volume is not utilized for doing any external work.

**Ans. (a)**

**Sol.** The specific heat of ideal gas of constant pressure is the sum of specific heat at constant volume and a constant term. This constant term comes due to work done component. This work done component is missing when heat is added at constant volume.

**4.** **Statement (I):** A homogeneous mixture of gases that do not react within themselves can be treated as a pure substance.

**Statement (II):** Flue gases can be treated as a homogeneous mixture of gases.

**Ans. (b)**

**Sol.** The composition of pure substance is invariable and same through out the sample i.e. constitutents of prue substance do not react themselves.

**5.** **Statement (I):** Air-blast injection in diesel engines could reduce engine efficiency.

**Statement (II):** Air-blast injection in diesel engines is not instantaneous but happens when the piston moves outward with the injection valve remaining open for whatever reason.

**Ans. (c)**

**Sol.** In air injection or air blast injection, metered fuel is carried by high pressure air around 65-70 bars into cylinders at the end of compression stroke. The compressed air is around 2.3% of total air consumption of engine and instantly enters the cylinder.

**6.** **Statement (I):** Use of non-azeotropic mixtures used as the refrigerant in a vapour compression system improves the coefficient of performance.

**Statement (II):** The increase in this coefficient is attributable to reduction in volume.

**Ans. (c)**

**Sol.** The non-azeotropic or zeotropic mixtures are non-isothermal refrigerant i.e. temperature of refrigerant varies during heat addition and rejection.

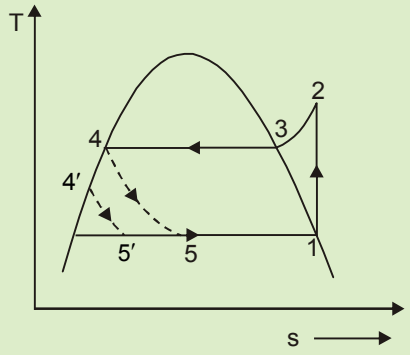
Since average temperature of heat addition increases in evaporator and average temperature of heat rejection reduces in condenser which results in increased CoP not reduction in volume.

**7.** **Statement (I):** Sub-cooling of a refrigerant liquid increases the coefficient of performance of a refrigeration cycle.

**Statement (II):** Sub-cooling reduces the work requirement of the refrigeration cycle.

**Ans. (c)**

**Sol.** The T-s diagram of vapour compression cycle,




Process $4-4'$ is subcooling

Process 1–2 is work requirement.

The subcooling increases refrigerant effect from $(h_1 - h_5)$ to $(h_1 - h_{5'})$ and nowork requirement.

8. **Statement (I):** In vapour-absorption system, larger the value of specific solution circulation, more the pump work.

**Statement (II):** Higher solution circulation rates of poor as well as rich solutions need larger pressure drops in the system.

**Ans.** **(c)**

**Sol.** In vapour absorption system, high pressure side pressure (generator and condenser) and low pressure side pressure (absorber and evaporator) are decided by desired application temperatures. The flow rate of solution controls the capacity of the system. So high capacity requires high pump work. Solution circulation rates and pressure drop has no relation.

9. **Statement (I):** Outward radial flow turbines do race inherently.

**Statement (II):** In outward radial flow turbines, the centrifugal head impressed upon the exiting water leads to flow increase.

**Ans.** **(a)**

**Sol.** In outward radial turbine water enters at the centre and flows radially outwards towards the outer periphery of the runner and hence the fluid gains centrifugal head while flowing through it.

10. **Statement (I):** Regarding the power transmitted by a clutch, greater the speed, lower the torque to be transmitted for fixed power rating.

**Statement (II):** The clutch is placed on the low-speed side to transmit larger torque.

**Ans.** **(c)**

**Sol.** The power rating of a mechanical system, Power = Torque × Rotational.

Hence higher the speed, lower will be the torque so a clutch should be provided on high speed side with suitable heat dissipation arrangement. This clutch will be small and cost effective.

11. **Statement (I):** The volume of air taken into the cylinder of a reciprocating air compressor is less than the stroke volume of the cylinder,

**Statement (II):** Air that has been compressed to clearance volume expands to larger volumes during the suction stroke.

**Ans.** **(a)**

**Sol.** In reciprocating compressor there is a clearance space between the piston crown and the top of the cylinder . Air trapped in this clearance volume is never delivered, it expands as the piston moves back and limit the volume of fresh air which can be induced to a value less than the swept volume.

12. **Statement (I):** Providing reheat in a Rankine cycle would increase the efficiency of the cycle.

**Statement (II):** Reheat in Rankine cycle reduces specific steam consumption.

**Ans.** **(b)**

**Sol.** By reheating there is gain of 4 to 7% of thermal efficiency take place as the output of turbine is increased. Reheating may also shortout blade erosion and corrosion problem in turbine.

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Specific steam consumption,

$$= \frac{3600}{W_{net}} kg/kWh$$

Reheating increases $W_{net}$ . So, SSC is reduces.

**13.** **Statement (I):** Heat carried away by hot gases in chimney draught is much greater than the work required for lifting the same gases thorugh the height of the chimney. Yet artificial draught is not preferred.

**Statement (II):** Artificial draught involves large initial cost as well as large maintenance cost.

**Ans.** **(b)**

**Sol.** The choice of chimmney or artificial draught is application is specific. The artificial draft require installation of FD & and ID fan and some other accesories. The installation of these equipments are very costly affair.

**14.** **Statement (I):** The overall combustion efficiency of a fuel oil based plant is less as compared to that of a coal burning plant.

**Statement (II):** Fuel oils contain comparatively larger percentage of hydrogen, which produce more moisture per kg of fuel burnt.

**Ans.** **(a)**

**Sol.** Fuel oil (%H) is $\geq 10.99\%$ (%H) in coal (4.5 – 5.5)

Fuel oils contain hydrogen in a large percentage which on heating react with oxygen produce moisture content in fuel which drop the calrofic value of fuel oil.

**15.** **Statement (I):** Proximate analysis of coal is done to determine its calorific value.

**Statement (II):** In proximate analysis of coal, the percentages of moisture, volatile matter, fixed carbon and ash are determined.

**Ans.** **(d)**

**Sol.** Proximate analysis is done to examine four factors : Moisture, volatile compound, ash content and fixed carbon. Calorimeters are used for calorific value estimation.

**16.** **Statement (I):** Water entering into a condenser from the cooling tower has much dissolved impurities.

**Statement (II):** In a closed cooling system, the water is continuously aerated, therefore, there is abundant dissolved oxygen in this water.

**Ans.** **(c)**

**Sol.** A cooling tower is an open cooling system and water can dissolved in purities from air because of direct contact.

A condenser a closed cooling system and there exists a vacuum in the condenser during operation. Hence there exist a possibilities of air leakage which is continuously deaerated.

**17.** **Statement (I):** Pyranometer is used to measure diffuse solar radiation by blocking the direct radiation with a shadow band.

**Statement (II):** Pyrheliometer is used to measure diffuse radiation.

**Ans.** (c)

**Sol.** The pyroheliometer is a broadband instrument that measures the direct (or beam) component of solar radiation at normal incidence. It does not measure diffuse radiation.

The diffuse radiation is measured by pyrometer.

18. **Statement (I):** Directionally solidified materials have good creep resistance.

**Statement (II):** Directionally solidified materials may be so loaded that there is no shearing stress along, or tensile stress across, the grain boundaries.

**Ans.** (c)

**Sol.** Directionally solidified material posses extremely good elevated temperature capability due to elimination of highly stressed transverse grain bounderies.

Statement II is not explaining the reason as stated above.

19. **Statement (I):** The ideal material for shafts transmitting power is CI.

**Statement (II):** CI resists compression well.

**Ans.** (d)

**Sol.** Cast iron (CI) is brittle in nature so, its torsional (shear) strength is less hence can not used as shaft.

Cast iron is strong in compression but weak under tension.

20. **Statement (I):** Hardenability curves are developed based on the fact that any given steel item always develops the same microstructure under a standardized cooling rate.

**Statement (II):** Industry employs Jominy hardenability test to measure hardenability.

**Ans.** (b)

**Sol.** The hardenability of a ferrous alloy is measured by Jominy test. A round metal bar of standard size is transfered to 100% austenite through heat treatment, and is then quenched on one end with room temperature water. The cooling rate will be highest at the end being quenched and will decrease as the distance from the end increases. Subsequent to cooling a flat surface ground on the test piece and the hardenbility is then found by measuring the hardness along the bar.

Farther away from the quenched end that the hardness extends, the higher the hardenability. This in formation is plotted on graph.

21. **Statement (I):** Cams used in high-speed application should have displacement, velocity and acceleration curves of the follower in continuity.

**Statement (II):** Abrupt changes in these curves will cause high contact stresses at the bearings and make the operation noisy.

**Ans.** (a)

**Sol.** Abrupt changs in displacement, velocity and acceleration curves cause jerk in the system and high magnitude of forces.

22. **Statement (I):** Resonance is a special case of forced vibration in which the natural frequency of the body is the same as the impressed frequency of the external periodic force whereby the amplitude of the forced vibration peaks sharply.

**Statement (II):** The amplitude of forced vibration of a body increases with increase in the frequency of the externally impressed periodic force.

**Ans. (c)**

23. **Statement (I):** All worm drives (worm and worm wheel) are reversible.

**Statement (II):** The worm and worm wheel are made of different materials.

**Ans. (d)**

**Sol.** Only low speed ratio worm drives are reversible while high speed ratio drives are non reversible.

24. **Statement (I):** There is no balancing methodology in the case of reciprocating engines.

**Statement (II):** Balancing of dynamic forces is achieved mostly by resorting to multi-cylinder engine concept.

**Ans. (b)**

**Sol.** Single cylinder reciprocating engine can not be balanced completely by any method. But in multicylinder engine case, it is possible to balance the engine in particular configuration e.g.six cylinder

25. **Statement (I):** Two circular discs of equal masses and thickness made of different materials will have same moment of inertia about their central axes of rotation.

**Statement (II):** Moment of inertia depends upon the distribution of mass within the body.

**Ans. (a)**

26. **Statement (I):** The speed of a governed water turbine will remain constant irrespective of load.

**Statement (II):** In governing, the water supply is regulated to maintain the speed constant.

**Ans. (a)**

**Sol.** The primary objective in turbine operation is to maintain a constant speed of rotation irrespective as the varying load. This is achieved by means as governing in a turbine.

27. **Statement (I):** In sugarcane crushing rollers, the fit between the cast roll and the forged steel shaft is of interference type.

**Statement (II):** This helps in removing the roll from the shaft whenever not needed.

**Ans. (c)**

28. **Statement (I):** Thicker sections of casting take longer to solidify than thinner sections.

**Statement (II):** Thicker sections of casting carry residual stresses.

**Ans. (b)**

29. **Statement (I):** Sand with grains of uniform round shape is preferred for preparing moulds.

**Statement (II):** If grains are large and regular in shape, the air-venting property of the mould prepared with them would be better.

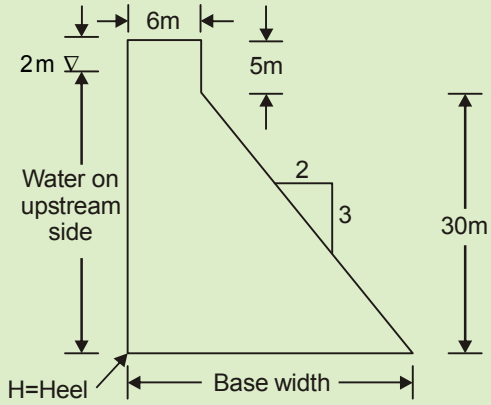
**Ans. (a)**

**30.** **Statement (I):** Bar chart plots in the time dimension the planned performance of various activities of a project.

**Statement (II):** One advantage of a bar chart is that the inter sequence and linkage of all activities is indicated therein.

**Ans. (c)**

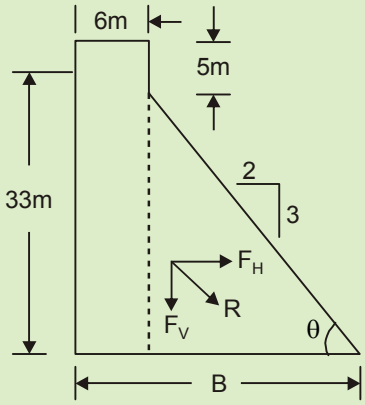
**31.** A section of a dam made of concrete, $\rho = 2.6$, total height = 35 m, with top walkway width of 6 m, is shown. The upstream bottommost point is called the Heel of the dam. The sloped part on downstream side is 3 vertical on 2 horizontal. Water stands till 2m short of the top of the dam section. The net resultant force acting on the base level of the dam is nearly




(a) 1370 k kgf (b) 1385 k kgf
(c) 1400 k kgf (d) 1433 k kgf

**Ans. (d)**

**Sol.** Assuming unit width of dam, the dam section,




Base width of dam,

$$B = 6 + \frac{30}{\tan\theta} = 6 + \frac{30 \times 2}{3} = 26\,m$$

Horizontal force $F_H = \frac{1}{2}\gamma H^2$

$$F_H = \frac{1}{2} \times 1000 \times (33)^2 \text{ kgf}$$

$$= 544.5 \text{ k kgf}$$

Vertical force ($F_v$) = weight of the dam

$$F_v = \left(6 \times 35 + \frac{1}{2} \times 20 \times 30\right) \times 2.6 \times 1000$$

$$= 1326 \text{ k kgf}$$

Resultant force = $\sqrt{(F_H)^2 + (F_v)^2}$

$$= \sqrt{(544.5)^2 + (1326)^2}$$

$$= 1433.45 \text{ k kgf}$$

**32.** A spherical waterdrop of 1 mm in diameter splits up in air into 64 smaller drops of equal size. The surface tension coefficient of water in air is 0.073 N/m. The work required in splitting up the drop is

(a) $0.96 \times 10^{-6}$ J (b) $0.69 \times 10^{-6}$ J
(c) $0.32 \times 10^{-6}$ J (d) $0.23 \times 10^{-6}$ J

**Ans. (b)**

**Sol.** By mass conservation

$$\frac{4}{3}\pi(0.5)^3 = 64 \times \frac{4}{3}\pi(r')^3$$

$$r' = \frac{0.5}{4} = 0.125\text{mm}$$

$$E_1 = T \cdot (\text{surface area})$$

$$= 0.073 \times 4\pi(0.5)^2 \times 10^{-6}$$

$$E_2 = 0.073 \times 4\pi\left(\frac{1}{8}\right)^2 \times 64 \times 10^{-6}$$

$$= 0.073 \times 4\pi \times 10^{-6}$$

$$\Delta E = 0.073 \times 4\pi(1 - 0.25) \times 10^{-6}$$

$$= 0.073 \times 4\pi \times \frac{3}{4} \times 10^{-6}$$

$$= 0.687 \times 10^{-6} \text{ J}$$

**33.** Consider the following statements pertaining to stability of floating bodies:

1. A floating body will be stable when the centre of gravity is above the centre of buoyancy.
2. The position of metacentres corresponding to different axes of rotation are generally different for the same floating object.
3. For cargo ships, the metacentric height varies with loading.

Which of the abvoe statements are correct?

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 1 and 3 only (d) 2 and 3 only

**Ans. (d)**

**Sol.** Floating body will be in stable equilibrium when center of Buoyancy lies above the center of gravity.

Metacenteric height GM = BM – BG

$$= \frac{I}{V} - BG$$

hence GM varies with axis of consideration.

The Metacentric heights are different for rolling, pitching and yachting.

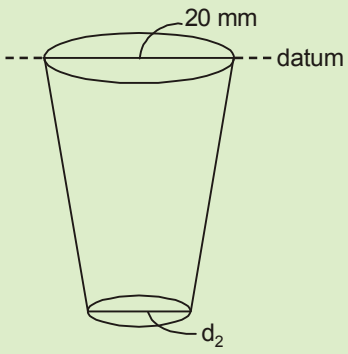
**34.** Water is coming out from a tap and falls vertically downwards. At the tap opening, the stream diameter is 20 mm with uniform velocity of 2 m/s. Assuming steady inviscid flow, constant pressure atmosphere everywhere, and neglecting curvature and surface tension effects, the diameter of the stream 0.5 m below the tap opening is nearly

(a) 11.7 mm (b) 14.6 mm
(c) 17.5 mm (d) 20.4 mm

**Ans. (b)**

**Sol.** Applying Bernoulli equation

$$\frac{P}{\gamma}+\frac{V_1^2}{2g}+\cancel{Z_1} = \frac{P_2}{\gamma}+\frac{V_2^2}{2g}+\cancel{Z_2}$$




$$P_1 = P_2\ P_{atm}$$

$$\cancel{Z_1} = 0$$

$$\cancel{Z_2} = -0.5$$

$$v_1 = 2\text{m/s}$$

$$\frac{Z^2}{2\times 10} = \frac{V_z^2}{2\times 10}-0.5$$

$$v_2 = 3.74\ \text{m/sec}$$

By continuity equation

$$A_1V_1 = A_2V_z$$

$$\frac{\pi d_1^2}{A}\times 2 = \frac{\pi}{A}d_2^2\times 3.74 \qquad (d_1 = 20\text{mm})$$

$$d_2 = \sqrt{\frac{20^2\times 2}{3.74}}$$

$$= 14.62\ \text{mm}$$

**35.** Consider the following statements regarding Bernoulli's equation :

1. It is assumed that no energy has been supplied.
2. The velocity of a steady stream of fluid flow will depend on the cross-sectional area of the stream.
3. Consider two sections 1 and 2 along a flow stream. In this reach, if q is work done by a pump, w is work absorbed by turbine, $\rho$ is density of water and g is acceleration of gravity, with p, v and z carrying standard meanings, Bernoulli's equation will read

$$\frac{p_1}{\rho}+\frac{v_1^2}{2g}+z_1=\frac{p_2}{\rho}+\frac{v_2^2}{2g}+z_2+w+g$$

Which of the above statements are correct?

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (a)**

**Sol.** For find statement

$$\frac{P}{\gamma}+\frac{V_1^2}{2g}+q+\cancel{Z_1} = \frac{P}{\gamma}+\frac{V_2^2}{2g}+\cancel{Z_2}+w$$

**36.** An oil flows through a pipe at a velocity of 1.0 m/s. The pipe is 45 m long and has 150 mm diameter. What is the head loss due to friction, if $\rho = 869\ \text{kg/m}^3$ and $\mu = 0.0814\ \text{kg/m s}$?

(a) 0.61 m (b) 0.51 m
(c) 0.41 m (d) 0.31 m

**Ans. (a)**

**Sol.** $\nu$ = 1m/sec d= 0.15

L = 45m s = 869 kg/m$^3$

$h_L$ = ? $\mu$ = 0.0814

In flow through pipe

$$h_L = \frac{32\mu\bar{V}L}{rgD^2}$$

$$= \frac{32\times0.0814\times1\times45}{869\times10\times0.15^2}$$

$$= \frac{117.22}{195.52}$$

= 0.6 m

**37.** Consider the following statements:

1. At low Reynolds numbers of any flow, viscous forces dominate over inertial forces.
2. Transition from laminar to turbulent flow occurs over a range of Reynolds numbers depending on the surface presented to the flow.

Which of the above statements is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

**Ans. (c)**

**Sol.** $$Re = \frac{\text{Inertial force}}{\text{Viscous force}}$$

$\Rightarrow$ at low reynold number, viscous force dominates over inertial force.

**38.** In a steady laminar flow of a given discharge through a circular pipe of diameter D, the head loss is proportional to

(a) $D^{-1}$ (b) $D^{-2}$
(c) $D^{-3}$ (d) $D^{-4}$

**Ans. (d)**

**Sol.** Head loss in pipe is given by

$$h_L = \frac{32\mu\times\bar{4}L}{\rho gD^2} = \frac{128\mu QL}{\rho gID^4}$$

$$\boxed{h_L \propto \frac{1}{D^4}}$$

**39.** A two-dimensional flow field is defined as $\vec{V} = \vec{i}x - \vec{j}y$. The equation of the stream-line passing through the point (1, 2) is

(a) xy + 2 = 0 (b) $x^2$ y + 2 = 0
(c) xy – 2 = 0 (d) $x^2$ y –2 = 0

**Ans. (c)**

**Sol.** $\vec{V} = \hat{i}x - \hat{j}y$

Here u = x

v = –y

For stream function

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

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

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

or $\ln xy = \ln y$

or $xy = c$

for $x = 1, y = 2$

$xy = c$ gives $c = 2$

So, $xy = c$

$\Rightarrow$ $xy - 2 = 0$

**40.** The centre-line velocity in a pipe flow is 2m/s. What is the average flow velocity in the pipe if the Reynolds number of the flow is 800?

(a) 2 m/s (b) 1.5 m/s
(c) 1 m/s (d) 0.5 m/s

**Ans. (c)**

**Sol.**

Flow through a pipe is given by

$$v = v_{max}\left[1-\left(\frac{r}{R}\right)^2\right]$$

and mean velocity in pipe related to maximum velocity is given by

$$V_{mean} = \frac{V_{max}}{2} = \frac{2}{2} = 1$$

**41.** During a constant pressure expansion of a gas, 33.3% heat is converted into work while the temperature rises by 20 K. The specific heat of the gas at constant pressure as a proportion of work, W is

(a) 8% (b) 10%
(c) 12% (d) 15%

**Ans. (d)**

**Sol.** $\frac{W}{Q} = 0.333$

$Q = C_p \Delta T$

for constant pressure process

$\therefore$ $\frac{W}{C_p \Delta T} = 0.333$

or $\frac{C_p}{W} = \frac{1}{0.333 \times \Delta T} = \frac{1}{0.333 \times 20}$

In percentage $\frac{C_p}{W} = \frac{100}{0.333 \times 20} = 15$

**42.** A cylinder contains $10m^3$ of an ideal gas at a pressure of 2 bar. This gas is compressed in a reversible isothermal process till its pressure increases to 15 bar. What quantum of work will be required for this process? (You can use the table given herewith).

| Number | 2 | 2.5 | 3 | 5 | 7 |
|---|---|---|---|---|---|
| $\log_{10}$ | 0.301 | 0.397 | 0.475 | 0.698 | 0.845 |

(a) 4500 kJ (b) 4030 kJ
(c) 450 kJ (d) 403 kJ

**Ans. (b)**

**Sol.** Work done $W = p_1 v_1 \ln \frac{p_1}{p_2}$

$$= 2\times10^5 \times 10 \times \ln \frac{2}{15}$$

$$= 2\times10^6 \times 2.303 \log \frac{2}{15}$$

$$= 2\times10^6 \times 2.303 \left[\log 2 - (\log 5 + \log 3)\right]$$

$$= 2\times10^6 \times 2.303 \times [0.301 - (0.698 + 0.475)]$$

$$= 4016 \text{ kJ}$$

**43.** A system of 100 kg mass undergoes a process in which its specific entropy increases from 0.3 kJ/kg K to 0.4 kJ/kg K. At the same time, the entropy of the surroundings decreases from 80 kJ/kg K to 75 kJ/kg K. The process is

(a) reversible and isothermal
(b) irreversible
(c) reversible only
(d) isothermal only

**Ans. (b)**

**Sol.** $(\Delta S)_{univ} = (\Delta S)_{sys} + (\Delta S)_{sur}$

$(\Delta S)_{sys} = 100(0.4 - 0.3) = 10 \text{ kg/k}$

$(\Delta S)_{sur} = 75 - 80 = -5 \text{ kg/k}$

$(\Delta S)_{univ} = 10 - 5 = 5 > 0$

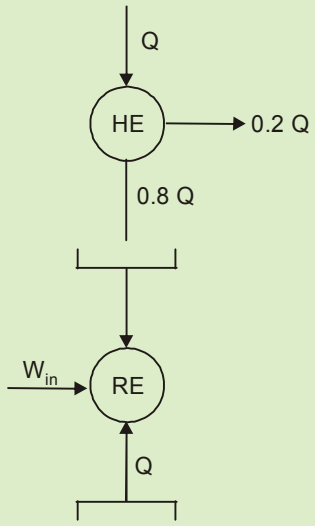
So, process is irreversible.

**44.** A reversible heat engine rejects 80% of the heat supplied during a cycle of operation. If the engine is reversed and operates as a refrigerator, then its coefficient of performance shall be

(a) 6 (b) 5
(c) 4 (d) 3

**Ans. (c)**

**Sol.**




$$(C_{OP})_{HP} = \frac{1}{\eta_{HE}}$$

& $(C_{OP})_{HP} = 1 + (C_{OP})_{RE}$

or, $(C_{OP})_{RE} = \frac{1}{\eta_E} - 1 = \frac{1}{0.2} - 1 = 4$

**45.** For the same efficiency of the Brayton cycle and the Carnot cycle working between temperature limits of $T_{max}$ and $T_{min}$, the power contribution of the Brayton cycle will be

(a) zero
(b) maximum
(c) minimum
(d) 50% of the Carnot cycle

**Ans. (a)**

**Sol.** $\eta_{\text{brayton cycle}} = 1 - \frac{c}{t}$

where $c = \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma+1}{\gamma}}$

$t = \frac{T_{max}}{T_{min}}$

for $\eta_{\text{brayten}} = \eta_{\text{carnot}}$

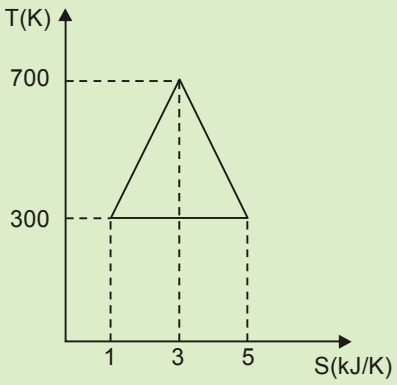
$c = 1$, means $\frac{T_2}{T_1} = 1 = (r_P)^{\gamma+\gamma}$

or, $(1)^{\frac{\gamma}{\gamma+1}} = \left(\frac{P_2}{P_1}\right)$

i.e., $P_2 = P_1$

so, contribution of power ratio is zero

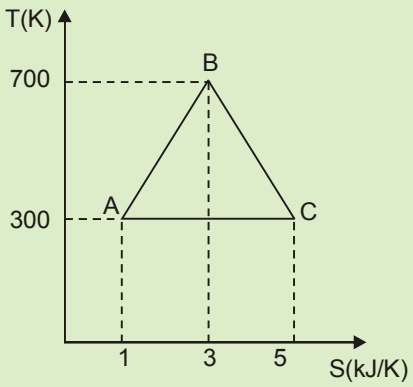
**46.** The thermal efficiency of the hypothetical cycle shown is




(a) 0.6 (b) 0.5
(c) 0.4 (d) 0.3

**Ans. (c)**

**Sol.**




Net work done W = area of $\Delta ABC$

$= \frac{1}{2} \times (5-1) \times (700-300)$

$= \frac{1}{2} \times 4 \times 400 = 800 \text{ kJ}$

Heat added Q = area of 1-A–B–C–5–1

= area of $\Delta ABC +$ area of 1-A-C-5-1

= 800 + (5 – 1) × (300)

= 800 + 4 × 300 = 2000 kJ

efficiency $\eta = \frac{n}{Q} = \frac{800}{2000} = 0.4$

**47.** A heat engine working on the Carnot cycle receives heat at the rate of 50 kW from a source at 1300 K and rejects it to a sink at 400 K. The heat rejected is

(a) 20.3 kW (b) 15.4 kW
(c) 12.4 kW (d) 10.8 kW

**Ans. (b)**

**Sol.** $\frac{Q}{T_1} = \frac{Q_2}{T_2}$ for Carnot cycle

$$\frac{50}{1300} = \frac{Q_2}{400}$$

$$\Rightarrow \quad Q_2 = \frac{50 \times 400}{1300} = 15.4 \text{ kW}$$

**48.** An ideal gas is flowing through an insulated pipe at the rate of 3.3 kg. There is a pressure drop of 15% from the inlet to the outlet of the pipe. What is the rate of energy loss because of this pressure drop due to friction, given that $R_{gas}$ = 0.287 kJ/kg K and the reference temperature $T_0$ is 300 K?

(a) 42.62 kW (b) 40.26 kW
(c) 38.14 kW (d) 35.13 kW

**Ans. (a)**

**Sol.** Rate of energy loss = $mRT_0 \frac{\Delta p}{p}$

$$= 3.3 \times 0.287 \times 300 \times \frac{0.15p}{p}$$

$$= 42.62 \text{ kW}$$

**49.** A furnace is provided with an insulating refractory lining. The overal thermal conductivity of the material is 0.03 W/mK. The thickness of the lining is 100 mm. The inner and outer temperatures are 250°C and 50°C, respectively. The heat loss to the surroundings will be

(a) 30 J/m$^2$/s (b) 60 J/m$^2$/s
(c) 60 J/s (d) 30 J/s

**Ans. (b)**

**Sol.**

$$Q = \frac{kA\Delta\theta}{t}$$

$$= \frac{0.03 \times A \times (250 - 50)}{100 \times 10^{-3}}$$

$$\text{or, } \frac{Q}{A} = 0.03 \times 200 \times 10$$

$$= 60 \text{J m}^2\text{/sec}$$

**50.** A wall of 0.6m thickness has normal area of 1.5 m$^2$ and is made up of material of thermal conductivity 0.4 W/mK. If the temperature on the two sides of the wall are 800°C and 1000°C, the thermal resistance of the wall is

(a) 1.8 K/W (b) 1.8 W/K
(c) 1 K/W (d) 1 W/K

**Ans. (c)**

**Sol.**

$$R_{th} = \frac{L}{K_A} = \frac{0.6}{0.4 \times 1.5} = 1$$

**51.** Heat is lost from a 100 mm diameter steam pipe placed horizontally in ambient air at 30°C. If the Nusselt number is 25 and the thermal

conductivity of the air is 0.03 W/m K, then the heat transfer coefficient will be

(a) 7.5 W/m²K (b) 15 W/m²K
(c) 25 W/m²K (d) 35 W/m²K

**Ans. (a)**

**Sol.**

$$Nu = \frac{h \times D}{K_{air}} = \frac{h \times 0.1}{0.03}$$

$$\text{or, } 25 = \frac{h \times 0.1}{0.03}$$

or, h = 75 W/m²K

**52.** Air at 1 atmospheric pressure and 27°C blows across a 12 mm diameter sphere at a free stream velocity of 4 m/s. A small heater inside the sphere maintains the surface temperature at 77°C. With k = 0.026 W/m (kelvin) and with (Nu) = 31.4, the heat loss by the sphere would be

(a) 1.93 J/s (b) 1.76 J/s
(c) 1.65 J/s (d) 1.54 J/s

**Ans. (d)**

**Sol.**

$$N_u = \frac{hD}{k_{air}} = 31.4$$

$$\text{or, } h = \frac{31.4 \times 0.026}{\left(\frac{12}{1000}\right)}$$

= 68.033 Wm²/K

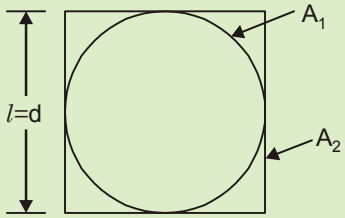
Heat loss by the sphere,

= $hA\Delta T$

$$= 68.033 \times 4\pi\left(\frac{12}{1000} \times \frac{1}{2}\right)_x^2 (77 - 27)$$

= 1.539 ≈ 1.54

**53.** The view factors $F_{12}$ and $F_{21}$, for the sphere of diameter d and a cubical box of length l = d as shown in the figure, respectively, are

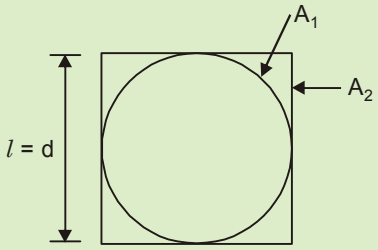



(a) 1 and $\frac{\pi}{3}$ (b) $\frac{\pi}{3}$ and 1

(c) 1 and $\frac{\pi}{6}$ (d) $\frac{\pi}{6}$ and 1

**Ans. (a)**

**Sol.**




→ For sphere by summation rule

$F_{11} + F_{12} = 1$

$F_{12} = 1$ as sphere can not view itself

By reciprocity theorem

$A_1F_{12} = A_2F_{21}$

$$\text{or, } F_{21} = \frac{A_1}{A_2} \times F_{12} = \frac{A_1}{A_2} = \frac{4\pi\left(\frac{d}{2}\right)^2}{6 \times l^2}$$

$$= \frac{\pi d^2}{6 \times d^2} = \frac{\pi}{6}$$

**54.** Knocking in a spark ignition engine can be reduced by

1. retarding the spark
2. supercharging
3. increasing the engine speed
4. using a fuel of long straight chain structure

Select the correct answer using the code given below.

(a) 1 and 4 (b) 1 and 3
(c) 2 and 3 (d) 2 and 4

**Ans. (b)**

**Sol.** By increasing engine speed & increases the turbulence of the mixture considerably resulting increasing flame speed and hence reduce the ignition delay.

In supercharing we increase the density of fluid which will rise the chance of knocking in SI and reverse in CI.

By retarding the spark timing, the peak pressure are reached down on the power stroke and are thus of lower magnitude. This might reduce the knocking.

**55.** A 4-cylinder diesel running at 1200 r.p.m. developed 18.6 kW. The average torque when one cylinder was cut out was 105 N m. If the calorific value of the fuel was 42000 kJ/kg and the engine used 0.34 kg of diesel/kW hr, the indicated thermal efficiency was nearly

(a) 29% (b) 26%
(c) 31% (d) 23%

**Ans. (a)**

**Sol.** Indicated power of one cylinder

$$= 18.6 - \frac{105 \times 23 \times 1200}{60}$$

$$= 5.405 \text{ kW}$$

$\therefore$ ip for u-cylinder engine = 5.405 × 4 = 21.62 kW

$$\text{bsfc} = \frac{\dot{m}_f}{\text{bp}} \quad \text{or} \quad \dot{m}_f = \text{bp} \times \text{bsfc}$$

$$\dot{m}_f = 18.6 \times \frac{0.34}{3600} \text{kg/s}$$

$$\eta_{it} = \frac{\text{ip}}{\dot{m}_f \times \text{CV}}$$

$$= \frac{21.62 \times 3600}{18.6 \times 0.34 \times 42000}$$

$$= 0.293 \quad \text{or} \quad 29.3\%$$

**56.** In a Morse test on a 2-cylinder, 2-stroke SI engine, the brake power is 9 kW and the BHP of individual cylinders with spark cutoff are 4.25 kW and 3.75 kW, respectively. The mechanical efficiency of the engine is

(a) 90% (b) 80%
(c) 52.5% (d) 45.5%

**Ans. (a)**

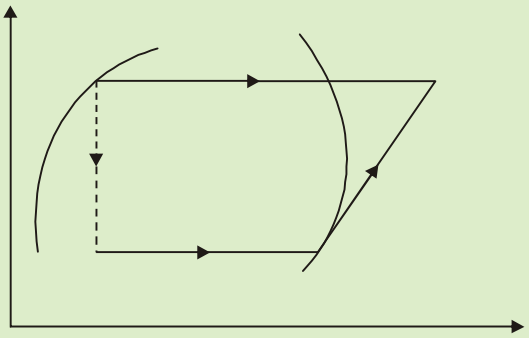
**Sol.**

$$b_p = 9 \text{ kW}$$
$$ip_1 = 4.75 \text{ kW}$$
$$ip_2 = 5.25 \text{ kW}$$

Total ip of engine = $iP_1 + iP_2 = 4.75 + 5.25 = 10$

so, $\eta = \frac{bp}{ip} = \frac{9}{10} = 90\%$

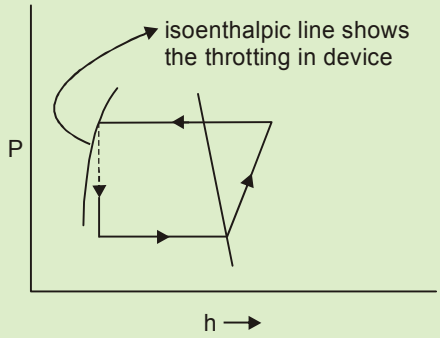
**57.** The ordinates and abscissae of the diagram given for the vapour-compression refrigeration cycle represent



(a) pressure and volume
(b) temperature and entropy
(c) enthalpy and entropy
(d) pressure and enthalpy

**Ans. (d)**

**Sol.**




**58.** Consider the following statements for refrigeration and air-conditioning:

1. In a refrigerating machine, the heat exchanger that absorbs heat is connected to a conditioned space.
2. A refrigerating cycle operating reversibly between two heat reservoirs has the highest coefficient of performance.
3. The lower the refrigeration required and the higher the temperature of heat rejection to the surroundings, the larger the power consumption.

Which of the above statements are correct?

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (d)**

**Sol.**

- Statement '1' refer to evaporator
- Statement 2 support the cop.

$$CoP = \frac{\text{Heat obsorbed}}{\text{Workdone per minute}}$$

$$= \frac{\text{Heat observed}}{\text{Heat rejected} - \text{Heat added}}$$

$CoP = f(T)$

For lower refregeration requirement and higher heat rejection work input required will

get increase and hence the power consumption.

**59.** In a refrigerator, the evaporator and condenser coil temperatures are –33°C and 27°C, respectively. Assumign that the maximum COP is realized, the required power input for a refrigerating effect of 4 kW is

(a) 8 kW (b) 4 kW
(c) 2 kW (d) 1 kW

**Ans. (d)**

**Sol.**

$$\frac{(273-33)}{(273+27)-(273-33)} = \frac{RE}{W_{input}} = \frac{RE}{P_{input}}$$

$$\frac{240}{60} = \frac{4}{P_{input}}$$

or, $P_{input}$ = 1 kW

**60.** Consider the following statements:

The volumetric efficiency of a reciprocating compressor can be improved by

1. decreasing the clearnace volume
2. cooling the intake air
3. heating the intake air

Which of the above statements is/are correct?

(a) 2 only (b) 3 only
(c) 1 and 2 (d) 1 and 3

**Ans. (c)**

**Sol.**

$$\eta_v = 1 + c - c\left(\frac{P_L}{P_1}\right)^{\frac{1}{\eta}}$$

as $\frac{P_2}{P_1} > 1$ so, by decreasing the clearance volume, volumetric efficiency get increased.

- By cooling the intake air increases the value of '$\gamma$' so,

$$\eta_v = 1 + c - \left(\frac{P_2}{P_1}\right)^{\frac{1}{\gamma}} \times c$$

increase as value of $\left(\frac{P_2}{P_1}\right)^{\frac{1}{\gamma}}$ will reduce.

**61.** In a Hartnell governor, the mass of each ball is 4 kg. The maximum and minimum centrifugal forces on the balls are 1800 N and 100 N at radii 25 cm and 20 cm, respectively. The lengths of vertical and horizontal arms of the bell-crank levers are the same. What is the spring stiffness?

(a) 780 N/cm (b) 740 N/cm
(c) 720 N/cm (d) 680 N/cm

**Ans. (d)**

**Sol.**

$$K = 2\left(\frac{a}{b}\right)^2\left(\frac{F_2 - F_1}{r_2 - r_1}\right)$$

$$= 2 \times 1 \times \left(\frac{1800 - 100}{25 - 20}\right)$$

= 680 N/cm

**62.** Consider the following statements regarding the ends of the pressure vessels flanged by pre-tensioned bolts:

1. Pre-tensioning helps to seal the pressure vessel.

2. Pre-tensioning reduces the maximum tensile stress in the bolts.
3. Pre-tensioning countermands the fatigue life of the bolts.
4. Pre-tensioning helps to reduce the deleterious effect of pressure pulsations in the pressure vessel.

Which of the above statements are correct?

(a) 1, 2 and 3 only
(b) 1, 3 and 4 only
(c) 2 and 4 only
(d) 1, 2, 3 and 4

**Ans. (b)**

**Sol.** Pre-tensioning does not reduce the maximum tensile stress in the bolts.

**63.** Two shafts, one solid and the other hollow, made of the same material, will have the same strength and stiffness, if both are of the same

(a) length as well as weight
(b) length as well as polar modulus
(c) weight as well as polar modulus
(d) length, weight as well as polar modulus

**Ans. (b)**

**Sol.** $K = \frac{GJ}{L}$

$I = \frac{Tr}{J}$

If J of both the shafts are same then L has to be same for both for same stiffness and vice-versa.

For same 'J', $J_{solid} = J_{Hollow}$

$$\frac{\pi}{32}d^4 = \frac{\pi}{32}\left(d_0^4 - d_i^4\right),$$

This does not gurantee the same weight

**64.** A solid shaft is to transmit 20 kW at 200 r.p.m. The ultimate shear stress for the shaft material is 360 MPa and the factor of safety is 8. The diameter of the solid shaft shall be

(a) 42 mm (b) 45 mm
(c) 48 mm (d) 51 mm

**Ans. (c)**

**Sol.** P = 20 kW

N = 200 rpm

$\Rightarrow$ $\omega$ = 20.94 rad/s

Int = 360 MPa

FoS = 8

$\therefore$ Torsion,

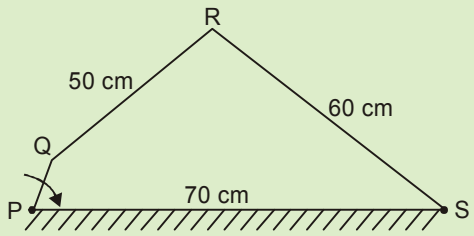
$$T = \frac{P}{\omega} = \frac{20\times10^3}{\left(\frac{2\pi\times200}{60}\right)} = 954.92\ N-m$$

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

$$\Rightarrow \quad \frac{Int}{FoS} = \frac{360\times10^6}{8} = \frac{16\times954.92}{\pi\times d^3}$$

$\Rightarrow$ d = 47.63 mm

**65.** In the 4-bar mechanism as shown, the link PQ measures 30 cm and rotates uniformly at 100 rev/min. The velocity of point Q on link PQ is nearly




(a) 2.54 m/s (b) 3.14 m/s
(c) 4.60 m/s (d) 5.80 m/s

**Ans. (b)**

**Sol.** PQ = 30 cm

N = 100 rpm

$\Rightarrow \quad \omega = \frac{2\pi N}{60}$

$$V = \omega(PQ) = \frac{2\pi \times 100}{60} \times 0.30$$

= 3.14 m/sec

**66.** The rim of a flywheel is subjected to
(a) direct tensile stress and bending stress
(b) torsional shear stress and bending stress
(c) direct shear stress and bending stress
(d) compressive stress and bending stress

**Ans. (a)**

**Sol.** Rim of a flywheel is subjected to

(i) Tensile stress due to the centrifugal force

(ii) Bending stress due to restraint of the arms.

**67.** A stockist has to supply 400 units of a product every Monday to his customers. He gets the product at Rs. 50 per unit from the manufacturer. The cost of ordering and transportation from the manufacturer to the stockist's premises is Rs. 75 per order. The cost of carrying inventory is 7.5% per year of the cost of the product. What are the economic lot size and the total optimal cost (including capital cost) for the stockist?
(a) 989 units/order and Rs. 20,065.80/week
(b) 912 units/order and Rs. 20.065.80/week
(c) 989 units/order and Rs. 18,574.50/week
(d) 912 units/order and Rs. 18,574.50/week

**Ans. (b)**

**Sol.** $$EOQ = \sqrt{\frac{2DC_0}{C_c}} = \sqrt{\frac{2 \times 400 \times 52 \times 75}{\frac{7.5}{100} \times 50}}$$

= 912 units

Total optimal cost

$$= p \times D + \frac{D}{EOQ} \times C_0 + \frac{EOQ}{2} \times C_c$$

$$= 400 \times 52 \times 50 + \frac{400 \times 52}{912} \times 75 \times 2$$

Total optimal cost per week

$$= \frac{400 \times 52 \times 50 + \frac{400 \times 52 \times 75 \times 2}{912}}{52}$$

= Rs. 20,065.80 per week

**68.** Consider just only the following parameters:
1. Grinding wheel diameter
2. Regulating wheel diameter
3. Speed of grinding wheel
4. Speed of regualting wheel

Which of the above parameters will influence the axial feed rate in centreless grinding?

(a) 2 and 4 (b) 2 and 3
(c) 1 and 3 (d) 1 and 4

**Ans. (a)**

**Sol.**

$f \propto$ speed regulating wheel

$\propto$ Dia of regulating wheel

$\boxed{f = \pi DN\sin\alpha}$

**69.** A metric thread of pitch 2 mm and thread angle 60° is inspected for its pitch diameter usign the 3-wire method. The indicated diameter of the wire will be nearly

(a) 0.85 mm (b) 1.05 mm
(c) 1.15 mm (d) 2.05 mm

**Ans. (c)**

**Sol.** $$d = \frac{P}{2\cos\frac{\theta}{2}} = \frac{2}{2\times\cos\frac{60}{2}}$$

$$= \frac{1}{\cos 30°} = 1.15\text{mm}$$

**70.** Consider the following statements with reference to NC machines:
1. Both closed-loop and open-loop systems are used.
2. Papers, tapes, floppy tapes and cassettes are used for data storage.
3. Digitizers may be used as interactive input devices.
4. Post-processor is an item of hardware.

Which of the above statements are correct?

(a) 1, 2 and 4 (b) 1, 3 and 4
(c) 2, 3 and 4 (d) 1, 2 and 3

**Ans. (d)**

**71.** Consider the following benefits of CIM:
1. Less direct labour
2. Less scrap and rework
3. Higher machine use

Which of the above are correct?

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 1 and 3 only (d) 2 and 3 only

**Ans. (d)**

**72.** A firm's inventory turnover of Rs. 8,00,000 is 5 times the cost of goods sold. If the inventory turnover is improved to 8 with the cost of goods sold remaining the same, a substantial amount of fund is either released from, or gets additionally invested in, inventory. Which one of the following statements is correct?

(a) Rs. 1,60,000 is released.
(b) Rs. 1,60,000 is additionally invested.
(c) Rs. 60,000 is released.
(d) Rs. 60,000 is additonally invested

**Ans. (c)**

**Sol.** Inventory turnover = 5 = $\frac{8,00,000}{\text{old inventory}}$

$\therefore$ old inventory = $\frac{800000}{5}$

Rs. 160,000

$$\text{Inventory Turnover} = 8 = \frac{8,00,000}{\text{new inventory}}$$

$$\therefore \text{New inventory} = \frac{800000}{8} = \text{Rs.}100,000$$

$\therefore$ Old inventory – new inventory

= 160,000 – 1,00,000 = Rs. 60,000 released

**73.** An 8-hour measurment study in a plant reveals that 320 number of units were produced. If idle time = 15% and performance rating = 120%, with allowance = 12% of normal time, the standard time per unit produced will be

(a) 1.823 minutes (b) 1.714 minutes

(c) 1.645 minutes (d) 1.286 minutes

**Ans. ( )**

**Sol.** Standard time ST = observed time × Rating factor (1 + Allowance)

$$\text{or} \quad ST = \frac{480 \times 0.85}{320} \times 1.2 \times 1.12$$

= 1.714 minutes

**74.** An organization's sales during a financial year is Rs. 6,00,000 with 90% of it on credit. At the end of the year, the receivables turnover was found to be 5. Considering 365 days to a year, the average collection period and receivables are, respectively

(a) 81 days and Rs. 1,08,000

(b) 73 days and Rs. 1,08,000

(c) 81 days and Rs. 1,20,000

(d) 73 days and Rs. 1,20,000

**Ans. (b)**

**Sol.** $\text{Receivables turnover} = \frac{\text{Net credit solar}}{\text{average receivable}}$

$$5 = \frac{6,00,000 \times 0.9}{\text{Average receivable}}$$

$$\text{Average receivable} = \frac{6,00,000 \times 0.9}{5}$$

= 1,08,000

$$\text{Average collection period} = \frac{365}{5} = 73 \text{ days}$$

**75.** A particular item has a demand of 9000 units/ year. The cost of one procurement is Rs. 108 and the holding cost per u nit is Rs. 2.40/year. The replacement is instantaneous and no shortages are allowed. What is the optimum number of orders/year?

(a) 7 orders/year (b) 8 orders/year

(c) 9 orders/year (d) 10 orders/year

**Ans. (d)**

**Sol.** $$EOQ = \sqrt{\frac{2DC_0}{C_c}}$$

$$= \sqrt{\frac{2 \times 9000 \times 108}{2.4}} = 900$$

$$\text{Optimum no. of order/year} = \frac{D}{EOQ}$$

$$= \frac{9000}{900} = 10 \text{ orders/year}$$

**76.** Which one of the following is correct with respect to microcontrollers?

(a) Integration of a microprocessor with I/O interfaces and memory and other peripherals in a single IC chip

(b) A single very large scale integrated (VLSI) chip that contains programmable electronic components that perform control functions

(c) Digital circuits for data handling and computation

(d) The primary computation and system control operations

**Ans. (a)**

**Sol.** Microcontroller is complete functional microcomputer, i.e. it contains the circuitry of microprocessor and in addition it has built in memory (RAM, ROM), I/O circuits and pripherals necessary for an applications.

**77.** Which one of the following statements is correct?

Seismic transducer working in the displacement mode should have

(a) weak springs and heavy mass

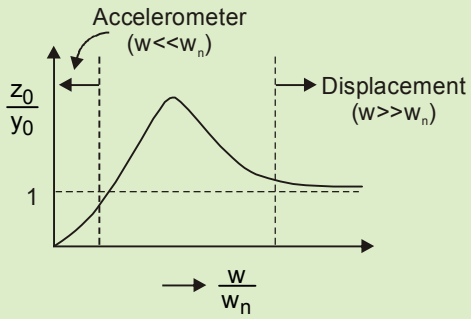
(b) stiff springs and light mass

(c) weak springs and light mass

(d) stiff springs and heavy mass

**Ans. (d)**

**Sol.**




Displacement Pickup. $(\omega >> \omega_n)$

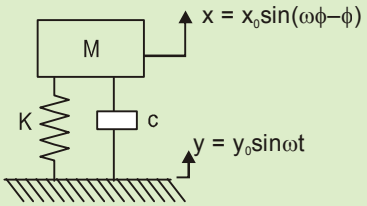
Means $\omega_a$ should be small

$$\omega_n = \sqrt{\frac{K}{M}}$$

$\therefore$ Increase m and decrease K.

$\Rightarrow$ work spring and heavy mass

System modling




$$m\ddot{x} = -c(\dot{x}-\dot{y}) - k(x-y)$$

$\Rightarrow m\ddot{z} + c\dot{z} + kz = -m\ddot{y}$ where $z = x-y$

$$\therefore \quad \frac{z_a}{y_0} = \frac{(\omega/\omega_n)^2}{\left[\left(1-\left(\frac{\omega}{\ln}\right)^2\right)^2 + \left(2\xi\frac{\omega}{\ln}\right)^2\right]^{1/2}}$$

If $\omega >> \omega_n \Rightarrow \frac{z_0}{y_0} \to 1;$

$\Rightarrow$ Displacement pickup $\omega << n\omega_n$

$\Rightarrow \frac{z_0}{y_0} \Rightarrow \left(\frac{\omega}{\omega_n}\right)^2 \Rightarrow$ Acceleration

**78.** What will be the velocity of piston movement for a single-acting hydraulic actuator, when the fluid pressure is 100 bar, the diameter of the piston is 50 mm and the flow rate is 0.3 $m^3$/min?

(a) 2.41 m/s (b) 2.55 m/s

(c) 2.67 m/s (d) 2.84 m/s

**Ans. (b)**

**Sol.** Discharge, $Q = \frac{ALN}{60}$

Also, displacement,

$x = r(1-\cos\theta)$ where, $r = \frac{1}{2}L$

Velocity, $v = \frac{dx}{dt} = \omega r \sin\theta$

$\therefore$ Time average velocity,

$$V = \frac{\omega r}{\pi} = \frac{\frac{2\pi N}{60}\cdot\frac{1}{2}}{\pi} = \frac{NL}{60}$$

Given: $Q = \frac{0.3}{60} = \frac{ALN}{60} \Rightarrow ALN = 0.3$

$A = \frac{\pi}{4}d^2 = \frac{\pi}{4}\times(0.05)^2 = 1.9635\ 10^{-6}$

$\Rightarrow$ LN = 152.78

$\Rightarrow$ $V = \frac{LN}{60} = 2.546$ m/s

**79.** A stepper motor is to be used to drive the linear axis of a certain mechatronics system. The motor output shaft is connected to a screw thread with a 30 mm pitch. Linear resolution of 0.5 mm is stipulated. What is the needed step angle ?

(a) 9° (b) 8°

(c) 7° (d) 6°

**Ans. (d)**

**Sol.** Step angle = $\frac{\text{Linear Resolution}}{\text{Pitch}}\times 360°$

$= \frac{0.5}{30}\times 360°$

$= 6°$

**80.** Consider the following statments regarding a stepper motor :

1. The rotation angle of the motor is proportional to the input pulse.

2. The motor has full torque at standstill

3. Speed and electric control signal of the motor vary mutually linearly.

Which of the above statement are correct?

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (d)**

**Sol.** Stepper motors are DC motors that moves is descrete steps. Unlike normal DC motors, if provides maximum torque of low speeds. Its rotational speed varies directly proportional to the frequency of the pulse.

**81.** The following table lists the tasks in a project and the time duration for each task :

| Task | Preceding | Normal duration |
|---|---|---|
| A | – | 16 |
| B | – | 20 |
| C | A | 8 |
| D | A | 10 |
| E | B,C | 6 |
| F | D,E | 12 |

The critical path, the project duration and the free float for activity A are, respectively.

(a) A-C-E-F; 42 weeks and 0 week

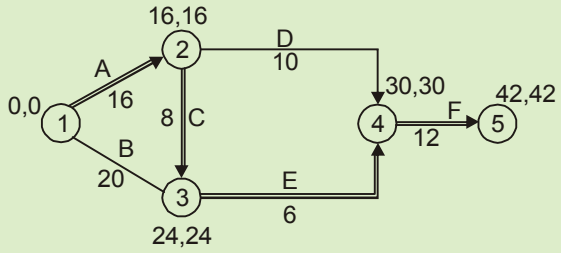
(b) B-E-F; 42 weeks and 1 week

(c) B-C-D-F; 50 weeks and 2 weeks

(d) A-C-E-F; 50 weeks and 0 week

**Ans. (a)**

**Sol.**




$$F_T = (16 - 0) - 16 = 0$$

**82.** Consider the following statements with reference to SCARA Robot :

1. It has four degrees of freedom

2. It has only one forward kinematic solution.

3. It has two inverse kinematic solutions.

Which of the above statements are correct?

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (d)**

**Sol.** **SCARA Robot:**

– 4 DoFS,

– 1 Forward kinematic solution (for given joints rotation, unique end-effector (EE)

– 2 Inverse kinematic solution (For given EE configuration, two sets of solution exist).

**83.** Consider the following statements regarding the law of Robotics :

1. A Robot shall not injure a human being or through inaction allow a human being harmed.

2. A Robot must obey orders given by humans except when such orders conflict with first law.

3. A Robot must always protect its own existence.

Which of the above statements are correct?

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (a)**

**Sol.** Statement (1) is It should be

A robot shall not injure a human being or, through in action, allow a human being harmed.

Statement (2) is right.

Statement (3) Should be - A Robot must always protect its own existance as long as such protection does not conflict with the first and second law of Robotics

**84.** The number of degrees of freedom in a 3D Robot of TRL : R type configuration is :

(a) 4 (b) 3

(c) 2 (d) **1**

**Ans. (a)**

**85.** Which of the following are the basic differences between vibration signature and noise signature?

1. Vibration signature is essentially in the frequency range zero to 100 cps whereas noise signature is in the range 20 cps to 3000 cps.

2. Vibration signature has welldefined peaks whereas the noise signal is smeared.

3. The intensities of noise signatures are much less than that of vibration signatures.

4. Detection of vibration signature calls for a microphone whereas that of noise can do with a pickup.

Select the correct answer using the code given below:

(a) 1 and 4 (b) 2 and 3

(c) 1 and 2 (d) 3 and 4

**Ans. (b)**

**Sol.** Vibration signature range might go beyond 100 Hz and may be even more than 20,000 Hz.

Vibration signature $\rightarrow$ Acceleration (Pick-up)

Noise $\rightarrow$ microphone

**86.** Consider the following features relating to Robot kinematics with reference to SCARA Robot :

1. Shoulder and elbow rotational axes are vertical.

2. The Robot could perform insertion tasks along the vertical direction.

3. Its general configuration is analogous to that of a human arm.

Which of the above features are correct?

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (d)**

**Sol.** Revolute joints of shoulder and elbow rotational axes are vertical.

**87.** A flywheel fitted to a steam engine has a mass of 500 kg and radius of gyration 300 mm. The starting torque is 900 N m. What is the kinetic energy after 10 s ?

(a) 225 kJ (b) 450 kJ

(c) 900 kJ (d) 1800 kJ

**Ans. (c)**

**Sol.** $I = mk^2 = 500 \times (0.3)^2 = 45 \text{ kg-m}^2$

Angular acce. $\alpha = \frac{T}{I} = \frac{900}{45} = 20 \text{ rad/s}^2$

$\therefore \quad \omega = \alpha t = 20 \times 10 = 200 \text{ rad/s}$

$KE = \frac{1}{2} I\omega^2 = \frac{1}{2} \times 45 \times (200)^2 = 900 \text{ kJ}$

**88.** In a counterflow heat exchanger, hot gases enter at 250°C and leave at 100°C. Atmospheric air enters at 50°C and leaves at 80°C. The effectiveness of the heat exchanger will be :

(a) 0.20 (b) 0.25

(c) 0.30 (d) 0.35

**Ans. (*)**

**Sol.** $T_{h1} - T_{h2} = 250 - 100 = 150$

& $T_{c2} - T_{c1} = 80 - 50 = 30$

So, $C_h < C_c$

So, $\in = \frac{T_{h1} - T_{h2}}{T_{h1} - T_{C_1}} = \frac{250 - 100}{250 - 50}$

$= \frac{150}{200} = 0.75$

**89.** Two air streams with mass flow rates of 36 kg/min and 14 kg/min with respective enthalpies of 36 kJ/kg da and 50 kJ/kg da are mixed. The enthalpy of the mixture is nearly

(a) 64 kJ/kg da (b) 55 kJ/kg da

(c) 46 kJ/kg da (d) 40 kJ/kg da

**Ans. (d)**

**Sol.** $h = \frac{m_1 h_1 + m_2 h_2}{m_1 + m_2}$

$= \frac{36 \times 36 + 14 \times 50}{36 + 14} = 39.92 = 40$

**90.** Consider the following statements in respect of maximum efficiency of a two-stage reciprocating compressor :

1. The pressure ratios are same for each stage.

2. The work done is same in each stage.

3. The intercooling is perfect.

Which of the above statements are correct?

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (d)**

**Sol.** $r_p$ = pressure ratio for each stage of compress for maximum efficiency

$$= \left(\frac{P_{max}}{P_{min}}\right)^{1/2}$$

Work done in each stage will be same

as $w = f\left(\frac{P_{max}}{P_{min}}\right)$

- By perfect inter cooling we will achieve the isothermal compression which required the last work the efficiency will improve.

**91.** Consider the following statements :

The presence of air inside condensers

1. remains as a non-condensable gas
2. reduces the condensing coefficient
3. tends to cling to the surface
4. introduces large thermal resistance

Which of the above statements are correct?

(a) 1, 2 3 and 4 (b) 1, 2 and 3 only

(c) 3 and 4 only (d) 1, 2 and 4 only

**Ans. (a)**

**Sol.**

- The performance of condenser due to presence of air (which will remain non considerable) gets affected badly.
- It blanket the heat transfer surfaces such as outside the surface of condenser tubes which reduces the considering heat transfer co-efficient.
- By this total pressure $P_s + \rho_{air}$ get increase which increase the condeser pressure
- As air tend to cling the surface which reduces the condesing co-efficient.
- Because of low thermal conductivity of air, air imparts large thermal resistance,

**92.** The refrigeration system of an ice plant working between temperatures of –5°C and 25°C produces 20 kg of ice per minute from water at 20°C. The specific heat of water is 4.2 kJ/kg and latent heat of ice is 335 kJ/kg. The refrigeration capacity of the refrigeration plant is

(a) 9040 kJ/min (b) 8750 kJ/min

(c) 8380 kJ/min (d) 8010 kJ/min

**Ans. (c)**

**Sol.** Heat required to form the ice from 20°

$= 20 \times 4.2 \times 20 + 20 \times 335$

$= 8380$ kJ/min = Refrigeration Capacity of plant.

**93.** Consider the following statements in respect of a vapour-absorption refrigration cycle :

1. The absorption refrigeration cycle is generally used when waste heat is avilable from an existing source or when free energy like solar energy is to be used.

2. There are no moving parts in the absortpion refrigeration plant except a small liquid pump.

3. The value of the coefficient of performance is nearly the same in both vapour-absorption and vapour- compression refrigeration plants.

Which of the above statements are correct?

(a) 1, 2 and 3 (b) 1 and 2 only

(c) 1 and 3 only (d) 2 and 3 only

**Ans. (b)**

**Sol.** The vapour absorption system in place of compressor absorber equipments (Generator, absorber small pump) are used which replaces the moving part.

- In this system strong solution in generater is heated by same external sources, these external source can be waste heat (e.g. steam in hospital is waste) or free energy like solar energy is available.
- The COP of absorption system is about 20 to 30% of the vapour compression system.

**94.** Air at 30°C and 1 bar has a specific humidity of 0.016 kg/kg of dry air. By considering the saturation pressure of water vapour at 30°C as 4.246 kPa, the relative humidity of th air will be

(a) 66.1% (b) 60.2%

(c) 58.8% (d) **56.8%**

**Ans. (c)**

**Sol.** $\omega = \dfrac{0.622P_v}{P_b - P_v}$

$$0.016 = \frac{0.622 \times P_v}{1 - P_v}$$

$$\text{or} \quad \frac{1 - P\nu}{P\nu} = \frac{0.622}{0.016} = 38.875$$

$$\text{or} \quad P\nu = \frac{1}{39.875} = 0.0250\,\text{bar}$$

2.5 kρa

$$Q = \frac{P_v}{P_S} = \frac{2.5}{4.246} = 58.8\%$$

**95.** Consider the following statements in respect of an evaporative cooling process :

1. The wet-bulb temperature remains constant.

2. The dew-point temperature remains constant.

3. The enthalpy remains constant.

Which of the above statements are correct?

(a) 1, 2 and 3

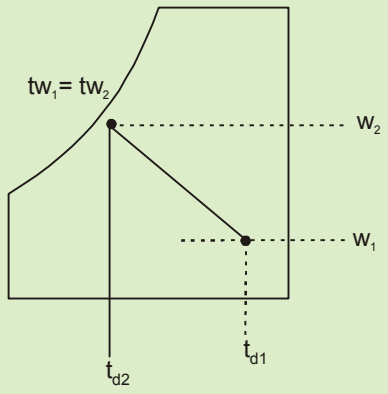
(b) 1 and 2 only

(c) 2 and 3 only

(d) 1 and 3 only

**Ans. (d)**

**Sol.** In evaporative cooling process wetbulb temp and enthalpy remain constant.



$h_2 = h_1 + (w_L - w_1)hfw$

$(w_2 - w_1)hfw$ is very small

So, $h_2 = h_1$

**96.** For a steady process, the conditions at stage 1 and stage 2 are , respectively, $h_1 = 300$ kJ/Kg, $h_2 = 150$ kJ/kg, $S_1 = 1.25$ kJ/kg K and $S_2 = 0.8$ kJ/kg K. The 'availability' at the ambient temperature 300 K will be :

(a) 15 kJ (b) 20 kJ

(c) 25 kJ (d) 35 kJ

**Ans. (a)**

**Sol.** Availability $= h_1 - h_0 - T_0(S_1 - S_2)$

$= 300 - 150 - 300(1.25 - 0.8)$

$= 150 - 300 \times 0.45$

$= 15$ kg

**97.** If the maximum pressure in both air standard Otto and diesel cycles is the same, then the relations for compression ratio r and the efficiency $\eta$ between the two cycles are :

(a) $r_{Diesel} > r_{Otto}$ and $\eta_{Diesel} > \eta_{Otto}$

(b) $r_{Otto} > r_{Diesel}$ and $\eta_{Diesel} > \eta_{Otto}$

(c) $r_{Diesel} > r_{Otto}$ and $\eta_{Otto} > \eta_{Diesel}$

(d) $r_{Otto} > r_{Diesel}$ and $\eta_{Otto} > \eta_{Diesel}$

**Ans. (a)**

**Sol.**

Note: only in one case where efficiency of otto cycle is more than and in disel cycle is same compression ratio rest of the cases efficiency of disel cycle is always greater than otto cycle.

In this case by considering same maximum pressure and heat input or same maximum pressure and work output or same peak pressure, peak temp. and peak rejection compression ratio and efficiency of disel cycle is more than otto cycle.

**98.** Which of the following statements are correct?

1. The specific speed of a turbine is the speed at which a homologous turbine develops 1 mhp under unit heat at its maximum efficiency.

2. The specific speed is a dimensionless parameter used for the selection of turbines.

3.The function of guide vanes in reaction turbines is to minimize shock at entry of the fluid onto the runner blades.

Select the correct answer using the code given below :

(a) 1, 2 and 3 (b) 2 and 3 only

(c) 1 and 2 only (d) 1 and 3 only

**Ans. (a)**

**Sol.** The specific speed may be dimensional or non-dimensional and is an important parameter in turbine selection.

**99.** A centrifugal pump lifts $0.0125 m^3/s$ of water from a well with a static lift of 30 m. If the brake power of the driving electric motor is 5 kW, what is the overall efficiency of the pump-set ?

(a) 57.6% (b) 63.9%

(c) 65.3% (d) 73.6%

**Ans. (d)**

**Sol.** $Q = 0.0125 m^3/s$

$H = 30$ m

$P = \gamma QH = 9.8 \times 0.0125 \times 30$ kW

$= 3.6$ kW

$\eta = \frac{3.675}{5} = 0.735$

$\Rightarrow \quad \eta = 73.5\%$

**100.** Two rods, one of length $l$ and the other of length $2l$, are made of the same material and have same diameter. Both ends of the longer rod are maintained at 100°C. One end of the shorter rod is maintained at 100°C while the other end is insulated. Both rods are exposed to the same environment at 40°C. The temperature at the insulated end is measaured to be 55°C The temperature at the midpoint of the longer rod would be :

(a) 45°C (b) 50°C

(c) 55°C (d) 60°C

**Ans. (c)**

For insulated rod, (shorter rod)

$Q_{convection} = Q_{radiation}$

or, $hA\Delta\theta = \frac{KA\Delta\theta'}{L}$ ...(i)

For longer rod at mid point,

$Q_{convection} = Q_{conduction}$

$hA\Delta\theta = \frac{KA\Delta\theta'}{L}$ ...(ii)

Both equation (i) and (ii) are same so, temp. at midpoint of rod = 55°C

**101.** Consider the following statements in repsect of ideal and practical gas turbine cycles :

1. In the ideal cycle case, the cycle efficiency depends on the pressure ratio only.

2. In the practical cycle case (with irreversibilities in the compression and expansion processes), The cycle efficiency depends on the maximum temperature as well as on the pressure ratio.

3. In the practical cycle case, at a given maximum temperature, the maximum efficiency and the maximum work done occur at a same pressure ratio.

Which of the above statements are correct ?

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (a)**

**Sol.**

- The efficiency of ideal gas turbine cycle depends on the pressure ratio,

$$\eta = 1 - \frac{1}{r^{\gamma-1}}$$

- The practical cycle, the efficiency of turbine and compression came in picture due to irreversibilities so final efficiency depend not only pressure ratio but also maximum temp.
- The maximum work done and efficiency of the gas turbine is given at temp. ratio

$$t_{min} = \frac{r^{\frac{\gamma-1}{\gamma}}}{\eta_t + \eta_c}$$

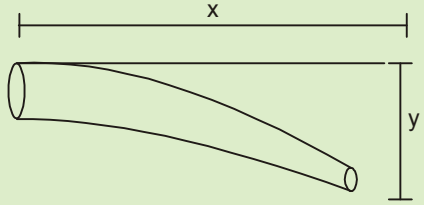
Here $T_{03}$ = maximum temp. of cycle.
if $T_{03}$ is fixed, then
r = pressure ratio will also fixed only variation may happen in $\eta_t$ and $\eta_c$

**102.** A jet of water issues from a sharp-edged vertical orifice under a constant heat of 0.51 m. At a certain point of the issuing jet, the horizontal and vertical coordinates measured from vena contracta are 0.406 m and 0.085 m, respectively. What is the value of the coefficient of velocity ?

(a) 0.975 (b) 0.925
(c) 0.875 (d) 0.825

**Ans. (d)**

**Sol.**




$$x = vt \qquad ...(i)$$

$$y = \frac{1}{z}gt^2 \qquad ...(ii)$$

$$\Rightarrow \quad v = \sqrt{\frac{gx^2}{2y}}$$

$$V_{th} = \sqrt{2gh}$$

$$C_v = \frac{v}{V_{th}} = \sqrt{\frac{x^2}{4yh}} = \sqrt{\frac{0.406^2}{4 \times 0.085 \times 0.51}}$$

$$= 0.975$$

**103.** In the working of a vapour-compression refrigeration plant, the following enthalpies are recorded at salient points in the cycle :

1. Enthalpy at inlet to compressor (saturated vapour), $h_1 = 300\ kJ/kg$.

2. Enthalpy at outlet of compressor (after isentropic compression), $h_2 = 330\ kJ/kg$

3. Enthalpy at exit of condenser (saturated liquid), $h_3 = 150\ kJ/kg$.

What is the COP of the plant ?

(a) 3 (b) 4
(c) 5 (d) **6**

**Ans. (c)**

**Sol.** $W_{input} = h_2 - h_1 = 330 - 300 = 30$

$$RE = h_7 - h_3 = 300 - 150 = 150$$

So, $C_{OP} = \frac{RE}{W_{input}} = \frac{150}{30} = 5$

**104.** Consider the following statements for single-stage reciprocating compressors :

1. Isothermal process is the most desirable process for compression.

2. The size of clearance volume provided in the compressor has no effect on work done per kg of air delivered.

3. The volumetric efficiency of the compressor decreases with increasing pressure.

Which of the above statements are correct?

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (d)**

**Sol.** As work input for isothermal process is minimum. then for polytropic then for adiabatic. so isothermal process is desirable proces of compression.

$$\eta_{vol} = 1 + c - c\left(\frac{P_2}{P_1}\right)^{1/n}$$

By increase in pressure ratio volumetric efficiency will decrease in compressor. So, statement 3 is correct.

**105.** Consider the following statements in respect of regenerative Rankine cycle :

1. Regeneration increases the efficiency of the cycle.

2. The boiler capacity is increased for a given output.

3. The capacity of the condenser is reduced.

Which of the above statements are correct?

(a) 1, 2 and 3 (b) 1 and 2 only

(c) 1 and 3 only (d) 2 and 3 only

**Ans. (a)**

**Sol.** Regeneration increases the mean temperature of heat addition of rankine cycle, hence the efficiency of cycle.

Due to extraction of bledoff steam in every stage, less amount of steam will condensed in condenser so, it reduced the condenser capacity (size of condenser).

The major disadvantage of regenerative cycle is requirement of larger boiler capacity for a given power.

**106.** Consider the following statements in respect of $(l)$ the temperature of the medium, $(m)$ the refrigerant and $(n)$ the condenser and absorption system-in a refrigeration unit :

1. Temperature of the medium being cooled must be below that of the evaporator.

2. Refrigerant leaves the condenser as liquid.

3. Any solar thermally operated absorption system is capable only of intermittent operation.

Which of the above statements are correct ?

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (c)**

**Sol.** In absorption system the temperature of medium being cooled is more than the evoporater temperature.

In this system refrigerant leaves the condenser as liquid.

Solar thermally operated system can be used for intermittent operation because of the availability of absorber source.

**107.** Volumetric analysis of a certain flue gas gave $CO_2$ 15%, $O_2$ 5% and rest as $N_2$. The gas was at a temperature of 200°C and a pressure of 5 bar. The partial pressure of $N_2$ in the flue gas is

(a) $250\ kN/m^2$ (b) $300\ kN/m^2$

(c) $350\ kN/m^2$ (d) $400\ kN/m^2$

**Ans. (d)**

**Sol.** let 1 mole of gas is there

mole of nitrogen will be = $1-0.15-0.05$

= 0.8 mole

So, Partial pressure of nitrogen will be

= $P_{total} \times$ mole of nitrogen

= $5 \times 0.8 = 4\ bar = 400\ KN/m^2$

**108.** Consider the following statements :

1. The efficiency of heat transfer in a condenser will improve by increase of the overall heat transfer coefficient.

2. The efficiency of heat transfer in a condenser will improve by increase of the velocity of flow of water in the tube.

3. The difference between the temperature of steam entering the condenser and the inlet water temperature should be maximum for maximum efficiency.

Which of the above statements are correct?

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (d)**

**Sol.** $Q = U_0 A_0 \Delta T_m$

$Q \propto U_0$

So, rate of heat transfer is increased by increasing the overall heat transfer co-efficient.

Also, $Q = m_s(h_{steam} - h_{condensate})$

$= m_c cp_c(T_{cq} - T_{Ci})$

Where $m_c$ = mass flow rate of water

$m_c = \rho_{AV}$

V = Flow rate

$h_{steam} - h_{condensate} \propto T_s - T_c$

**109.** The total power developed by a three stage velocity compounded impulse steam turbine is 900 kW. The power magnitudes developed in the first and the second stages are, respectively

(a) 500 kW and 300 kW

(b) 100 kW and 300 kW

(c) 500 kW and 100 kW

(d) 100 kW and 100 kW

**Ans. (a)**

**Sol.** Power output ratio in velocity compounded 3 stage turbine is 5:3:1.

So, Work put in first stage

$$= 900 \times \frac{5}{5+3+1} = 500 \text{ kW}$$

Work out put in 2nd stage

$$= 900 \times \frac{3}{5+3+1} = 300 \text{ kW}$$

**110.** Consider the following statements in respect of natural-draft cooling towers :

1. Theoretically the water can be cooled to even below the dry-bulb temperature of the induced air flow.

2. Natural draft cooling towers are 100 m or more in height.

3. The inner and outer surfaces are surfaces of revolution of a segment of a hyperbola about the vertical axis-affording improved strength rather than any thermodynamic augmentation.

Which of the above statements are correct?

(a) 1, 2 and 3 (b) 1 and 2 only

(c) 1 and 3 only (d) 2 and 3 only

**Ans. (d)**

**Sol.** Cooling towers vary in size from small roof-top units to very large Hyperboloid structure that can be upto 200 meters tall 100m in diameter or rectangular structure that can be over 40m tall and 80 m. The Hyperboloid structure of cooling tower is mainly associated with strength not with thermodynamic Augumentation. This used in Nuclear plant where height of tower requirement is more due to safety.

In Natural draft cooling tower there is no uses of fan. Because of it these are very tall. So, statement 1 is wrong.

**111.** Consider the following statements :

1. Wind velocity at about 20 m height above the ground is taken as the rated velocity for design of windmills.

2. The total power of a wind stream is directly proportional to the cube of average velocity.

3. Wind turbine operates with variable load over a narrow range between cut-in and cut-out velocities.

4. Vertical wind machine operates in all wind directions, but it needs yaw adjustment.

Which of the above statements are correct?

(a) 1 and 2 (b) 1 and 4

(c) 3 and 4 (d) 2 and 3

**Ans. (d)**

**Sol.** • The total power of wind stream in wind turbine is given by

$$P = \frac{1}{2}c_p \rho A V^3$$

where P = Power

$C_p$ = Power co-efficient

$\rho$ = air density

A = swept area of turbine

V = Wind speed

Wind turbines operate from cut in speed 3 to 4m/sec to cut-out speed around 25m/sec which is a narrow range of speed.

Vertical wind machines are omni-directional do not require complex mechanism and motors to yaw the rotor and pitch the blades. So, we can say statement '4' is wrong.

Only 2 and 3 are correct.

**112.** Which fuel cell is suitable for spacecraft applications ?

(a) Direct methanol fuel cell

(b) Proton exchange membrane fuel cell

(c) Alkaline fuel cell

(d) Phosphoric acid fuel cell

**Ans. (c)**

**Sol.** • Proton exchange membrane fuel cell is under process of application so, we can not say directly it can be suitable for space craft.

• Direct methonal fuel cell is a type of proton exchange membrane fuel cell.

• Alkaline fuel cell has been used in Appolo space craft and it is also termed as Bacon fuel cell.

**113.** A flywheel on a motor speeds up from rest to 1000 r.p.m. in 6 seconds. the number of revolutions made thereby is nearly :

(a) 200 (b) 100

(c) 50 (d) 20

**Ans. (c)**

**Sol.** $\omega = \omega_0 + \alpha t$

$$\Rightarrow \quad \frac{1000}{60} = 0 + \alpha \times 6$$

$$\Rightarrow \quad \alpha = \frac{1000}{60 \times 6}$$

$$\theta = \theta_0 + \frac{1}{2}\alpha t^2$$

$$= 0 + \frac{1}{2} \times \frac{1000}{60 \times 6} \times (6)^2$$

= 50 rotations

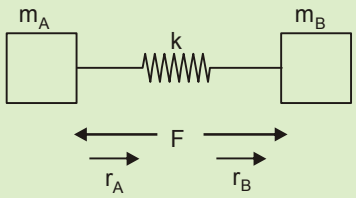
**114.** Two steel balls of 2 kg and 4 kg mass, respectively are pressed on the two ends of a spring, all pre-placed on a smooth surface. When released, the smaller ball moves with an acceleration of $2 m/s^2$. The simultaneous acceleration of the bigger ball will be :

(a) $0.5\ m/s^2$ (b) $1\ m/s^2$

(c) $2\ m/s^2$ (d) $4\ m/s^2$

**Ans. (b)**

**Sol.** Here, $\vec{F}_{ext.} = \frac{d\vec{p}}{dt}$




C = centre of mass

$\vec{M}_A \vec{r}_A + M_B \vec{r}_B = 0$

$M_A \vec{V}_A + M_B \vec{V}_B = 0$

$M_A \vec{a}_A + M_B \vec{a}_B = 0$

$\therefore$ Acceleration of bigger mass, $a_B = \frac{2\times 2}{4} = 1\ m/s^2$.

**115.** A bullet of mass 0.03 kg moving with a speed of 400 m/s penetrates 12 cm into a fixed block of wood. The average force exerted by the wood on the bullet will be :

(a) 30 kN (b) 20 kN

(c) 15 kN (d) 10 kN

**Ans. (b)**

**Sol.** $V^2 = u^2 + 2as$

$\Rightarrow \quad a = \frac{0-(400)^2}{2\times 0.12}$

$= 666.67 \times 10^3\ m/s^2$

$v = u + at$

$\therefore \quad t = -\frac{u}{a} = \frac{400}{666.67\times 10^3}$

$= 0.6 \times 10^{-3}$ sec

Average force $= \frac{\Delta P}{\Delta t} = \frac{mv-0}{\Delta t}$

$= \frac{0.03\times 400}{0.6\times 10^{-3}} N$

$= 20$ kN

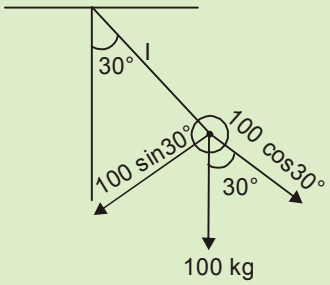
**116.** A ball of weight 100 N is tied to a smooth wall by a cord making an angle of 30° to the wall. The tension is the cord is :

(a) 200 N (b) $\frac{200}{\sqrt{3}} N$

(c) 100 N (d) $50\sqrt{3} N$

**Ans. (d)**

**Sol.** FBD of system is as follow :




at equilibrium

$T = 100 \cos 30°$

$T = 100 \times \frac{\sqrt{3}}{2}$

$= 50\frac{\sqrt{3}}{2}$

**117.** The modulus of rigidity of an elastic material is found to be 38.5% of tghe value of its Young's modulus. The poisson's ratio $\mu$ of the material is nearly :

(a) 0.28 (b) 0.30

(c) 0.33 (d) 0.35

**Ans. (b)**

**Sol.** $G = \frac{E}{2(1+\gamma)}$

$\Rightarrow \quad \frac{G}{E} = \frac{1}{2(1+\gamma)} = 0.385$

$\Rightarrow \quad 1+\gamma = \frac{1}{2\times 0.385}$

$\Rightarrow \quad \gamma = 0.298$

**118.** A bar produces a lateral strain of magnitude $60\times10^{-5}$ mm when subjected to a tensile stress of magnitude 300 MPa along the axial direction. What is the elastic modulus of the material if the poisson's ratio is 0.3?

(a) 200 GPa (b) 150 GPa

(c) 125 GPa (d) 100 Gpa

**Ans. (b)**

**Sol.** Lateral strain = Axail strain × $\gamma$

$\therefore$ Axial, $E_x = \frac{60\times10^{-5}}{0.3} = 200\times10^{-5}$

$\sigma_x = 300$ MPa

$E = \frac{\sigma_x}{E_x} = \frac{300\times10^6}{200\times10^{-5}}$

$= 150$ GPa

**119.** In the design of beams for a given strength, consider that the conditions of economy of use of the material would avail as follows :

1.Rectangular cross-section is more economical than square section area of the beam.

2. Circular section is more economical than square section.

3. I-section is more economical than a rectangular section of the same depth.

Which of the above are correct ?

(a) 1, 2 and 3 (b) 1 and 2 only

(c) 2 and 3 only (d) 1 and 3 only

**Ans. (d)**

**Sol.** Sectional modulus (z) ↑ ⇒ more economical.

$$\sigma = \frac{My}{I} = \frac{M}{(I/Y)} = \frac{M}{Z}$$

$$\Rightarrow \quad Z\uparrow = 6\downarrow$$

$$Z_{\square} > Z_{\bigcirc}$$

**120.** Which one of the following statements is correct?

(a) The strain produced per unit volume is called resilience.

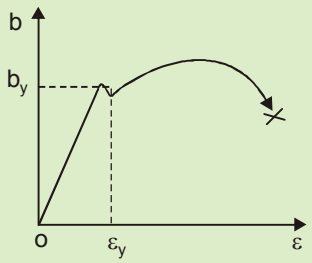
(b) The maximum strain produced per unit volume is called proof resilience.

(c) The least strain energy stored in a unit volume volume is called proof resilience.

(d) The greatest strain energy stores in a unit volume of a material without permanent deformation is called proof resilience.

**Ans. (d)**

**Sol.** Definition of Resilience




**121.** A beam of rectangular section (12 cm wide × 20 cm deep) is simply supported over a span of 12 m. It is acted upon by a concentrated load of 80 kN at the midspan. The maximum bending stress induced is :

(a) 400 MPa (b) 300 MPa

(c) 200 MPa (d) 100 MPa

**Ans. (b)**

**Sol.**
$$I = \frac{6\times 3}{12} = \frac{12\times(20)^3}{12}\text{cm}^4$$

$$= 8 \times 10^3 \text{ cm}^4$$

Span, $L = 12\text{m}$

Load, $P = 80$ kN

$$M_{max} = \frac{PL}{4} = 240 \text{ kNm}$$

$$\sigma = \frac{My}{I} = \frac{240\times10^3\times0.1}{8\times10^{-5}}$$

$$= 300 \text{ Mpa}$$

**122.** A uniform bar, simply supported at the ends, carries a concentrated load P at mid-span. If the same load be, alternatively, uniformly

distributed over the full length of the bar, the maximum deflection of the bar will decrease by

(a) 25.5% (b) 31.5%

(c) 37.5% (d) 50.0%

**Ans. (c)**

**Sol.** $\delta_{concentrated} = \frac{PL^3}{48EI}$

$$\delta_{uniformly} = \frac{5\omega L^4}{384EI} = \frac{5PL^3}{284EI} \quad (P = \omega L)$$

$$\therefore \text{ \% decrement in } \delta = \frac{\left(\frac{1}{48} - \frac{5}{384}\right)}{\left(\frac{1}{48}\right)}$$

$$= 37.5\%$$

**123.** A thin cylindrical pressure vessel and a thin spherical pressure vessel have the same mean radius, same wall thickness and are subjected to same internal pressure. The hoop stresses set up in these vessels cylinder in relation to sphere) will be in the ratio

(a) 1 : 2 (b) 1: 1

(c) 2 : 1 (d) **4 : 1**

**Ans. (c)**

**Sol.** $\frac{\sigma_{hoop/cylinder}}{\sigma_{hoop/sphere}} = \frac{\frac{Pd}{2t}}{\frac{Pd}{1t}} = 2 : 1$

**124.** A boy walks up a stalled escalator in 90 seconds. When the same escalator moves, he is carried up in 60 seconds. How much time would it take him to walk up the moving escalator?

(a) 48 seconds (b) 36 seconds

(c) 30 seconds (d) 24 seconds

**Ans. (b)**

**Sol.** Let '$\ell$' be length of escalator,

Velocity, $v_b = \frac{1}{90}$

$$v_{escable} = \frac{\ell}{60}$$

If both starts moving,

$$\text{Time} = \frac{\ell}{\left(\frac{\ell}{90} + \frac{\ell}{60}\right)}$$

$$= 36 \text{ sec}$$

**125.** A 10 mm diameter bar of mild steel of elastic modulus $200 \times 10^9$ Pa is subjected to a tensile load of 50000 N, taking it just beyond its yield point. The elastic recovery of strain that would occur upon removal of tensile load will be

(a) $1.38 \times 10^{-3}$ (b) $2.68 \times 10^{-3}$

(c) $3.18 \times 10^{-3}$ (d) $4.62 \times 10^{-3}$

**Ans. (c)**

**Sol.** $d = 10\ mm$

$E = 200\ GPa$

$P = 5000\ N$

Stress, $\sigma = \frac{P}{A} = \frac{4P}{\pi d^2} = 636.62\ MPa$

$E = \frac{\sigma}{E} = 3.18 \times 10^{-3}$

**126.** On completion of heat treatment, the austenite structure would be retained if :

(a) the rate of cooling is greater than the critical cooling rate

(b) the rate of cooling is less than the critical cooling rate

(c) the initiating temperatrue of martensite formation is above the room temperature

(d) the finishing temperature of martensite formation is below the room temperature

**Ans. (d)**

**Sol.** When the finishing temperature of martensite ($M_f$) is below the room temperature then we get the retained austenite.

The martensite start ($M_s$) and martensite finish ($M_f$) temperature are related and these temperatures are controlled by various alloying element including carbon and chromium.

**Note:** Higher carbon reduces the Ms and $M_f$ temperature, until the $M_f$ temperature can be lower than room temperature.

**127.** Which of the following statements is correct ?

(a) Iron-carbon and TTT diagrams are both equilibrium diagrams.

(b) Iron-carbon and TTT diagrams are both non-equilibrium diagrams.

(c) Iron-carbon diagram is an equilibrium diagram but TTT diagram is a non-equilibrium diagram

(d) Iron carbon diagram is a non-equilibrium diagram but TTT diagram is an equilibrium diagram.

**Ans. (c)**

**Sol.** Iron carbon diagram is a equilibrium phase diagram but does not show time as a variable and hence the effects of different cooling rates on steel does not revealed. Moreover, equilibrium conditions are not maintained in heat treatment. Although, the iron-carbon equilibrium diagram reveals on the phases and corresponnding microstructure under equilibrium conditions but several useful properties of steel can be obtained under non-equilibrium conditions e.g. variable rates of cooling as produced during quenching and better transformation of austenite into pearlite and martensite.

**128.** The correct order of increasing resistivity among the following materials is :

(a) nickel, doped silicon, sodium silicate, pure silica

(b) doped silicon, nickel, pure silica, sodium silicate

(c) Nickel, pure silica, sodium silicate, doped silicon

(d) Sodium silicate, nickel, pure silica, doped silicon

**Ans. (a)**

**Sol.** Nickel is a metal so it will have higher electrical conductivity because of valence electrons free movement in solid.

Due to dopping 'Si' become a extrinsic semiconductor which have higher conductivity than intrinsic semiconductor.

Sodium silicate is a partial conductor of electricity due to presence of sodium ion and silicate ion.

Pure silica is piezoelectric material which have lower electrical conductivity than sodiumsilicate

**Note:** Resistivity is opposite of conductivity.

**129.** Consider the following statements :

On heating an elastomer under tensile load, its shrinkage

1. maximizes the enthalpy
2. maximizes the entropy
3. minimizes the free energy
4. avoids breaking

Which of the above statements are correct ?

(a) 1 and 2 (b) 2 and 3

(c) 3 and 4 (d) 1 and 4

**Ans. (b)**

**Sol.** In heating elostomere under tensile load entropy get decrease because of only one possible microstate but by shrinkage entropy get increased because of many possible microstates.

By Helmhottz free energy equation free energy is given by

$$A = U - Ts$$

where U = internal energy

T = temp.

S = entropy

So, By increase in entropy free energy get reduced,

So, option 2 and 3 are true

**130.** Which of the following properties will be the meaningful indicator/indicators of uniform rate of elongation of a test piece of a structural material before necking happens in the test piece ?

1. Ductility
2. Toughness
3. Hardness

Select the correct answer using the code given below :

(a) 1 only (b) 2 only

(c) 3 only (d) 1, 2 and 3

**Ans. (b)**

**Sol.** Toughness is ability of a material to absorb energy and plastically deform without fracture. It can also defined as the amount of energy per unit volume that a material can absorb before rupturing.

**131.** Which one of the following alloying elements increases the corrosion resistance of steel?

(a) Vanadium (b) Chromium
(c) Nickel (d) Copper

**Ans. (b)**

**Sol.** Chromium is the main constituent responsible for increasing the corosion resistant of steel and because of it stainless steel in industry frequently termed as high chrome low chrome steel.

e.g. SS304, SS91b, etc.

If chromium percentage in steel is more than 10.5% then only steel is termed as corrosion resistant or stainless steel.

**132.** Which of the following mechanisms are examples of forced closed kinematic pairs?

1. Cam and roller mechanism
2. Door-closing mechanism
3. Slider-crank mechanism

Select the correct answer using the code given below.

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (a)**

**Sol.** Slider-crank mechanism is not forced - closed mechanism.

**133.** A planer mechanism has 10 links and 12 rotary joints. Using Grubler's criterion, the number of degrees of freedom of the mechanism is

(a) 1 (b) 3
(c) 2 (d) 4

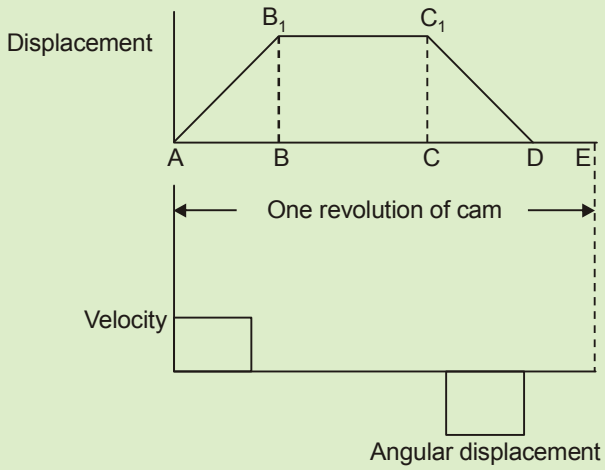
**Ans. (b)**

**Sol.** $\text{dof} = 3(n-1) - 2J - h - Fr$

$= 3(10-1) - 2 \times 12 - 0 - 0$

$= 3$

**134.** The displacement and velocity diagrams of a cam and follower mechanism are shown:




Which of the following statements is/are correct?

1. The acceleration of the follower at the beginning and at the end of each stroke will be zero.
2. The follower remains at rest in the dwell period.
3. During period DE, the motion of the follower is retarding.

Select the correct answer using the code given below.

(a) 1, 2 and 3 (b) 1 only
(c) 2 only (d) 3 only

**Ans. (c)**

**Sol.** Acceleration of follower of beginning is infinite not zero.

**135.** The number of instantaneous centres of rotation in a slider-crank quick return mechanism is

(a) 10 (b) 8

(c) 6 (d) 4

**Ans. (c)**

**Sol.** No of instantaneous centre,

$$= \eta_{c_2} = 4_{c_2} = \frac{4\times 3}{2} = 6$$

**136.** A simple spring-mass vibrating system has a natural frequency of N. If the spring stiffness is halved and the mass doubled, then the natural frequency will be

(a) 0.5 N (b) N

(c) 2N (d) 4N

**Ans. (a)**

**Sol.** $$\omega' = \sqrt{\frac{K'}{M'}} = \sqrt{\left(\frac{K}{2}\right)/2m}$$

$$= \frac{1}{2}\sqrt{\frac{K}{M}} = 0.5 \text{ N}$$

**137.** A car of mass 1450 kg is constructed on a chassis supported by four springs. Each spring has a force constant of 40000 N/m. The combined mass of the two people occupying the car is 150 kg. What is the period of execution of two complete vibrations?

(a) 0.63 s (b) 1.59 s

(c) 4.96 s (d) 1.26 s

**Ans. (d)**

**Sol.** $$\omega_n = \sqrt{\frac{K}{M}} = \sqrt{\frac{4\times 40000}{1450+150}}$$

$$= 10 \text{ rad/s}$$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{10}$$

$$= 0.628 \text{ SEC}$$

$\therefore$ Time for two complete vibrations = 2T = 1.256 sec

**138.** Consider the following statements:

Arterfacts to prevent harmful effects resulting from vibrations of an unbalanced machine fixed on its foundation include

1. mounting the machine on springs thereby minimizing the transmission of forces
2. using vibration isolating materials to prevent or reduce the transmission of forces
3. moving the foundation so as to have only degree of freedom towards reducing the transmission of forces

Which of the above statements are correct?

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (d)**

**139.** Two heavy rotors are mounted on a single shaft. Considering each of the rotors separately, the transverse natural frequencies are 100 cycles/s and 200 cycles/s, respectively. The lower critical speed will be

(a) 12000 r.p.m. (b) 9360 r.p.m.

(c) 8465 r.p.m. (d) 5367 r.p.m.

**Ans. (d)**

**Sol.** Using Dunkerlon's Method

$$\frac{1}{w_n^2} = \frac{1}{w_{n1}^2} + \frac{1}{w_n^2}$$

$$= \frac{1}{(100)^2} + \frac{1}{(200)^2}$$

$$= \frac{1}{8000}$$

$$\Rightarrow \quad w_n = 89.44 \text{ cycle/s}$$

$$\therefore \quad \text{rpm} = 89.44 \times 60 = 5366.56 \text{rpm}$$

**140.** Considering the following statements:

In the case of gears of involute profiles, increase in the centre to centre distance between the mounting shafts

1. increases the pressure angle
2. will not affect the law of gearing
3. shortens the path of contact
4. increases the contact ratio

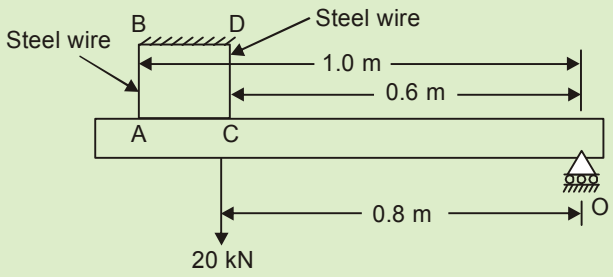
Which of the above statements are correct?

(a) 1, 2 and 4 (b) 1, 2 and 3
(c) 1, 3 and 4 (d) 2, 3 and 4

**Ans. (b)**

**Sol.** Increasing centre distances lead to decrease in contact ratio.

**141.** A rigid bar ACO as shown is hinged at O and is held in a horizontal position by two identical vertical steel wires AB and CD. A point load of 20 kN is hung at the position shown. The tensions in wires AB and CD are




(a) 15.2 kN and 7.1 kN
(b) 11.8 kN and 7.1 kN
(c) 15.2 kN and 5.0 kN
(d) 11.8 kN and 5.0 kN

**Ans. (b)**

$$\frac{\delta_{AB}}{1} = \frac{\delta_{CO}}{0.6}$$

$$\Rightarrow \quad \delta_{CD} = 0.6 \times \delta_{AB}$$

$$\Rightarrow \quad \frac{T_{CD}L}{AE} = 0.6 \times \frac{T_{AB}L}{AE}$$

$$\Rightarrow \quad T_{CO} = 0.6\ T_{AB}$$

Moment about 0, $\sum M = 0$

$$\Rightarrow \quad T_{AB} \times 1 + T_{CD} \times 0.6 = 20 \times 0.8$$

$$\Rightarrow \quad 1.36T_{AB} = 20 \times 0.8$$

$$T_{AB} = 11.76 \text{ KN}$$

$$T_{CD} = 7.05 \text{ KN}$$

**142.** An epicyclic gear train has 3 shafts A, B and C, A is the input shaft running at 100 r.p.m. clockwise. B is the output shaft running at 250 r.p.m. clockwise. The torque on A is 50 kN m (clockwise), C is a fixed shaft. The torque needed to fix C is

(a) 20 kN m (anti-clockwise)
(b) 20 kN m (clockwise)
(c) 30 kN m (anti-clockwise)
(d) 30 kN m (clockwise)

**Ans. (c)**

**Sol.** $\sum \tau N = 0$

$\Rightarrow \quad \tau_A N_A + \tau_B N_B + \tau_B N_C = 0$

$\Rightarrow \quad 100 \times 50 + 250 \times \tau_B = 0$

$\Rightarrow \quad \tau_B = -20 \text{ kNm}$

Now, $\Sigma\tau = 0$

$\tau_c = -\tau_A - \tau_B$

$= -50 + 20$

$= -30 \text{ kNm}$

$= 30 \text{ kNm (ccw)}$

**143.** A fixed gear having 200 teeth is meshed with a smaller gear having 50 teeth. The two gears are connected by an arm. The number of turns made by the smaller gear for one revolution of the arm about the centre of the bigger gear is

(a) 1 (b) 2
(c) 3 (d) 5

**Ans. (d)**

**Sol.**

Given : y = 1; ?? if fixed $\Rightarrow \quad y - \frac{x}{y} = 0$

$\Rightarrow \quad x = 4$

$\therefore \quad$ Pinion = x + y = 4 + 1 = 5

**144.** Consider the following statements:

1. Balancing of several masses rotating in the same plane can be effected by a single mass.
2. Balancing of several masses in different planes can be done by 2 masses in 2 planes on either side of the reference plane or on the same side.
3. Reciprocating masses cannot be completely balanced by rotating masses.
4. Secondary unbalanced forces will be negligible compared to primary imbalance forces.

Which of the above statements are correct?

(a) 1, 2, 3 and 4 (b) 1, 2 and 3 only
(c) 3 and 4 only (d) 1, 2 and 4 only

**Ans. (b)**

**Sol.** Secondary unbalanced forces were be negligible only when, the ratio, $n = \frac{l}{r} >> 1$.

That means not always.

$$a_{rec} = \ddot{x} = -w^2 r\left(\cos\theta + \frac{\cos 2\theta}{x}\right)$$

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Received so far..... [ If found any discrepancy please bring it to our notice. ]

**145.** A body of mass 10 kg with its CG 200 mm from the axis of rotation is to be completely balanced by another mass B of 5 kg placed in the same plane. The radius at which the CG of mass B should be is

(a) 500 mm (b) 400 mm

(c) 300 mm (d) 200 mm

**Ans. (b)**

**Sol.** $M_1r_1 = M_2Y_2$

$$\Rightarrow \quad r_2 = \frac{10\times 200}{5} = 400\,mm$$

**146.** Consider the following statements:

1. In stationary constant speed engines, the spring-loaded governor mechanism is fitted on the cam-shaft of the engine.
2. Hunting occurs when the governor is not sensitive.
3. Isochronous governors have the same speed over a wide range of governor action.
4. A governor is said to be unstable if the radius of rotation falls as the speed increases.

Which of the above statements are correct?

(a) 1, 2, 3 and 4 (b) 1, 2 and 4 only

(c) 1, 3 and 4 only (d) 2 and 3 only

**Ans. (c)**

**Sol.** Hunting occurs when a governor is too sensitive.

**147.** An aircraft cruising at 360 kmph takes a right turn on an arc of 100 m radius. The turbines and propellers have a total mass of 500 kg with radius of gyration of 25 cm. The engine rotates at 2000 r.p.m. The magnitude of the gyroscopic couple generated is

(a) 6.55 kN m (b) 7.65 kN m

(c) 9.81 kN m (d) 13.1 kN m

**Ans. (a)**

**Sol.** $V_{alternate}$ = 360 kmph

$$= 360\times\frac{5}{18}\,m/s$$

$$= 100\ m/s$$

Radius, r = 100 m

$$\therefore \text{ Angular Precession, } \Omega = \frac{V}{r} = 1\,rad/sec$$

$$I = MK^2 = 500\times(0.25)^2 = 31.25\,Kg-m^2$$

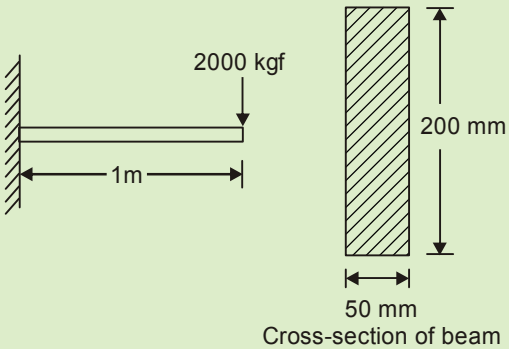
w = engine spin = 2000 rpm

$$= \frac{2000\times 2\pi}{60} = 209.45\,rad/s$$

$$\therefore \text{Gyroscopic couple } C = I w\Omega$$

$$= 6.544\ KN.m$$

**148.** The maximum shearing stress induced in the beam section at any layer at any position along the beam length (shown in the figure) is equal to



Cross-section of beam

(a) 30 kgf/cm$^2$ (b) 40 kgf/cm$^2$
(c) 50 kgf/cm$^2$ (d) 60 kgf/cm$^2$

**Ans. (a)**

**Sol.** Shear stress, $\tau = \frac{VQ}{Ib}$

$$Q = A\bar{y}$$

$$= \left(\frac{bh}{2}\right).\frac{h}{4}$$

$$= \frac{bh^2}{8} = \frac{50\times(200)^2}{8}\text{may}$$

$$\tau = \frac{VQ}{2b}$$

$$= \frac{V.\frac{bh^2}{8}}{\left(\frac{bh^2}{12}\right)\times b} = \frac{3}{2}.\frac{V}{bh}$$

$$= \frac{3}{2}\times\frac{2000}{50\times200}\text{Kgf/mm}^2$$

$$= 30\text{Kgf/cm}^2$$

**149.** Consider the following statements:

For a component made of ductile material, the failure criterion will be

1. endurance limit, if the external force is fluctuating
2. fatigue, if the external force is fluctuating
3. yield stress, if the external force is static

Which of the above statements are correct?

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

**Ans. (b)**

**Sol.** If external force is fluctuating then material get fail at stress which is considerably lower than the normal stress of static load. This behaviour is termed as fatigue. These are two termonology used is fatigue fracture. These are fatigue strength and fatigue life. The graph in between these tells the fatigue strength and finally define endurnace limit of particular material. Under fatigue failure ductile material will fail as like as brittle material.

For ductile material under static load material start yielding at yield point beyond which material get deformed permanently and finally fail by cup and cone fracture at UTS. the allowable stress of material is also governed by yield stress and in Industry beyond it material termed as fail.

**Note:** Due to yielding Lauders band take place in ductile material due to static loading which act as a stress intensifier.

**150.** A machine component is subjected to a flexural stress, which fluctuates between 300 MN/m$^2$ and –150 MN/m$^2$. Taking the yield strength = 0.55 of the ultimate strength, endurnace strength = 0.50 of the ultimate strength and factor of safety to be 2, the value of the minimum ultimate strength according to modified Goodman relation will be

(a) 1100 MN/m$^2$ (b) 1075 MN/m$^2$
(c) 1050 MN/m$^2$ (d) 1025 MN/m$^2$

**Ans. (c)**

**Sol.** $\left.\begin{aligned}\text{Alternating stress}, b_a &= \frac{b_{max} - b_{min}}{2} = 225 \\ \text{Mean Stress}, b_m &= \frac{b_{max} + b_{min}}{2} = 75\end{aligned}\right\}$

$$\Rightarrow \tan\theta = \frac{60}{6m} = 5$$

Modulated-Goodmax

$$\frac{60}{Se} + \frac{6m}{Sut} = \frac{1}{n}$$

$$\Rightarrow \quad \frac{225}{0.5Sut} + \frac{75}{Sut} = \frac{1}{2}$$

$$\Rightarrow \quad sut = 1050 \text{ MN/m}^2$$