IES MASTER

Institute for Engineers (IES/GATE/PSUs)

ESE 2020

Prelims Exam

Paper - II

MECHANICAL ENGINEERING

Detailed Solution

(SET-A)

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1. The time taken to face a workpiece of 80 mm diameter for the spindle speed of 90 rpm and cross feed of 0.3 mm/rev will be

(a) 4.12 min (b) 3.24 min

(c) 2.36 min (d) 1.48 min

Ans. (d)

Sol. Given diameter of workpiece, d = 80 mm

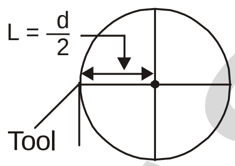
Spindle speed, N = 90 rpm

Cross feed, f = 0.3 mm/rev.

Time taken to face the workpiece,

$$T_m = \frac{L}{fN}$$

$$L = \frac{80}{2} = 40 \text{ mm}$$



Then, $T_m = \dfrac{40}{90 \times 0.3}$

T_m = 1.48 min

2. A feed f for the lathe operation is

(a) $\dfrac{N}{L \times T_m}$ mm/rev (b) $\dfrac{L}{N \times T_m}$ mm/rev

(c) $\dfrac{T_m}{N \times L}$ mm/rev (d) $\dfrac{T_m \times L}{N}$ mm/rev

where: T_m = Machining time in min.

N = Speed in rpm

L = Length of cut in mm

Ans. (b)

Sol. $\because$ We know, machining time, $T_m = \dfrac{L}{fN}$

where, L = length of cut

f = feed

N = rpm

$$\boxed{f = \frac{L}{N \times T_m}}$$

3. The main advantage of the radial drilling machine is that

(a) It is very compatible and handy for machining

(b) It is accurate, economical, portable and least time consuming while machining

(c) Heavy workpieces can be machined in any position without moving them

(d) Small workpieces can be machined and it can be used for mass production as well

Ans. (c)

Sol. Advantages of radial drilling:

1. They are generally powerful and can turn a large diameter drill.
2. They allow a fixed positioning of the workpiece, and the drill can be easily moved to the required position.

So, the correct answer is option (c).

4. For the purpose of sampling inspection, the maximum percent defective that can be considered satisfactory as a process average is

(a) Rejectable Quality Level (RQL)

(b) Acceptable Quality Level (AQL)

(c) Average Outgoing Quality Limit (AOQL)

(d) Lot Tolerance Percent Defective (LTPD)

Ans. (d)

Sol. Lot tolerance percent defective (LTPD):

Lot tolerance percent defective (LTPD), expressed in percent defective, is the poorest quality in an individual lot that should be accepted. The LTPD has a low probability of acceptance.

5. Hard automation is also called

(a) Selective automation

(b) Total automation

(c) Group technology

(d) Fixed position automation

Ans. (d)

Sol. Fixed position Automation is also known as Hard Automation.

It refers to the use of special purpose equipment to automate a fixed sequence of processing or assemble operations.

6. The method of CNC programming which enables the programmer to describe part geometry using variables is

(a) Computer assisted part programming

(b) Computer aided drafting programming

(c) Conversational programming

(d) Parametric programming

Ans. **(d)**

Sol. Parametric programming:

It is an enhancement to the methods like manual part programming, computer assisted part programming & conversational programming.

It enables the programmer to describe part geometry using variables.

Once described, entering specific values for the variables that unique identify the part generates an actual tool path CNC program.

7. Revolving joint of the robot is referred to as

(a) L joint (b) O joint

(c) T joint (d) V joint

Ans. **(d)**

Sol. Revolving joint: Revolving joint is generally known as V-joint. Here the output link axis is perpendicular to the rotational axis and the input link is parallel to the rotational axis.

8. Repairing of a machine consists of 5 steps that must be performed sequentially. Time taken to perform each of the 5 steps is found to have an exponential distribution with a mean of 5 minutes and is independent of other steps. If these machines break down in Poisson fashion at an average rate of 2/hour and if there is only one repairman, the average idle time for each machine that has broken down will be

(a) 120 minutes (b) 110 minutes

(c) 100 minutes (d) 90 minutes

Ans. **(c)**

Sol. Here, number of phases k = 5,

service time per phase = 5 minutes.

$\therefore$ Service time per unit = 5 × 5 = 25 minutes.

$$\therefore \quad \mu = \frac{1}{25}\text{ units / minute}$$

$$= \frac{12}{5}\text{ units / hour}$$

$$\lambda = 2 \text{ units/hour}$$

Average idle time of the machine = Average time spent by the machine in the system.

$$W_s = \frac{k+1}{2k}\cdot\frac{\lambda}{\mu}\cdot\frac{1}{\mu-\lambda}+\frac{1}{\mu}$$

$$= \frac{5+1}{2\times5}\times\frac{2\times5}{12}\times\frac{1}{\frac{12}{5}-2}+\frac{5}{12}$$

$$= \frac{1}{2}\times\frac{5}{2}+\frac{5}{12}=\frac{20}{12}=\frac{5}{3}\text{ hours}$$

= 100 minutes

9. A portion of the total float within which an activity can be delayed for start without affecting the floats of preceding activities is called

(a) Safety float (b) Free float

(c) Independent float (d) Interfering float

Ans. **(c)**

Sol. Independent float: It is that portion of the total float within which an activity can be delayed for start without affecting the float of the preceding activities.

10. An oil engine manufacturer purchases lubricant cans at the rate of Rs 42 per piece from a vendor. The requirement of these lubricant cans is 1800 per year. If the cost per placement of an order is Rs. 16 and inventory carrying charges per rupee per year is 20 paise, the order quantity per order will be

(a) 91 cans (b) 83 cans

(c) 75 cans (d) 67 cans

Ans. **(b)**

Sol. Given: Demand D = 1800 per year

Ordering cost, C_o = 16

Carrying cost C_h = 210 paise/rupee/year

$$EOQ = \sqrt{\frac{2DC_o}{C_h}} \quad \because C_h = 0.20\times42$$

$$EOQ = \sqrt{\frac{2\times1800\times16}{0.20\times42}}$$

$$EOQ = \sqrt{6857.142857}$$

$= 82.8078$

EOQ = 83

11. Consider the following data regarding the acceptance sampling process:

N = 10,000, n = 89, c = 2, P = 0.01 and P_a = 0.9397

The Average Total Inspection (ATI) will be

(a) 795 (b) 687

(c) 595 (d) 487

Ans. **(b)**

Sol. $ATI = n + (1 - P_a)(N - n)$

$= 89 + (1 - 0.9397) \times (10000 - 89)$

$= 686.633$

≈ 687

12. The Non-Destructive Inspection (NDI) technique employed during inspection for castings of tubes and pipes to check the overall strength of a casting in resistance to bursting under hydraulic pressure is

(a) Radiographic inspection

(b) Magnetic particle inspection

(c) Fluorescent penetrant

(d) Pressure testing

Ans. **(d)**

Sol. Proof test is a kind of pressure test employed for pipes in resistance to bursting under hydraulic pressure.

In it hydrostatic pressure shall be applied to the assembly. The actual test pressure prior to rupture must be at least equal to the computed proof test pressure defined below.

$$P = \frac{2st}{D}$$

P = Proof test pressure

S = Actual tensile strength of run pipe

t = Nominal run pipe wall thickness

D = specified outside diameter of the run pipe

Test is considered successful if the pipe withstand rupture. and test pressure 150% is applied.

13. Consider the situation where a microprocessor gives an output of an 8-bit word. This is fed through an 8-bit digital-to-analogue converter to a control valve. The control valve requires 6.0 V being fully open. If the fully open state is indicated by 11111111, the output to the valve for a change of 1-bit will be

(a) 0.061 V (b) 0.042 V

(c) 0.023 V (d) 0.014 V

Ans. **(c)**

Sol. The full-scale output voltage of 6.0 V will be divided into 2^8 intervals. A change of 1 bit is thus a change in the output voltage of

$$\frac{6.0}{2^8} = 0.023 \text{ V.}$$

14. Which of the following factors are to be considered while selecting a microcontroller?

1. Memory requirements
2. Processing speed required
3. Number of input/output pins

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

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

Ans. **(d)**

Sol. In selecting a microcontroller the following factors need to be considered:

(1) Number of input/output pins:

How many input-output pins are going to be needed for the task concerned?

(2) Interfaces required:

What interfaces are going to be required? For example, is PWM required? Many microcontrollers have PWM outputs, e.g. the PIC17C42 has two.

(3) Memory requirements:

What size memory is required for the task?

(4) The number of interrupts required:

How many events will need interrupts?

(5) Processing speed required:

The microprocessor takes time to execute instructions, this time being determined by the processor clock.

15. Which of the following statements regarding interface circuit are correct?

1. Electrical buffering is needed when the peripheral operates at a different voltage or current to that on the microprocessor bus system or there are different ground references.
2. Timing control is needed when the data transfer rates of the peripheral and the microprocessor are different.
3. Changing the number of lines is needed when the codes used by the peripherals differ from those used by the micro-processor.

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

Ans. **(a)**

Sol. (i) Electrical buffering is needed when the peripheral operates at a different voltage or current to that on the microprocessor bus system or there are different ground references.

(ii) Timing control is needed when the data transfer rates of the peripheral and the microprocessor are different.

(iii) Code conversion is needed when the codes used by the peripherals differ from those used by microprocessor.

16. Alternative paths provided by vertical paths from the main rung of a ladder diagram, that is, paths in parallel, represent

(a) Logical AND operations
(b) Logical OR operations
(c) Logical NOT operations
(d) Logical NOR operations

Ans. **(b)**

Sol. Alternative paths provided by vertical paths from the main rung of a ladder diagram, that is, paths is parallel, represents logical OR operations.

An example of an OR gate control system is a conveyer Belt transporting bottled products of packaging where a deflector plate is activated to deflect bottles into a reject bin if either the weight is not within certain tolerances or there is no cap on the bottle.

17. The resolution of an encoder with 10 tracks will be nearly

(a) 0.15° (b) 0.25°
(c) 0.35° (d) 0.45°

Ans. **(c)**

Sol. The resolution of an encoder with 10 track for n track

$$\text{Resolution} = \frac{360}{2^n}$$

$$= \frac{360}{2^{10}} = 0.35°$$

18. Which of the following features is/are relevant to variable reluctance stepper motors?

1. Smaller rotor mass; more responsive
2. Step size is small
3. More sluggish

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

Ans. **(a)**

Sol. A variable reluctance stepper motor has a ferromagnetic rotor than a permanent magnet motor. Motion and holding result from the attraction of stator and poles to positions with minimum magnetic reluctance that allow for maximum magnetic flux. A variable reluctance motor has the advantage of a lower rotor inertia and therefore a faster dynamic response.

19. Which of the following statements regarding hydraulic pumps are correct?

1. The gear pump consists of two close-meshing gear wheels which rotate in opposite directions.
2. In vane pump, as the rotor rotates, the vanes follow the contours of the casing.
3. This leakage is more in vane pump compared to gear pump.

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

Ans. **(b)**

Sol. 1. The gear pump consists of two close-meshing gear wheels which rotate in opposite directions.

2. In vane pump as the rotor rotates, the vane follow the contours of the casing.

   The results in fluid becoming trapped between successive vanes and the casing and transported round from the inlet port to outlet port.

3. The leakage is less in vane pump than with the gear pump.

20. The selection of the right controller for the application depends on

1. The degree of control required by the application.
2. The individual characteristics of the plants.
3. The desirable performance level including required response, steady-state deviation and stability.

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. 1) The degree of control required by the application.

2) The individual characteristics of the plant.

3) The desirable performance level including response, steady-state deviation and stability.

21. Consider a system described by

$$x = Ax + Bu$$
$$y = Cx + Du$$

The system is completely output controllable if and only if

(a) The matrix

$$\left[CB \vdots CBA \vdots CB^2A \vdots \cdots \vdots CB^{n-1}A \vdots D\right]$$

is of rank n

(b) The matrix

$$\left[CB \vdots CAB \vdots CA^2B \vdots \cdots \vdots CA^{n-1}B \vdots D\right]$$

is of rank m

(c) The matrix

$$\left[BC \vdots BAC \vdots BA^2C \vdots \cdots \vdots BA^{n-1}C \vdots D\right]$$

is of rank m

(d) The matrix

$$\left[BC \vdots ABC \vdots CA^2B \vdots \cdots \vdots CB^{n-1}A \vdots D\right]$$

is of rank n

where:

x = State vector (n-vector)

u = Control vector (r-vector)

y = Output vector (m-vector)

A = n × n matrix

B = n × r matrix

C = m × n matrix

D = m × r matrix

Ans. **(b)**

Sol. Consider the system described by

$$x = Ax + Bu \quad \ldots(i)$$

$$y = Cx + Du \quad \ldots(ii)$$

where x = state vector (n-vector)

u = control vector (r-vector)

y = output vector (m-vector)

A = n × n matrix

B = n × r matrix

C = m × n matrix

D = m × r matrix

The system described by equation (i) and (ii) is said to be completely output controllable if it is possible to construct an unconstrained control vector u(t) that will transfer any given initial output y (t_0) to any final output y (t_1) in a finite time interval $t_0 \le t \le t_1$.

It can be proved that the condition for complete output controllability is as follows: The system described by equations (i) and (ii) is completely output controllable if and only if the m × (n +1)r matrix

$$\left[CB \mid CAB \mid CA^2B \mid \cdots \mid CA^{n-1}B \mid D\right]$$

is of rank m.

22. Which one of the following symbols is used as the notation for designating arm and body of a robot with jointed arm configuration?

(a) TRL (b) TLL, LTL, LVL

(c) LLL (d) TRR, VVR

Ans. (d)

Sol.

Robot configuration (Arm & Body)		Symbol
Polar configuration	$\rightarrow$	TRL
Cylindrical configuration	$\rightarrow$	TLL, LTL, LVL
Cartesian configuration	$\rightarrow$	LLL
Jointed arm configuration	$\rightarrow$	TRR, VVR

23. A compliant motion control of robots can be understood by the problem of controlling of

(a) Position and velocity of joints

(b) Position and acceleration of the end-effector

(c) Manipulator motion and its force interactions with the environment.

(d) Joint velocities of given end-effector velocity.

Ans. (c)

Sol. The role of a compliant motion scheme is to control a robot manipulation in contract with its environment. By accommodating with the interaction force.

24. For the vector v = 25 i + 10 j + 20 k, perform a translation by a distance of 8 in the x-direction, 5 in the y-direction and 0 in the z-direction. The translated vector Hv will be

(a) $\begin{bmatrix} 1 \\ 20 \\ 33 \\ 15 \end{bmatrix}$ (b) $\begin{bmatrix} 33 \\ 15 \\ 20 \\ 1 \end{bmatrix}$

(c) $\begin{bmatrix} 15 \\ 33 \\ 1 \\ 20 \end{bmatrix}$ (d) $\begin{bmatrix} 1 \\ 15 \\ 20 \\ 33 \end{bmatrix}$

Ans. (b)

Sol. Given vector, V = $25\hat{i} + 10\hat{j} + 20\hat{k}$

Translation in x direction = 8

Translation in y-direction = 5

Translation in z-direction = 0

$$\text{Translation vector} = \begin{bmatrix} 1 & 0 & 0 & 8 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 25 \\ 10 \\ 20 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 33 \\ 15 \\ 20 \\ 1 \end{bmatrix}$$

Directions: Each of the next six (06) items consists of two statements, one labelled as 'Statement (I)' and the other labelled as 'Statement (II)'. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(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.

25. **Statement (I) :** The greater the chemical affinity of two metals, the more restricted is their solid solubility and greater is the tendency of formation of compound.

Statement (II) : Wider the separation of elements in the periodic table, greater is their chemical affinity.

Ans. (a)

Sol. The greater the chemical affinity of two metals the more restricted is their solid solubility and the greater is the tendency towards compound formation.

26. **Statement (I) :** The size of a memory unit is specified in terms of the number of storage locations available; 1 K is 2^{10} = 1024 locations and thus a 4 K memory has 4096 locations.

Statement (II) : Erasable and programmable ROM (EPROM) is a form of memory unit used for ROMs that can be programmed and their contents altered.

Ans. (b)

Sol. The size of the memory is determined by the number of wires in the address bus. The memory elements in a unit consist essentially of large numbers of storage cells with each cell capable of storing either a 0 or a 1 bit. The storage cells are grouped in locations with each location capable of storing one word. In order to access the stored word, each location is identified by a unique address. Thus with a 4-bit address bus we can have 16 different addresses with each, perhaps, capable of storing 1 byte, i.e. a group of 8 bits.

The size of a memory unit is specified in terms of the number of storage locations available; 1 K is 2^{10} = 1024 locations and thus a 4 K memory has 4096 locations.

The term erasable and programmable ROM (EPROM) is used for ROMs that can be programmed and their contents altered.

27. **Statement (I) :** Microprocessors which have memory and various input/output arrangements, all on the same chip, are called microcontrollers.

Statement (II) : The microcontroller is the integration of a microprocessor with RAM, ROM, EPROM, EEPROM and I/O interfaces, and other peripherals such as timers, on a single chip.

Ans. (a)

Sol. Systems using microprocessors basically have three parts: a central processing unit (CPU) to recognize and carry out program instructions (this is the part which uses the microprocessor), input and output interfaces to handle communications between the microprocessor and the outside world (the term port is used for the interface), and memory to hold the program instruction and data. Microprocessors which have memory and various input/output arrangements all on the same chip are called microcontrollers.

The microcontroller is the integration of a microprocessor with memory and input/output interfaces, and other peripherals such as timers, on a single chip.

28. **Statement (I) :** Capacitive proximity sensor can only be used for the detection of metal objects and is best with ferrous metals.

Statement (II) : One form of capacitive proximity sensor consists of a single capacitor plate probe with the other plate being formed by the object, which has to be metallic and earthed.

Ans. (d)

Sol. One form of capacitive proximity sensor consists of a single capacitor metallic and earthed figure. As the object approaches so the 'plate separation' of the capacitor changes, becoming significant and detectable when the object is close to the probe.

Magnetic field proximity sensors are relatively simple and can be made using a permanent magnet. The magnet can be made a part of object being detected or can be part of the sensor device. It can only be used for the detection of metal object and is best with ferrous metal.

29. **Statement (I) :** SCARA configuration provides substantial rigidity for the robot in the vertical direction, but compliance in the horizontal plane.

Statement (II) : A special version of the Cartesian coordinate robot is the SCARA, which has a very high lift capacity as it is designed for high rigidity.

Ans. (c)

Sol. A special version of the jointed arm robot is the SCARA stands for selective compliance assembly robot arm, and this configuration provides substantial rigidity of the robot in the vertical direction, but compliance in the horizontal plane. This makes it ideal for many assembly tasks.

30. **Statement (I) :** The stepper motor is a device that produces rotation through equal angles, the so-called steps, for each digital pulse supplied to its input.

Statement (II) : Stepper motors can be used to give controlled rotational steps but cannot give continuous rotation, as a result their applications are limited to step angles only.

Ans. (c)

Sol. The stepper motor is a device that produces rotation through equal angles, the so-called steps, for each digital pulse supplied to its input.

Stepper motors can be used to give controlled rotational steps but also can give continuous rotation with their rotational speed controlled by controlling the rate at which pulses are applied to it to cause stepping. This gives a very useful controlled variable speed motor which finds many applications.

31. A stone weighs 400 N in air and when immersed in water it weighs 225 N. If the specific weight of water is 9810 N/m^3, the relative density of the stone will be nearly

(a) 5.9 (b) 4.7

(c) 3.5 (d) 2.3

Ans. (d)

Sol. Let, Density of stone is ρ and volume V.

Case 1: When stone is weighted in air.

Weight, W = $\rho gV - \rho_a gV$

$\rho_a gV$ is buoyancy force due to air.

So, $400 = \rho gV - \rho_a gV$

[$\because$ Density of air, $\rho_a = 1.18$ kg/m^3]

$$\Rightarrow \quad \rho - \rho_a = \frac{400}{gV} \quad \text{...(i)}$$

Case 2: When stone is weighted in water

$$225 = \rho gV - \rho_w gV$$

$\rho_w gV$ is buoyancy force due to water.

$$\text{So,} \quad \rho - \rho_w = \frac{225}{gV} \quad \text{...(ii)}$$

Divide both equations,

$$\frac{\rho - \rho_a}{\rho - \rho_w} = \frac{400}{225}$$

$$\frac{\rho - 1.18}{\rho - 1000} = \frac{400}{225}$$

$$\because \rho_w = \frac{9810}{9.81} = 1000 \text{ kg/m}^3$$

$$\Rightarrow \quad \rho = 2284$$

Relative density,

$$\gamma = \frac{2284}{1000} \simeq 2.3$$

32. A flat plate 0.1 m^2 area is pulled at 30 cm/s relative to another plate located at a distance of 0.01 cm from it, the fluid separating them being water with viscosity of 0.001 Ns/m^2. The power required to maintain velocity will be

(a) 0.05 W (b) 0.07 W

(c) 0.09 W (d) 0.11 W

Ans. (c)

Sol. $\because$ Shear stress, $\tau = \mu\frac{dv}{dy} = \mu\frac{v}{y}$

Power required to maintain flow,

$$P = (\tau \times A) \times v$$

$$= \left(\mu\frac{v}{y} \times A\right) \times v$$

$$= \mu A\frac{v^2}{y}$$

Given: μ = 0.001 N-s/m^2

y = 0.01 cm

v = 30 cm/s

A = 0.1 m^2

So, the putting the respective values,

$$P = 0.001 \times 0.1 \times \frac{(30)^2 \times 10^{-2}}{0.01}$$

$$\boxed{P = 0.09 \text{ W}}$$

The correct answer is (c).

33. When the pressure of liquid is increased from 3 MN/m^2 to 6 MN/m^2, its volume is decreased by 0.1%. The bulk modulus of elasticity of the liquid will be

(a) 3×10^{12} N/m^2 (b) 3×10^9 N/m^2
(c) 3×10^8 N/m^2 (d) 3×10^4 N/m^2

Ans. (b)

Sol.

$\because$ Bulk modulus of elasticity,

$$k = -\frac{\Delta P}{\Delta V} \times V$$

Given: $\Delta P = 6 - 3 = 3$ MN/m^2

$= 3 \times 10^6$ N/m^2

$$\frac{\Delta V}{V} = -0.1\% = -\frac{0.1}{100}$$

$= -10^{-3}$

so, $$k = \frac{-3 \times 10^6}{-10^{-3}} = 3 \times 10^9 \text{ N/m}^2$$

The correct answer is (b).

34. A curve that is everywhere tangent to the instantaneous local velocity vector, is

(a) Streak line (b) Path line
(c) Normal line (d) Streamline

Ans. (d)

Sol.

Streamlines are the lines drawn through the flow field in such a manner that the velocity vector of the field at each and every point on the streamline is tangent to the streamline at that instant.

so, A curve that is everywhere tangent to the instantaneous local velocity vector is 'streamline'.

35. A 120 mm diameter jet of water is discharging from a nozzle into the air at a velocity of 40 m/s. The power in the jet with respect to a datum at the jet will be

(a) 380 kW (b) 360 kW
(c) 340 kW (d) 320 kW

Ans. (b)

Sol. Given:

Diameter, d = 120 mm = 0.12 m

Velocity, V = 40 m/s

The power in the jet with respect to a datum at the jet will be,

$$P = \frac{1}{2}\dot{m}V^2 \qquad \because \dot{m} = \rho a V$$

$$= \frac{1}{2}(\rho a V)V^2$$

$$= \frac{1}{2}\rho a V^3$$

$$= \frac{1}{2} \times \frac{(1000)}{1000} \times \frac{\pi(0.12)^2}{4} \times (40)^3$$

So, P = 361.91 kW

$\because$ The closest option is (b) i.e. 360 kW

36. Which of the following applications regarding Navier-Stokes equations are correct?

1. Laminar unidirectional flow between stationary parallel plates.
2. Laminar unidirectional flow between parallel plates having no relative motion.
3. Laminar flow in circular pipes.
4. Laminar flow between concentric rotating cylinders

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

Ans. (a)

Sol.

- Navier stokes theorem based on no slip hypothesis.
- It can be applied for both steady and unsteady flow.
- For flow between two concentric rotating cylinder if Navier stokes theorem is applied then flow must be steady. For it if ones cylinders stand still, the solution in the limit

  $\frac{R_2 - R_1}{R_1} \to 0$ reduces to the Couette flow.

- So, in view of the above option 4 is wrong.

37. A crude oil having a specific gravity of 0.9 flows through a pipe of diameter 0.15 m at the rate of 8 lps. If the value of μ is 0.3 Ns/m^2, the Reynolds number will be nearly

(a) 295 (b) 235
(c) 205 (d) 165

Ans. **(c)**

Sol. Density of oil, $\rho = 0.9 \times 1000 = 900$ kg/m^3

Diameter, $d = 0.15$ m

Discharge, $Q = 8\ell ps = 8 \times 10^{-3}$ m^3/s

Viscosity, $\mu = 0.3$ Ns/m^2

Reynolds number, $Re = \dfrac{\rho V d}{\mu}$

$$\because \quad V = \frac{4Q}{\pi d^2}$$

$$Re = \frac{4\rho Q}{\pi d \times \mu}$$

$$= \frac{4 \times 900 \times 8 \times 10^{-3}}{\pi \times 0.15 \times 0.3}$$

$$\boxed{Re \approx 205}$$

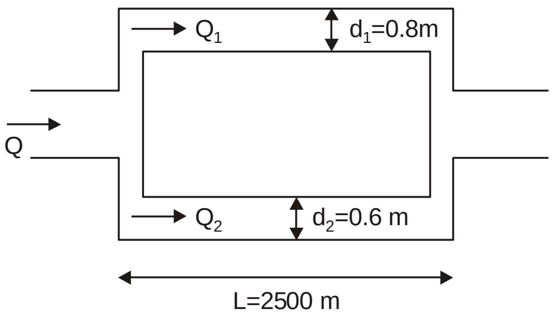
According to the given options, closest option is (c).

38. Two pipes of lengths 2500 m each and diameters 80 cm and 60 cm respectively, are connected in parallel. The coefficient of friction for each pipe is 0.006 and the total flow is 250 litres/s. The rates of flow in the pipes are nearly

(a) 0.17 m^3/s and 0.1 m^3/s
(b) 0.23 m^3/s and 0.1 m^3/s
(c) 0.17 m^3/s and 0.4 m^3/s
(d) 0.23 m^3/s and 0.4 m^3/s

Ans. **(a)**

Sol.



$f_1 = f_2 = 0.006$

$Q = 250\ \ell/s = 0.25$ m^3/s

Pipes are in parallel so head loss is equal

$$h_{f_1} = h_{f_2}$$

$$\frac{f_1 L_1 Q_1^2}{12 d_1^5} = \frac{f_2 L_2 Q_2^2}{12 d_2^5}$$

$$\Rightarrow \frac{Q_1}{Q_2} = \left(\frac{d_1}{d_2}\right)^{5/2} = \left(\frac{0.8}{0.6}\right)^{2.5} = (1.33)^{2.5} \quad ...(i)$$

$$Q_1 + Q_2 = 0.25 \quad ...(ii)$$

From equation (i) and (ii),

$Q_1 = 0.17$ m^3/sec

and $Q_2 = 0.08$ m^3/sec $\simeq$ 0.1 m^3/sec

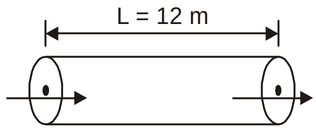
Method (ii) Shortcut: Pipes are in parallel so flow rate through both pipe i.e. $Q = Q_1 + Q_2$ check options.

39. A fluid of mass density 1790 kg/m^3 and viscosity 2.1 Ns/m^2 flows at a velocity of 3 m/s in a 6 cm diameter pipe. The head loss over a length of 12 m pipe will be nearly

(a) 62.0 m (b) 54.0 m
(c) 46.5 m (d) 38.5 m

Ans. **(d)**

Sol.



$\rho = 1790$ kg/m^3

$\mu = 2.1$ Ns/m^2

$v = 3$ m/s

$d = 0.06$ m

Head loss = ?

Major head loss is frictional head loss = $\dfrac{fLV^2}{2gd}$

$$h_f = \frac{32 \mu V L}{\rho g d^2} \quad \text{[circular pipe]}$$

$$= \frac{32 \times 2.1 \times 3 \times 12}{1790 \times 9.81 \times (0.06)^2}$$

$$= \frac{32 \times 12 \times 21 \times 3 \times 1000}{1790 \times 9.81 \times 36}$$

$$= \frac{32 \times 21 \times 10}{180}$$

$$= \frac{224}{6} \approx 38$$

The closest option is (d).

40. Which of the following characteristics regarding fluid kinematics is/are correct?

1. Streamline represents an imaginary curve in the flow field so that the tangent to the curve at any point represents the direction of instantaneous velocity at that point.
2. Path lines, streamlines and streak lines are identical in steady flow.

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

Ans. **(c)**

Sol. 1. **Streamline** is a line everywhere tangent to the velocity vector at a given instant

2. **Pathline** is the actual path traversed by a given fluid particle.

3. A **streakline** is the locus of particles that have earlier passed through a prescribed point.

So, the statement 1 is correct.

For steady flow, streamlines, pathlines and streaklines are identical because

(1) For a steady flow, the velocity vector at any point is invariant with time.

(2) The pathline of the particles with different identities passing through a point will not differ.

(3) The pathline could coincide with one another in a single curve which will indicate the streak line too.

So, both the statements are correct.

41. To maintain 0.08 m^3/s flow of petrol with a specific gravity of 0.7, through a steel pipe of 0.3 m diameter and 800 m length, with coefficient of friction of 0.0025 in the Darcy relation, the power required will be nearly

(a) 0.6 kW (b) 1.0 kW
(c) 2.6 kW (d) 3.0 kW

Ans. **(b)**

Sol. Given:

Coefficient of friction, f = 0.0025

Discharge, Q = 0.08 m^3/s

length, l = 800 m

Diameter, d = 0.3 m

Density, ρ = 0.7 × 1000 = 700 kg/m^3

Head loss to friction in pipe, $h_f = \frac{(4f)lV^2}{2dg}$

Here, remember that friction factor is four times to that of coefficient of friction.

$$\because\ v = \frac{4Q}{\pi d^2} \quad (\text{for pipe, } A = \frac{\pi d^2}{4})$$

So, power required, $P = \rho g Q h_f$

$$= \frac{\rho g Q \times (4f) l \times 16 Q^2}{2 \times \pi^2 \times d^5 g}$$

$$= \frac{\rho (4f) l \times 8 \times Q^3}{\pi^2 \times d^5}$$

Putting the respective values,

$$P = \frac{700 \times (4 \times 0.0025) \times 800 \times 8 \times (0.08)^3}{\pi^2 \times (0.3)^5 \times 1000}$$

$$\boxed{P = 0.956 \approx 1\,\text{kW}}$$

42. The diameter of a nozzle d for maximum transmission of power through it, is

(a) $\left[\frac{D^5}{8fL}\right]^{\frac{1}{4}}$ (b) $\left[\frac{D^5}{8fL}\right]^{\frac{1}{2}}$

(c) $\left[\frac{8D^5}{fL}\right]^{\frac{1}{4}}$ (d) $\left[\frac{8D^5}{fL}\right]^{\frac{1}{2}}$

where :

D = Diameter of pipe

f = Coefficient of friction

L = Length of pipe

Ans. **(a)**

Sol. Maximum transmission of power, the condition is given by equation as, $h_f = \frac{H}{3}$

But $$h_f = \frac{4f \cdot L \cdot V^2}{D \times 2g}$$

$$\therefore \quad \frac{4fLV^2}{D \times 2g} = \frac{H}{3} \text{ or } H = 3 \times \frac{4fLV^2}{D \times 2g}$$

But H is also = total head at outlet of nozzle + losses

Equating the two values of H, we get

$$3 \times \frac{4fLV^2}{D \times 2g} = \frac{\nu^2}{2g} + \frac{4fLV^2}{D \times 2g} \text{ or } \frac{12fLV^2}{D \times 2g} - \frac{4fLV^2}{D \times 2g} = \frac{\nu^2}{2g}$$

$$\text{or} \quad \frac{8fLV^2}{D \times 2g} = \frac{\nu^2}{2g}$$

But from continuity, $AV = a\nu$ or $V = \frac{a\nu}{A}$.

Substituting this value of V in equation (i), we get

$$\frac{8fL}{D \times 2g} \times \frac{a^2\nu^2}{A^2} = \frac{\nu^2}{2g} \text{ or } \frac{8fL}{D} \times \frac{a^2}{A^2} = 1$$

$$\left(\text{Divide by } \frac{\nu^2}{2g}\right) \quad \text{...(ii)}$$

$$\text{or} \quad \frac{8fL}{D} \times \frac{\left(\frac{\pi}{4} d^2\right)^2}{\left(\frac{\pi}{4} D^2\right)^2} = 1$$

$$\text{or} \quad \frac{8fL}{D} \times \frac{d^4}{D^4} = 1 \text{ or } d^4 = \frac{D^5}{8fL}$$

$$d = \left(\frac{D^5}{8fL}\right)^{1/4}$$

43. A piston-cylinder device with air at an initial temperature of 30°C undergoes an expansion process for which pressure and volume are related as given below:

p(kPa)	100	37.9	14.4
V (m^3)	0.1	0.2	0.4

The work done by the system for n = 1.4 will be

(a) 4.8 kJ (b) 6.8 kJ

(c) 8.4 kJ (d) 10.6 kJ

Ans. **(d)**

Sol. Work done in polytropic process is given by,

$$W = \frac{P_1V_1 - P_2V_2}{n-1}$$

Here, n = 1.4 (given)

Using, P_1 = 100 kPa, V_1 = 0.1 m^3

and P_3 = 14.4 kPa, V_3 = 0.4 m^3

So, work done, $W = \frac{P_1V_1 - P_3V_3}{n-1}$

$$= \frac{100 \times 0.1 - 14.4 \times 0.4}{1.4 - 1}$$

$$\boxed{W = 10.6 \text{ kJ}}$$

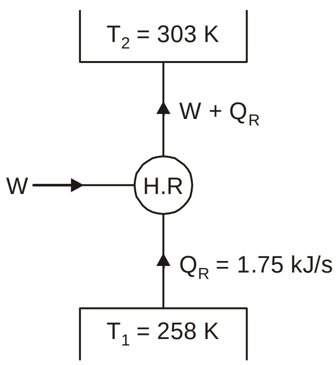
44. A domestic food freezer maintains a temperature of –15°C. The ambient air temperature is 30°C. If heat leaks into the freezer at the continuous rate of 1.75 kJ/s, the least power necessary to pump this heat out continuously will be nearly

(a) 0.1 kW (b) 0.2 kW

(c) 0.3 kW (d) 0.4 kW

Ans. **(c)**

Sol.



Least power will be required when this refrigeration cycle operates on reversed Carnot cycle.

$$\text{so,}\quad (COP)_{ref.} = \frac{T_1}{T_2 - T_1} = \frac{Q_R}{W}$$

$$\Rightarrow \quad \frac{258}{303-258} = \frac{1.75}{W}$$

$$\Rightarrow \quad W = \frac{1.75 \times 45}{258}$$

Power inputs, $\boxed{W = 0.30 \text{ kW}}$

45. An ideal gas is flowing through an insulated pipe at the rate of 3 kg/s. There is a 10% pressure drop from an inlet to exit of the pipe. The values of R = 0.287 kJ/kgK and T_o = 300 K. The rate of energy loss for the pressure drop due to friction, will be nearly

(a) 34 kW (b) 30 kW

(c) 26 kW (d) 22 kW

Ans. **(c)**

Sol. Rate of entropy generation

$$\dot{S}_{gen} = \dot{m}R\left(\frac{\Delta P}{P_1}\right)$$

$$= 3 \times 0.28 \times \frac{0.10P_1}{P_1} = 0.0861\,\text{kw/K}$$

Rate of exergy loss (Rate of energy loss for the pressure drop due to friction)

$$\dot{I} = T_0\,\dot{S}_{gen}$$

$$= 300 \times 0.0861 = 25.83 \simeq 26\text{ kW}$$

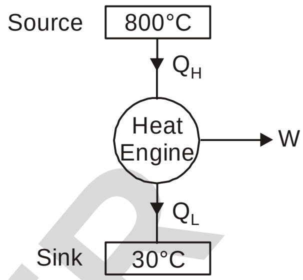
46. A cyclic heat engine operates between a source temperature of 800°C and a sink temperature of 30°C. The least rate of heat rejection per kW net output of engine will be nearly

(a) 0.2 kW (b) 0.4 kW

(c) 0.6 kW (d) 0.8 kW

Ans. **(b)**

Sol.



Reversible heat engine cycle will reject least rate of heat (Q_L) per kW net output (W) of engine.

For reversible condition,

$$Q \propto T$$

So,

$$\frac{Q_L}{W} = \frac{T_L}{T_H - T_L} = \frac{303}{770}$$

$$= 0.393 \approx 0.4\text{ kW}$$

47. A fictitious pressure that, if it acted on the piston during the entire power stroke, would produce the same amount of net work as that produced during the actual cycle is called

(a) Quasi equivalent pressure

(b) Mean equivalent pressure

(c) Mean effective pressure

(d) Quasi static pressure

Ans. **(c)**

Sol. Mean effective pressure is defined as a hypothetical pressure which is thought to be acting on the piston throughout the power stroke, would produce the same amount of net work as that produce during the actual cycle.

48. An ideal cycle based on the concept of combination of two heat transfer processes, one at constant volume and the other at constant pressure, is called

(a) Otto cycle (b) Dual cycle

(c) Diesel cycle (d) Carnot cycle

Ans. **(b)**

Sol. In a dual cycle a part of the heat is first supplied to the system at constant volume and then the remaining part at constant pressure.

49. The ideal thermodynamic cycle for the development of gas-turbine engine is

(a) Otto (b) Stirling

(c) Ericsson (d) Brayton

Ans. **(d)**

Sol. The Joule or Brayton cycle is the most idealized cycle for the simple gas turbine engine.

50. If the pressure at exhaust from the turbine is the saturation pressure corresponding to the temperature desired in the process heater, such a turbine is called

(a) Condensing turbine

(b) Extraction turbine

(c) Pass out turbine

(d) Back pressure turbine

Ans. **(d)**

Sol. The pressure at exhaust from the turbine is the saturation pressure corresponding to the temperature desired in the process heater, such a turbine is called back pressure turbine.

51. The purpose of providing fins on heat transfer surface is to increase

(a) Temperature gradient so as to enhance heat transfer by convection

(b) Effective surface area to promote rate of heat transfer by convection

(c) Turbulence in flow for enhancing heat transfer by convection

(d) Pressure drop of the fluid

Ans. **(b)**

Sol. The purpose of providing fins on heat transfer surface is to increase effective surface area to promote rate of heat transfer by convection.

52. For fully developed laminar pipe flow, the average velocity is

(a) One-half of the maximum velocity

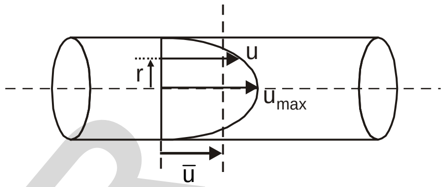
(b) One-third of the maximum velocity

(c) One-fourth of the maximum velocity

(d) Two-third of the maximum velocity

Ans. **(a)**

Sol. For fully developed laminar pipe flow,



Velocity distribution:

$$u = -\frac{1}{4\mu}\left(\frac{\partial P}{\partial x}\right)(R^2 - r^2)$$

Maximum velocity, u_{max} (r = 0) = $-\frac{1}{4\mu}\left(\frac{\partial P}{\partial x}\right)R^2$

Average velocity, $\bar{u} = -\frac{1}{8\mu}\left(\frac{\partial P}{\partial x}\right)R^2 = \frac{u_{max}}{2}$

The average velocity is one-half of the maximum velocity.

53. The overall heat transfer coefficient due to convection and radiation for a steam maintained at 200°C running in a large room at 30°C is 17.95 W/m^{2}K. If the emissivity of the pipe surface is 0.8; the value of σ = 5.67 × 10^{-8} W/m^{2}K^4; the heat transfer coefficient due to radiation will be nearly

(a) 17 W/m^{2}K (b) 14 W/m^{2}K

(c) 11 W/m^{2}K (d) 8 W/m^{2}K

Ans. **(c)**

Sol. Overall heat transfer coefficient,

$$h_0 = h_c + h_r$$

Here, h_c is heat transfer coefficient due to radiation.

h_r is heat transfer coefficient due to convection.

Now, $Q = h_r (T_o - T_i) = \sigma\left(T_o^4 - T_i^4\right)$

$$h_r = \frac{5.67 \times 10^{-8} \times 0.8 \times (473^4 - 303^4)}{(473 - 303)}$$

$$= 11 \text{ W/m}^2\text{K}$$

54. Large heat transfer coefficients for vapour condensation can be achieved by promoting

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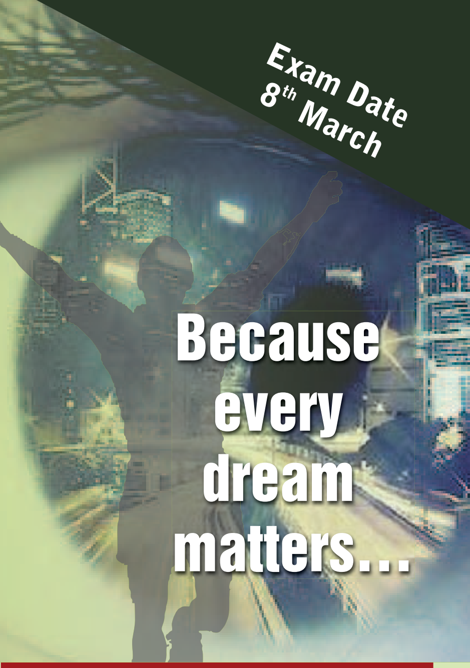

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(a) Film condensation

(b) Dropwise condensation

(c) Cloud condensation

(d) Dew condensation

Ans. (b)

Sol. Due to exposure of large surface area to the vapours in drop wise condensation heat transfer coefficient is higher (by as much as ten times) than that in film condensation.

55. Which one of the following valves is provided for starting the engine manually, during cold weather conditions?

(a) Starting jet valve

(b) Compensating jet valve

(c) Choke valve

(d) Auxiliary air valve

Ans. (d)

Sol. Auxiliary air valve is provided for cold starting the engine manually, during cold weather conditions.

56. A 4-cylinder, 4-stroke single acting petrol engine consumes 6 kg of fuel per minute at 800 rpm when the air-fuel ratio of the mixture supplied is 9 : 1. The temperature is 650 K and pressure is 12.5 bar at the end of compression stroke. Take R = 300 Nm/kg.K, diameter of cylinder as 8 cm, stroke of cylinder as 10 cm. The compression ratio will be nearly

(a) 6.2 (b) 5.7

(c) 5.2 (d) 4.6

Ans. (a)

Sol. Given:

Mass flow rate of fuel $(\dot{m}_f) = 6$ kg/min

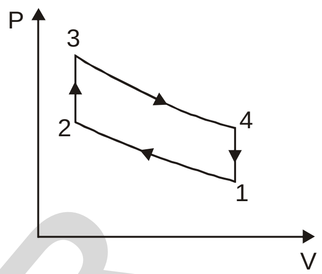
Note: Practically not possible due to small size of cylinder.

So it should be in 6 kg/hr

AFR = 9 : 1

Mass flow rate of air $(m_a) = 9 \times 6 = 54$ kJ/hr

Total rate of injection of air and fuel (m) = $m_a + m_f$ = 60 kg/hr



T_2=650 K

P_2=12.5 bar = 1250 kPa

R = 300 Nm/kgK = 0.3 kJ/kgK

$$P_2V_2 = \dot{m}RT_2$$

$$1250 \times V_2 = \frac{60}{3600} \times 0.3 \times 650$$

$$V_2 = 2.6 \times 10^{-3} \text{ m}^3/\text{sec}$$

Swept volume, $V_s = V_1 - V_2 = \dfrac{ALNK}{60 \times 2}$

$$= \frac{\pi}{4} \times (0.08)^2 \times 0.1 \times \frac{800 \times 4}{60 \times 2}$$

$$= 0.0134 \text{ m}^3/\text{sec}$$

So $V_1 = 0.0134 + V_2$

$$= 0.016 \text{ m}^3/\text{sec}$$

Compression ratio (r) = $\dfrac{V_1}{V_2}$

$$= \frac{0.016}{2.6 \times 10^{-3}} = 6.153 \approx 6.2$$

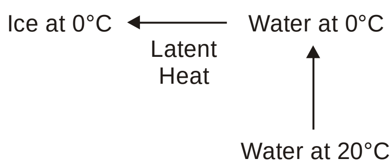
57. Ice is formed at 0°C from water at 20°C temperature of the brine is –8°C. The refrigeration cycle used is perfect reversed Carnot cycle. Latent heat of ice = 335 kJ/kg, and c_{pw} = 4.18. The ice formed per kWh will be nearly

(a) 81.4 kg (b) 76.4 kg

(c) 71.8 kg (d) 68.8 kg

Ans. (a)

Sol.



$$Q_{ref} = 335 \times m + 4.18 \times (20 - 0) \times m$$

$\therefore$ The cycle is working between –8°C and 20°C.

$$\text{So, } (COP)_{ideal} = \frac{-8+273}{20-(-8)} = \frac{265}{28}$$

$$\because \quad COP = \frac{Q_{ref}}{\text{Power Input}}$$

$$\Rightarrow \quad \frac{265}{28} = \frac{335 \times m + 4.18 \times 20 \times m}{3600}$$

$$\Rightarrow \quad m = \frac{265 \times 3600}{28 \times (335 + 4.18 \times 20)}$$

$$= 81.39 \approx 81.4 \text{ kg}$$

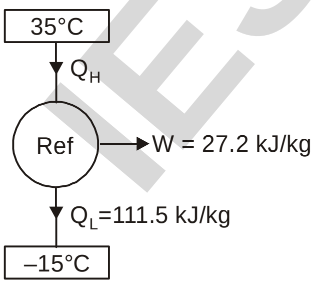
58. A Freon 12 simple saturation cycle operates at temperature of 35°C and –15°C for the condenser and evaporator. If the refrigeration effect produced by the cycle is 111.5 kJ/kg and the work required by the compressor is 27.2 kJ/kg, the value of COP will be nearly

(a) 4.1 (b) 3.6

(c) 3.1 (d) 2.6

Ans. **(a)**

Sol.



$$COP = \frac{\text{Refrigeration effect produced}}{\text{Work required}}$$

$$= \frac{111.5}{27.2} = 4.1$$

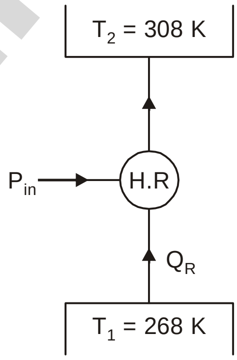
59. A cold storage is to be maintained at –5°C while the surroundings are at 35°C. The heat leakage from the surroundings into the cold storage is estimated to be 29 kW. The actual COP of the refrigeration plant used is one-third of an ideal plant working between the same temperatures. The power required to drive the plant will be

(a) 10 kW (b) 11 kW

(c) 12 kW (d) 13 kW

Ans. **(d)**

Sol.



$$(COP)_{actual} = \frac{1}{3}(COP)_{ideal}$$

$$\because \quad (COP)_{ideal} \text{ for refrigeration} = \frac{T_1}{T_2 - T_1}$$

$$\Rightarrow \quad \frac{Q_R}{P_{in}} = \frac{1}{3}\left[\frac{268}{308-268}\right]$$

$$P_{in} = 12.98 \text{ kW}$$

So, The power required to drive the plant, P = $12.98 \approx 13$ kW .

The closest option is (d).

60. A single acting two-stage air compressor deals with 4m^3/min of air at 1.013 bar and 15°C with a speed of 250 rpm. The delivery pressure is 80 bar. If the inter cooling is complete, the intermittent pressure after first stage will be

(a) 9 bar (b) 8 bar

(c) 7 bar (d) 6 bar

Ans. **(a)**

Sol. For minimum total work, the intermediate pressures are given by the stage pressure ratio,

$$r = \left(\frac{P_k}{P_o}\right)^{\frac{1}{n}}$$

where, n is the number of stages.

In a two stage system, this gives a geometric mean value for the intermediate pressure

$$P_i = \sqrt{P_k P_o}$$

$$= \sqrt{80 \times 1.013}$$

$$= \sqrt{81.04} = 9 \text{ bar}$$

61. Which of the following are the advantages of Nano-composite materials?

1. Decreased thermal expansion coefficients
2. Higher residual stress
3. Reduced gas permeability
4. Increased solvent resistance

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

Ans. (b)

Sol.

- Nano composites are used at high temperature where thermal stability is required. It is used with matrix of butyl rubber within which embedded thin platelets of veumiculite is used.
- Nano composites materials size is of nano range which is comparable to gas molecules sizes. So, gas permeability is less.
- Nano composites are resistant to solvent so, that they cannot dissolve in it.
- They do not have residual stress as these materials give excellent mechanical strength, toughness etc.

62. A rod of copper originally 305 mm long is pulled in tension with a stress of 276 MPa. if the modulus of elasticity is 110 GPa and the deformation is entirely elastic, the resultant elongation will be nearly

(a) 1.0 mm (b) 0.8 mm
(c) 0.6 mm (d) 0.4 mm

Ans. (b)

Sol. L = 305 mm

σ = 376 MPa

E = 110 GPa

Elongation

$$\Delta L = \frac{\sigma L}{E} = \frac{276 \times 305}{110 \times 10^3}$$

$$\Delta L = 0.765 \text{ mm}$$

$$\boxed{\Delta L \simeq 0.8 \text{ mm}}$$

63. A 1.25 cm diameter steel bar is subjected to a load of 2500 kg. The stress induced in the bar will be

(a) 200 MPa (b) 210 MPa
(c) 220 MPa (d) 230 MPa

Ans. (a)

Sol. Load M = 2500 kg

diameter d = 1.25 cm

$$\text{stress } \sigma = \frac{mg}{\frac{\pi}{4}d^2} = \frac{2500 \times 9.81}{\frac{\pi}{4} \times (12.5)^2}$$

$$\sigma = 199.85 \text{ MPa}$$

$$\boxed{\sigma \simeq 200 \text{ MPa}}$$

64. The maximum energy which can be stored in a body up to the elastic limit is called

(a) Proof resilience
(b) Modulus of resilience
(c) Impact toughness
(d) Endurance strength

Ans. (a)

Sol. Proof resilience is the maximum energy stored in a body up to the elastic limit.

65. A cast iron bed plate for a pump has a crack length of 100 μm. If the Young's modulus of cast iron is 210 GN/m^2 and the specific surface energy is 10 J/m^2, the fracture strength required will be nearly

(a) 1.0 × 10^8 N/m^2 (b) 1.2 × 10^8 N/m^2
(c) 1.4 × 10^8 N/m^2 (d) 1.6 × 10^8 N/m^2

Ans. **(b)**

Sol.

Fracture strength for brittle material,

$$\sigma = \sqrt{\frac{2E\gamma}{\pi c}}$$

where, E = Young's modulus

γ = specific surface energy

c = crack length

Given: $E = 210 \times 10^9 \text{ N/m}^2$

$\gamma = 10 \text{ J/m}^2$

$c = 100 \ \mu\text{m} = 100 \times 10^{-6} \text{ m}$

$$\sigma = \sqrt{\frac{2 \times 210 \times 10^9 \times 10}{\pi \times 100 \times 10^{-6}}}$$

$$= 1.15 \times 10^8 \text{ N/m}^2$$

$$\sigma \approx 1.2 \times 10^8 \text{ N/m}^2$$

66. A 13 mm diameter tensile specimen has 50 mm gauge length. If the load corresponding to the 0.2% offset of 6800 kg, the yield stress will be nearly

(a) 31 kg/mm² (b) 43 kg/mm²

(c) 51 kg/mm² (d) 63 kg/mm²

Ans. **(c)**

Sol. 0.2% offset yield strength,

$$\sigma_y = \frac{P_y}{A_o} = \frac{P_y}{\frac{\pi}{4}d^2}$$

$$= \frac{6800 \times 4}{\pi \times 13^2}$$

$$= 51.23 \text{ kg/mm}^2$$

67. The magnitude of the velocity of any point on the kinematic link relative to the other point on the same kinematic link is the product of

(a) A square root of an angular velocity of the link and the distance between the two points under consideration

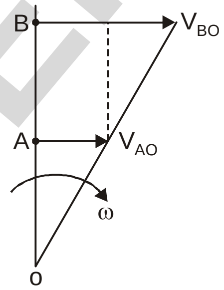
(b) An angular velocity of the link and the square of distance between the two points under consideration

(c) A square of an angular velocity of the link and the distance between the two points under consideration

(d) An angular velocity of the link and the distance between the two points under consideration

Ans. **(d)**

Sol.



$$\boxed{V_{BA} = \omega \times AB}$$

68. In a mechanism, the number of Instantaneous centres (I-centres) N is

(a) $\frac{n(n-1)}{2}$ (b) $\frac{n(2n-1)}{2}$

(c) $\frac{2n(n-1)}{3}$ (d) $\frac{n(2n-1)}{3}$

where :

n = Number of links

Ans. **(a)**

Sol. No. of I-centres in a mechanism containing n links

$$\boxed{N = \frac{n(n-1)}{2}}$$

69. In cycloidal motion of cam follower, the maximum acceleration of follower motion f_{max} at $\theta = \frac{\varphi}{4}$

(a) $\frac{h\pi\omega^2}{2\varphi^2}$ (b) $\frac{3h\pi\omega^2}{2\varphi^2}$

(c) $\frac{2h\pi\omega^2}{\varphi^2}$ (d) $\frac{3h\pi\omega^2}{\varphi^2}$

where:

h = Maximum follower displacement

ω = Angular velocity of cam

φ = Angle for the maximum follower displacement for cam rotation

Ans. (c)

Sol.

Acceleration,

$$f = \frac{2h\pi\omega^2}{\phi^2}\cdot\sin\left(\frac{2\pi\theta}{\phi}\right)$$

at $\theta = \frac{\phi}{4}$

$$f = f_{max} = \frac{2h\pi\omega^2}{\phi^2}\cdot\sin\left(\frac{2\pi\times\phi}{4}\right)$$

$$\boxed{f_{max} = \frac{2h\pi\omega^2}{\phi^2}}$$

70. A shaft of span 1 m and diameter 25 mm is simply supported at the end. It carriers a 1.5 kN concentrated load at mid-span. If E is 200 GPa, its fundamental frequency will be nearly

(a) 3.5 Hz (b) 4.2 Hz

(c) 4.8 Hz (d) 5.5 Hz

Ans. (d)

Sol.

Fundamental frequency $f = \frac{\omega_n}{2\pi}$

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{\Delta}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{g}{\frac{PL^3}{48EI}}} \qquad \left\{\Delta = \frac{PL^3}{48EI} \text{ for SSB}\right\}$$

$$= \frac{1}{2\pi}\sqrt{\frac{9810\times48\times200\times10^3\times\pi\times25^4}{1.5\times10^3\times1000^3\times64}}$$

$$\boxed{f = 5.5\text{ Hz}}$$

71. A vibrating system consists of mass of 50 kg, a spring with a stiffness of 30 kN/m and a damper. If damping is 20% of the critical value, the natural frequency of damped vibrations will be

(a) 16 rad/s (b) 20 rad/s

(c) 24 rad/s (d) 28 rad/s

Ans. (c)

Sol. m = 50 kg, k = 30 kN/m

$$\xi = 0.20$$

$$\omega_n = \sqrt{\frac{k}{m}}$$

$$= \sqrt{\frac{30\times10^3}{50}} = 24.49 \text{ rad/s}$$

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

$$= \sqrt{1-0.20^2}\times24.49$$

$$= 24 \text{ rad/s}$$

72. A refrigerator unit having a mass of 35 kg is to be supported on three springs, each having spring stiffness s. The unit operates at 480 rpm. If only 10% of the shaking force is allowed to transmit to the supporting structure, the value of stiffness will be nearly

(a) 2.7 N/mm (b) 3.2 N/mm

(c) 3.7 N/mm (d) 4.2 N/mm

Ans. (a)

Sol. m = 35 kg, N = 480 rpm

Stiffness = s

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

$$= \frac{2\pi\times480}{60} = 50.27 \text{ rad/s}$$

Transmissibility, $\epsilon_T = 0.10$

$$= \frac{1}{\pm(1-r^2)}$$

$\{$when $\xi = 0$, Assume $\xi = 0\}$

Consider –ive sign

$$10 = -1 + r^2$$

$$r^2 = 11$$

$$r = \sqrt{11}$$

$$\frac{\omega}{\omega_n} = 3.317$$

$$\omega_n = \frac{50.27}{3.317}$$

$$\sqrt{\frac{s_{eq}}{m}} = 15.16$$

$$s_{eq} = 15.16^2 \times 35 = 8043.89 \text{ N/m}$$

$$s = \frac{s_{eq}}{3} = 2.68 \times 10^3 \text{ N/m}$$

$$\boxed{s = 2.7\text{ N/mm}}$$

73. In which one of the following tooth profiles, does the pressure angle remain constant throughout the engagement of teeth?

(a) Cycloidal (b) Involute

(c) Conjugate (d) Epicycloid

Ans. **(b)**

Sol. In case of involute tooth profile pressure angle remains constant.

74. If the axes of the first and last wheels of a compound gear coincide, it is called

(a) Simple gear train

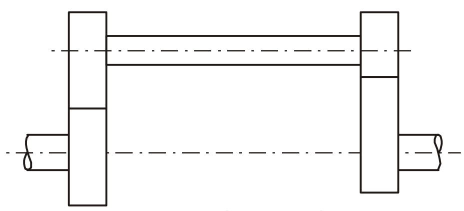
(b) Compound gear train

(c) Epicyclic gear train

(d) Reverted gear train

Ans. **(d)**

Sol.



Reverted gear train

75. In a reciprocating engine, the force along the connecting rod F_Q is

(a) $\frac{F_P}{\sqrt{n^2 - \sin^2\theta}}$ (b) $\frac{F_P}{2\sqrt{n^2 - \sin^2\theta}}$

(c) $\frac{nF_P}{2\sqrt{n^2 - \sin^2\theta}}$ (d) $\frac{nF_P}{\sqrt{n^2 - \sin^2\theta}}$

where

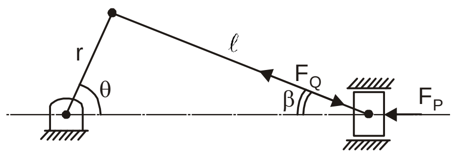
F_P = Force on piston

$n = \frac{L}{r}$

θ = Angle of crank from IDC

Ans. **(d)**

Sol.



$$F_Q\cos\beta = F_P$$

$$F_Q = \frac{F_P}{\cos\beta}$$

but $\sin\beta = \frac{\sin\theta}{n}$ $\left(\text{where } n = \frac{\ell}{r}\right)$

$$\cos\beta = \sqrt{1 - \frac{\sin^2\theta}{n^2}} = \frac{\sqrt{n^2 - \sin^2\theta}}{n}$$

so, $F_Q = \frac{nF_P}{\sqrt{n^2 - \sin^2\theta}}$

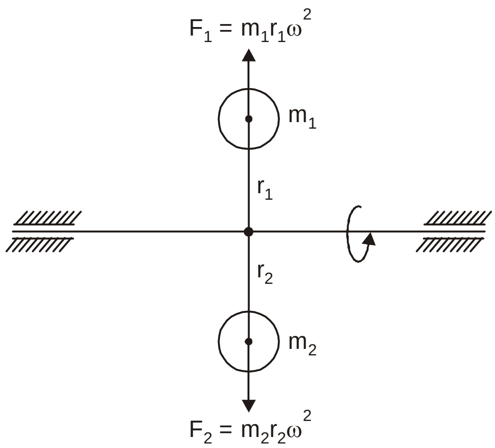
76. A mass m_1 attached to a shaft at radius r_1 rotating with angular velocity ω rad/s, can be balanced by another single mass m_2 which is attached to the opposite side of the shaft at radius r_2 in the same plane, if

(a) $m_1r_2 = m_2r_1$ (b) $m_1r_1 = m_2r_2$

(c) $m_1r_1\omega_1 = m_2r_2\omega_2$ (d) $m_1r_2\omega_1 = m_2r_1\omega_2$

Ans. **(b)**

Sol.



For complete balancing $F_1 = F_2$

$$\boxed{m_1 r_1 = m_2 r_2}$$

77. For a single cylinder reciprocating engine speed is 500 rpm, stroke is 150 mm, mass of reciprocating parts is 21 kg; mass of revolving parts is 15 kg at crank radius. If two-thirds of reciprocating masses and all the revolving masses are balanced, the mass at a radius of 150 mm will be

(a) 7.5 kg (b) 10.5 kg

(c) 12.5 kg (d) 14.5 kg

Ans. **(d)**

Sol. N = 500 rpm, stroke = 150 mm

r = 75 mm

$m_{rec.}$ = 21 kg

$m_{rev.}$ = 15 kg

$$C = \frac{2}{3}$$

r_b = 150 mm

$$m_b r_b = \left(m_{rev.} + \frac{2}{3} m_{rec.}\right) \cdot r$$

$$m_b \times 150 = \left(15 + \frac{2}{3} \times 21\right) \times 75$$

$$\boxed{m_b = 14.5\text{ kg}}$$

78. If the axes of the rolling of the ship and of the stabilizing rotor are parallel, it will result in

(a) A higher bow and lower stern

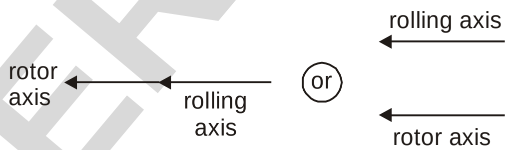
(b) A lower bow and higher stern

(c) Turning towards left

(d) No gyroscopic effect

Ans. **(d)**

Sol.



Since both the axis are parallel.

So, there is no gyroscopic effect

79. Coaxing is a process of

(a) improving the fatigue properties, attained by under-stressing and then raising the stress in small increments

(b) Decreasing the hardness by full annealing

(c) Increasing the uniaxial tensile strength by heating above recrystallization temperature and quenching in oil media

(d) Maintaining the ductility of the material by chemical treatment

Ans. **(a)**

Sol. The fatigue resistance of some metals may be improved by understressing followed by a process of gradually increasing the amplitude of the alternating stress in small increments a procedure ordinarily called ‘coaxing’.

80. According to the distortion-energy theory, the yield strength in shear is

(a) 0.277 times the yield stress

(b) 0.377 times the maximum shear stress

(c) 0.477 times the yield strength in tension

(d) 0.577 times the yield strength in tension

Ans. **(d)**

Sol. According to the distortion - energy theory, the yield strength in shear is 0.577 times the yield strength in tension.

By

$$2(S_{yt})^2 = \left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right]$$

$$\sigma_1 = \tau$$

$$\sigma_2 = -\tau$$

$$\sigma_3 = 0$$

$2(S_{yt})^2 = [(\tau + \tau)^2 + (-\tau - 0)^2 + (0 - \tau)^2]$

$2(S_{yt})^2 = [(4\tau^2 + \tau^2 + \tau^2)$

$(S_{yt})^2 = 3\tau^2$

$$\tau = \frac{S_{yt}}{\sqrt{3}}$$

$$\boxed{\tau = 0.577\, S_{yt}}$$

81. For the prediction of ductile yielding, the theory of failure utilized is

(a) Maximum strain energy theory

(b) Distortion energy theory

(c) Maximum normal strain theory

(d) Mohr theory

Ans. (b)

Sol. For the prediction of ductile yielding distortion energy theory is used.

82. A steel specimen is subjected to the following principal stresses: 120 MPa tensile, 60 MPa tensile and 30 MPa compressive. If the proportionality limit for the steel specimen is 250 MPa; the factor of safety as per maximum shear stress theory will be nearly

(a) 1.3 (b) 1.7

(c) 2.3 (d) 2.7

Ans. (b)

Sol.

$$\sigma_1 = 120 \text{ MPa}$$

$$\sigma_2 = 60 \text{ MPa}$$

$$\sigma_3 = -30 \text{ MPa}$$

$$S_{yt} = 250 \text{ MPa}$$

By maximum shear stress theory

$$\frac{S_{yt}}{FOS} = \sigma_1 - \sigma_3$$

$$FOS = \frac{S_{yt}}{\sigma_1 - \sigma_3}$$

$$FOS = \frac{250}{120 + 30}$$

$$FOS = 1.7$$

83. For which one of the following loading conditions is the standard endurance strength multiplied by a load factor, K_e = 0.9?

(a) Reversed beam bending loads

(b) Reversed axial loads with no bending

(c) Reversed axial loads with intermediate bending

(d) Reversed torsion loads

Ans. (b)

Sol. The load factor, k_e = 0.9 for reversed axial loads with no bending.

For, reversed torsional/shear loads (brittle material), k_e = 0.8

and for compressive reversed or bending loads, k_e = 1.

84. A 120 mm wide uniform plate is to be subjected to a tensile load that has a maximum value of 250 kN and a minimum value of 100 kN. The properties of the plate material are: endurance limit stress is 225 MPa, yield point stress is 300 MPa. If the factor of safety based on yield point is 1.5, the thickness of the plate will be nearly

(a) 12 mm (b) 14 mm

(c) 16 mm (d) 18 mm

Ans. (a)

Sol.

$$w = 120 \text{ mm}$$

$$P_1 = 250 \text{ kN}$$

$$P_2 = 100 \text{ kN}$$

$$S_{yt} = 300 \text{ MPa}$$

$$S_e = 225 \text{ MPa}$$

$$FOS = 1.5$$

Let t is the thickness of plate

$$\sigma_{max} = \frac{P_1}{A}$$

$$= \frac{250\times10^3}{120\times t}\text{ MPa}$$

$$\sigma_{min} = \frac{P_2}{A} = \frac{100\times10^3}{120t}\text{MPa}$$

Mean stress,

$$\sigma_m = \frac{\sigma_{max}+\sigma_{min}}{2}$$

$$= \frac{250\times10^3+100\times10^3}{2\times120\times t}$$

$$= \frac{175\times10^3}{120t}\text{MPa}$$

Amplitude stress

$$\sigma_A = \frac{\sigma_{max}-\sigma_{min}}{2}$$

$$= \frac{250\times10^3-100\times10^3}{2\times120t}$$

$$= \frac{75\times10^3}{120t}$$

By Goodman formula,

$$\frac{\sigma_m}{S_{yt}}+\frac{\sigma_A}{S_e} = \frac{1}{FOS}$$

$$\frac{175\times10^3}{120t\times300}+\frac{75\times10^3}{120t\times225} = \frac{1}{1.5}$$

$$t = 11.45 \text{ mm}$$

$$\simeq 12 \text{ mm}$$

85. A steel connecting rod having S_{ut} = 1000 MN/m^2, S_{yt} = 900 MN/m^2 is subjected to a completely reversed axial load of 50 kN. By neglecting any column action, if the values of k_e = 0.85, k_b = 0.9, k_a = 0.82, k_t = 1.5, q = 0.6 and N = 2, the diameter of the rod will be nearly

(a) 20 mm (b) 23 mm

(c) 26 mm (d) 29 mm

Ans. (c)

Sol.

$$S_e = K_aK_bK_cK_d\ (0.5\ S_{ut})$$

$$K_f = q(k_t - 1) + 1$$

$$K_f = 0.6\ (1.5 - 1) + 1$$

$$K_f = 1.3$$

$$K_d = \frac{1}{K_f} = \frac{1}{1.3} = 0.77$$

$$S_e = 0.82 \times 0.9 \times 0.85 \times 0.77 \times 0.5 \times 1000$$

$$S_e = 241.51 \text{ MPa}$$

Axial endurance stress

$$(S_e)_a = 0.8 \times 241.51$$

$$(S_e)_a = 193.2 \text{ MPa}$$

$$\frac{(S_e)_a}{FOS} = \frac{P}{\frac{\pi}{4}d^2}$$

$$d^2 = \frac{4P\times FOS}{\pi\times(S_e)_a}$$

$$d = \sqrt{\frac{4\times50\times10^3\times2}{\pi\times193.2}}$$

$$d = 25.67 \text{ mm}$$

$$\boxed{d\approx26\text{mm}}$$

86. During crushing or bearing failure of riveted joints

(a) The holes in the plates become oval shaped and joints become loose

(b) There is tearing of the plate at an edge

(c) The plates will crack in radial directions and joints fail

(d) The rivet heads will shear out by applied stress

Ans. (a)

Sol. During crushing failure of riveted joints the holes in the plates becomes oval shaped and joints become loose.

87. The double riveted joint with two cover plates for boiler shell is 1.5 m in diameter subjected to steam pressure of 1 MPa. If the joint efficiency is 75%, allowable tensile stress in the plate is 83 MN/m^2, compressive stress is 138 MN/m^2 and shear stress in the rivet is 55 MN/m^2, the diameter of rivet hole will be nearly

(a) 8 mm (b) 22 mm
(c) 36 mm (d) 52 mm

Ans. **(b)**

Sol. Given:

Pressure, P = 1 MPa

Diameter, d = 1.5 m

Joint efficiency, $\eta = 0.75$

$$\sigma_t = 83 \text{ MN/m}^2$$

$$\sigma_c = 138 \text{ MN/m}^2$$

$$\sigma_c = 55 \text{ MN/m}^2$$

For boiler shell,

thickness of cylindrical shell,

$$t = \frac{PD}{2\sigma_t \eta} + CA$$

$\because$ Here, CA (corrosion allowance)

Putting the respective values,

$$t = \frac{1 \times 1.5 \times 1000}{2 \times 83 \times 0.75} + 2$$

$$= 14.048 \text{ mm}$$

$\because$ $t > B$

So, using Unwin's formula,

Diameter of rivet, d = $6\sqrt{t}$

$$= 6\sqrt{14.048}$$

$$d = 22.48 \text{ mm}$$

So, the closest option is (b).

88. A bearing supports a radial load of 7000 N and a thrust load of 2100 N. The desired life of the ball bearing is 160 × 10^6 revolution at 300 rpm. If the load is uniform and steady, service factor is 1, radial factor is 0.65, thrust factor is 3.5, k = 3 and rotational factor is 1, the basic dynamic load rating of a bearing will be nearly

(a) 65 kN (b) 75 kN
(c) 85 kN (d) 95 kN

Ans. **(a)**

Sol.

$$P_e = XVF_r + yF_a$$

$$P_e = 0.65 \times 1 \times 7000 + 3.5 \times 2100 \text{ N}$$

$$= 11900 \text{ N}$$

$$L_{q0} = \left(\frac{C}{P_e}\right)^k$$

$$C = P_e \times (L_{q0})^{1/k}$$

$$C = 11900 \times (160)^{1/3}$$

$$C = 64603.14 \text{ N}$$

$$C = 64.6 \text{ kN}$$

$$\boxed{C \approx 65 \text{ kN}}$$

89. A solid cast iron disk, 1 m in diameter and 0.2 m thick, is used as a flywheel. It is rotating at 350 rpm. It is brought to rest in 1.5 s by means of a brake. If the mass density of cast iron is 7200 kg/m^3, the torque exerted by the brake will be nearly

(a) 3.5 kN m (b) 4.5 kN m
(c) 5.3 kN m (d) 6.3 kN m

Ans. **(a)**

Sol. Mass of flywheel

$$m = \rho \times \frac{\pi}{4} d^2 \times t$$

$$= 7200 \times \frac{\pi}{4} \times (1)^2 \times 0.2$$

$$= 1130.97 \text{ kg}$$

Moment of inertia (I)

$$I = \frac{MR^2}{2} = \frac{1130.97 \times (0.5)^2}{2}$$

$$= 141.37 \text{ kg-m}^2$$

$$\omega = \omega_0 + \alpha t$$

$$0 = \frac{2\pi \times 350}{60} + \alpha \times 1.5$$

$$\alpha = -\frac{2\pi \times 350}{60 \times 1.5} = -24.43 \text{ rad/s}^2$$

Torque (T) = $I\alpha$

= 141.37 × 24.43

= 3453.67 Nm

= 3.45 kNm

$\boxed{T \approx 3.5 \text{ kNm}}$

90. The torque transmitting capacity of friction clutches can be increased by

(a) Use of friction material with a lower coefficeint of friction

(b) Decreasing the mean radius of the friction disk

(c) Increasing the mean radius of the friction disk

(d) Decreasing the plate pressure

Ans. (c)

Sol. $T = \mu W R_m$

$T \alpha R_m$

So the torque transmitting capacity of friction clutches can be increased by increasing the mean radius of the friction disk.

91. The ideal gas-refrigeration cycle is the same as the

(a) Brayton cycle

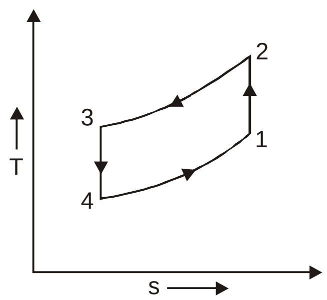
(b) Reversed Brayton cycle

(c) Vapour compression refrigeration cycle

(d) Vapour absorption refrigeration cycle

Ans. (b)

Sol. Reversed Brayton Cycle is used in gas-refrigeration cycle.



92. If the atmospheric conditions are 20°C, 1.013 bar and specific humidity of 0.0095 kg/kg of dry air, the partial pressure of vapour will be nearly

(a) 0.076 bar (b) 0.056 bar

(c) 0.036 bar (d) 0.016 bar

Ans. (d)

Sol.

Specific humidity,

$$\omega = \frac{0.622P_v}{P - P_v}$$

Given that, P = 1.013 bar

ω = 0.0095 kg/kg of dry air

$$0.0095 = \frac{0.622 \times P_v}{1.013 - P_v}$$

P_v = 0.016 bar

93. In air-conditioning systems, air may be cooled and dehumidified by

1. Spraying chilled water to air in the form of fine mist
2. Circulating chilled water or brine in a tube placed across the air flow.
3. Placing the evaporator coil across the air flow.

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)

In case of chilled water, it is very difficult to maintain temperature of chilled water less than DPT of entry air. Even if it is maintained, air carries water vapor along with it in the process of heat exchange by which humidity will increase. Hence this process reduce temperature but humidity goes up.

94. A duct of rectangular cross-section 600 mm × 400 mm carries 90 m^3/min of air having density of 1.2 kg/m^3. When the quantity of air in both cases is same, the equivalent diameter of a circular duct will be nearly

(a) 0.86 m (b) 0.76 m

(c) 0.64 m (d) 0.54 m

Ans. (d)

Sol. There are two methods for finding out the equivalent diameter for a given cross-section.

(A) The rectangular duct carrying the same quantity of air as circular duct and the pressure drop per unit length of duct in both cases is same.

$$\therefore \quad D = 1.265\left[\frac{(ab)^3}{(a+b)}\right]^{\frac{1}{5}}$$

where a and b are the two sides of the duct and D is the diameter of the circular duct.

(B) The air velocity through rectangular duct is same as circular and pressure drop per unit length of duct in both cases is same.

$$D = \frac{2ab}{a+b}$$

Now, Using the following equation,

$$D = 1.265\left[\frac{(ab)^3}{(a+b)}\right]^{\frac{1}{5}}$$

$$= 1.265\left[\frac{(60\times40)^3}{(60+40)}\right]^{\frac{1}{5}}$$

$$= 54.5 \text{ cm or } 0.54 \text{ m}$$

95. A room having dimensions of 5 m × 5 m × 3 m contains air at 25°C and 100 kPa at a relative humidity of 75%. The corresponding value of p_s is 3.169 kPa. The partial pressure of dry air will be nearly

(a) 106 kPa (b) 98 kPa

(c) 86 kPa (d) 78 kPa

Ans. (b)

Sol.

Relative humidity,

$$\phi = 75\% \text{ or } 0.75$$

Total pressure,

$$P_t = 100 \text{ kPa}$$

Now, $$\phi = \frac{P_v}{P_s}$$

$$0.75 = \frac{P_v}{3.169}$$

Partial pressure of water vapor,

$$P_v = 2.37 \text{ kPa}$$

Now, $$P_t = P_a + P_v$$

$$100 = P_a + 2.37$$

Partial pressure of dry air,

$$P_a = 97.63 \text{ kPa}$$

96. A measure of feeling warmth or coolness by the human body in response to the air temperature, moisture content and air motion is called

(a) Dry bulb temperature

(b) Effective temperature

(c) Wet bulb temperature

(d) Dew point temperature

Ans. (b)

Sol. There is no proper method to measure the feeling of comfort as it is controlled by number of variables. Assuring that purity of the air is maintained as required and proper air motion is provided which will be just sufficient to break-away the film of air formed and vapour adjacent to the body, the comfort feeling mostly depends upon the atmospheric conditions as dry bulb temperature and relative humidity. The American Society of Heating and Ventilating Engineers has made exhaustive tests on different kinds of people subjected to wide variations of combinations of temperature, relative humidity and air motion.

Effective Temperature: The effective temperature is a measure of feeling warmth or cold to the human body in response to the air temperature, moistures content and air motion.

97. While designing a Pelton wheel, the velocity of wheel 'u' is

(a) $K_u\sqrt{gH}$ (b) $2K_u\sqrt{gH}$

(c) $K_u\sqrt{2gH}$ (d) $2K_u\sqrt{2gH}$

where :

K_u = Speed ratio

H = Net head on turbine

g = Gravity

Ans. **(c)**

Sol.

Speed ratio,

$$k_u = \frac{u}{\sqrt{2gH}}$$

$$u = k_u\sqrt{2gH}$$

Here, H is net head on turbine and u is wheel velocity.

98. The turbines of the same shape will have the same

(a) Thomas number

(b) Reynolds number

(c) Specific speed

(d) Rotational speed

Ans. **(c)**

Sol. The specific speed of any turbine is the speed in r.p.m. of a turbine geometrically similar to the actual turbine.

99. A centrifugal pump is required to lift 0.0125 m^3/s of water from a well with depth 30 m. If rating of the pump motor is 5 kW, and the density of water is 1000 kg/m^3, the efficiency of the pump will be nearly

(a) 82% (b) 74%

(c) 66% (d) 58%

Ans. **(b)**

Sol. Q = 0.0125 m^3/s

H = 30 m

Actual power,

$$P_a = \rho QgH$$

$$= 1000 \times 0.0125 \times 9.81 \times 30$$

$$= 3.678 \text{ kW}$$

Pump motor power,

$$P_m = 5 \text{ kW}$$

Efficiency of pump,

$$\eta = \frac{P_a}{P_m}\times 100\%$$

$$= \frac{3.678}{5}\times 100\%$$

$$= 73.57\%$$

100. An inward flow reaction turbine has an external diameter of 1 m and its breadth at inlet is 250 mm. If the velocity of flow at inlet is 2 m/s and 10% of the area of flow is blocked by blade thickness, the weight of water passing through the turbine will be nearly

(a) 10 kN/s (b) 14 kN/s

(c) 18 kN/s (d) 22 kN/s

Ans. **(b)**

Sol. D_1 = 1m: B_1 = 0.25 m;

V_{f1} = 2 m/s

Blade thickness coefficient (k) = 0.9

$$Q = k\pi D_1B_1 \times V_{f1}$$

$$= 1.413 \text{ m}^3/\text{s}$$

Weight of water = ρgQ

$$= 13.86 \text{ kN/s}$$

101. The process of abstracting steam at a certain section of the turbine and subsequently using it for heating feed water supplied to the boiler is called

(a) Reheating

(b) Regeneration

(c) Bleeding

(d) Binary vapour cycle

Ans. **(b)**

Sol. Bleeding is a process by which we extract the steam from turbine which has various application in passout turbine regeneration etc. In regeneration extracted steam is used to heat feed water to boiler.

102. When blade speed ratio is zero, no work is done because the distance travelled by the blade is zero even if the torque on the blade

(a) is minimum

(b) is zero

(c) is maximum

(d) remains the same

Ans. **(c)**

Sol. In impulse steam turbine, the maximum efficiency is $\cos^2\alpha$ and maximum work done per kg of steam is $2V_b^2$ when $\rho = \cos\alpha/2$.

When $\rho = 0$, the work done becomes zero as the distance travelled by the blade (V_b) is zero, even though the torque on the blade is maximum.

When $\rho = 1$, the work done is zero as the torque acting on the blades becomes zero even though the distance travelled by the blade is maximum.

103. In an axial flow turbine, the utilization factor has an absolute maximum value of unity, for any degree of reaction if the value of nozzle angle α is

(a) 270° (b) 180°

(c) 90° (d) 0°

Ans. **(c)**

Sol. In axial flow gas turbine now a days blade angles is measured from axial, or flow direction.

i.e. Hence angle is measured with respect axis.

While in steam turbine it is with respect to tangential and direction.

so, α_1 = Angle of axial turbine

α = Angle of steam turbine

then, $\alpha_1 = 90 - \alpha$

Maximum utilization factor for steam turbine

$$= \frac{2\cos^2\alpha}{1+\cos^2\alpha}$$

So, for axial flow turbine it is

$$= \frac{2(\cos(90-\alpha_1))^2}{1+(\cos(90-\alpha_1))^2}$$

A/Q. $$\frac{2(\cos(90-\alpha_1))^2}{1+(\cos(90-\alpha_1))^2} = 1$$

α_1 = 90°

104. Which of the following are essential for a good combustion chamber of turbojet engine?

1. It should allow complete combustion of fuel.
2. It should maintain sufficiently high temperature in the zone of combustion in addition to proper atomization of fuel thus leading to continuous combustion.
3. It should not have high rate of combustion.
4. The pressure drop should be as small as possible

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

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

Ans. **(d)**

Sol. Because of turbine material limitations, only a limited amount of fuel can be burnt in the combustion chamber. The exhaust products downstream of the turbine still contain a considerable amount of excess oxygen. Additional thrust augmentation can be achieved from the turbojet engine by providing an after burner in which additional fuel can be burnt.

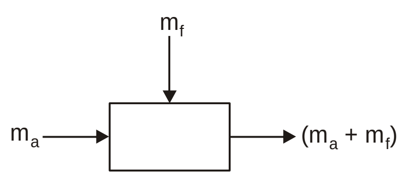
105. If m_f is the mass of fuel supplied per kg of air in one second, then the mass of gases leaving the nozzle of turbojet will be

(a) $(1-m_f)\,kg/s$ (b) $\frac{1}{(1+m_f)}kg/s$

(c) $(1+m_f)\,kg/s$ (d) $\frac{1}{(1-m_f)}kg/s$

Ans. **(c)**

Sol.



[Leaving mass from Nozzle]

As per question,

m_a is unity $\Rightarrow$ m_a = 1.

So, $m_a + m_f = (1 + m_f)$ kg/s.

106. Which one of the following may be considered as a single cylinder two-stroke reciprocating engine running at 2400 rpm to 2700 rpm for rapid chain of impulses?

(a) Turbo jet (b) Pulse jet

(c) Ram jet (d) Athodyd jet

Ans. **(a)**

Sol.

- Athodyel is nothing but an aero-thermodynamic duct.
- It is a straight duct type of engine without a compressor and turbine wheels.
- The entire compression is obtained by a ram, eliminating the need of turbine.
- Ramjet and pulse jet are the type of it.
- Turbojet uses turbine and compressor.

107. In jet propulsion of ships, when the inlet orifices are at right angles to the direction of motion of the ships, the efficiency of propulsion η is

(a) $\dfrac{2u^2}{V+u}$ (b) $\dfrac{2Vu}{(V+u)^2}$

(c) $\dfrac{2u}{(V+u)^2}$ (d) $\dfrac{2Vu}{V+2u}$

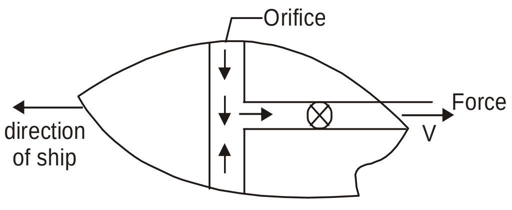
where :

V = Absolute velocity of the issuing jet

u = Velocity of the moving ship

Ans. **(b)**

Sol.



$V_r = V + u$

Mass of water / fluid issuing from orifice, back of the ship

$= \rho \times$ area of orifice $\times$ relative velocity

$= \rho \times a \times V_r = \rho \times a \times (V+u)$

Propulsive force exerted on the ship

$= \rho \times a \times (V+u)[V_r - u]$

$= \rho a (V+u) \times V$

So, Thrust power = $\rho \times a (V+u) \times V \times u = TP$

$$\eta_{prop} = \frac{TP}{TP + K.E.\ loss}$$

$$= \frac{\rho a (V+u) V \times u}{\rho a (V+u) V \times u + \frac{\rho a (V+u)(V-u)^2}{2}} = \frac{2Vu}{(V+u)^2}$$

where ρ = density of fluid / water

a = area of orifice

108. 0.8 kg of air flows through a compressor under steady state conditions. The properties of air at entry are : pressure 1 bar, velocity 10 m/s, specific volume 0.95 m^3/kg and internal energy 30 kJ/kg. The corresponding values at exit are 8 bar, 6 m/s, 0.2 m^3/kg and 124 kJ/kg. Neglecting change in potential energy, the power input will be

(a) 117 kW (b) 127 kW

(c) 137 kW (d) 147 kW

Ans. **(b)**

Sol. M_a = 0.8 kg

By steady flow energy equation

$$h_1 + \frac{c_1^2}{2000} + \frac{g_2^2}{1000} + q_{cv}$$

$$= h_2 + \frac{c_2^2}{2000} + \frac{g_2^2}{1000} + w_q$$

$$W_q = (h_1 - h_2) + \frac{c_1^2 - c_2^2}{2000}$$

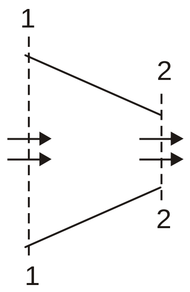
$$= (125 - 284) + \frac{10^2 - 6^2}{2000}$$

= –159 + 0.032

W_{input} = 159 kJ/kg

Total power input = 159 kJ/kg × 0.8 Kg/s

= 127 kW



$$\begin{array}{ll} P_1 = 1\,\text{bar} & P_2 = 8\,\text{bar} \\ C_1 = 10\,\text{m/s} & C_2 = 6\,\text{m/s} \\ v_1 = 0.95\,\text{m}^3/\text{kg} & v_2 = 0.2\,\text{m}^3/\text{ms} \\ u_1 = 30\,\text{ms/kg} & u_2 = 124\,\text{ms/mg} \\ h_1 = u_1 + P_1 v_1 & h_2 = u_2 + P_2 V_2 \end{array}$$

$$\begin{array}{ll} = 30 + (100 \times 0.95) & = 124 + 800(0.2) \\ = 125\,\text{ms/mg} & = 284\,\text{ms/mg} \end{array}$$

109. In a power plant, the efficiency of the electric generator, turbine, boiler, cycle and the overall plant are 0.97, 0.95, 0.92, 0.42 and 0.33 respectively. In the generated electricity, the auxiliaries will consume nearly

(a) 7.3% (b) 6.5%

(c) 5.7% (d) 4.9%

Ans. **(a)**

Sol. $\eta_{\text{plant}} = \eta_{\text{Boiler}} \times \eta_{\text{Turbine(mech)}} \times \eta_{\text{Generator}} \times \eta_{\text{Cycle}} \times \eta_{\text{Auxiliaries}}$

$$\therefore \eta_{\text{Auxiliaries}} = \frac{0.33}{0.97 \times 0.95 \times 0.92 \times 0.42}$$

= 0.9268

1 – 0.9268 = 0.0732

or 7.32% of total electricity generated is consumed by the auxiliaries.

110. The higher power requirements for compression in a steam power plant working on Carnot vapour cycle

(a) Increases the plant efficiency as well as work ratio

(b) Reduces the plant efficiency as well as work ratio

(c) Does not affect the plant efficiency as well as work ratio

(d) Increases the plant efficiency and reduces work ratio

Ans. **(b)**

Sol. $x = \dfrac{W_{net}}{Q_s} = \dfrac{W_T - W_c}{Q_s}$

Increase in power input (w_c) will reduce efficiency of cycle work ratio

$$= \frac{W_{net}}{W_T} = \frac{W_T - W_c}{W_T}$$

As power input increases, work ratio decreases.

111. For the same compression ratio, the Brayton cycle efficiency is

(a) Same as the Diesel cycle efficiency

(b) Equal to the Otto cycle efficiency

(c) More than the Diesel cycle efficiency

(d) Less than the Otto cycle efficiency

Ans. **(b)**

Sol. Efficiency of Brayton cycle = $1 - \dfrac{1}{(r_P)^{\gamma-1/\gamma}}$

$$= 1 - \frac{1}{(r)^{\gamma-1}}$$

Where r = compression ratio

Efficiency of otto cycle = $1 - \dfrac{1}{(r)^{\gamma-1}}$

Hence for same compression ratio, brayton cycle efficiency is equal to otto cycle efficiency.

112. An economizer in a steam generator performs the function of preheating the

(a) Combustion air

(b) Feed water

(c) Input fuel

(d) Combustion air as well as input fuel

Ans. **(b)**

Sol. Economizer heats the feed water supplied to the boiler drum by utilizing heat of exhaust gases.

113. Air enters the compressor of a gas turbine plant operating on Brayton cycle at 1 bar and 27°C. The pressure ratio in the cycle is 6. If the relation between the turbine work W_T and compressor work W_C is $W_T = 3W_C$ and $\gamma = 1.4$, the cycle efficiency will be nearly

(a) 40% (b) 50%

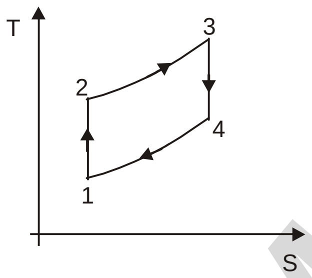
(c) 60% (d) 70%

Ans. **(a)**

Sol. $P_1 = 1$ bar; $T_1 = 27°C$

$r_P = 6$

$W_T = 3\ W_C$



Efficiency of Brayton cycle = $1-\dfrac{1}{(r_p)^{\gamma-1/\gamma}}$

$= 1-\dfrac{1}{(6)^{\frac{1.4-1}{1.4}}} = 0.40$ or 40%

114. A fluidized bed combustion system having an output of 35 MW at 80% efficiency when using a coal of heating value 26 MJ/kg with a sulphur content of 3.6% requires a particular limestone to be fed to it at a calcium-sulphur molar ratio of 3.0 so as to limit emissions of SO_2 adequately. The limestone used contains 85% $CaCO_3$. The required flow rate of limestone will be

(a) 2405 kg/h (b) 2805 kg/h

(c) 3205 kg/h (d) 3605 kg/h

Ans. **(a)**

Sol. Coal burning rate = $\dfrac{35}{0.80\times 26} = 1.683$ kg/s

= 6057.7 kg/h

$\therefore$ Flow rate of sulphur = $\dfrac{6057.7\times 0.036}{32}$

= 6.81 kmol/h

For a Ca : S molar ratio of 3.0, the flow rate of calcium is 6.81 × 3.0 = 20.44 kmol/h

$\therefore$ Mass flow rate of $CaCO_3$ required = 20.44 × 100

= 2044 kg/h (since molecular weight of $CaCO_3$ is 100)

$\therefore$ Mass flow of limestone = 2044/0.85 = 2404.7 kg/h which is about 40% of the coal burning rate.

115. In Orsat apparatus, when the percentage of carbon dioxide, oxygen and carbon monoxide are known, the remaining gas is assumed to be

(a) Hydrogen (b) Sulphur dioxide

(c) Nitrogen (d) Air

Ans. **(c)**

Sol. An orsat gas analyzer is a laboratory equipment used to analyse a gas sample for O_2, CO_2 and CO directly. Nitrogen gas content is calculated indirectly.

- Potassium hydroxide absorbs CO_2
- Pyrogallic acid absorbs O_2
- Copper chloride absorbs CO

Any left over gas is assumed to be nitrogen.

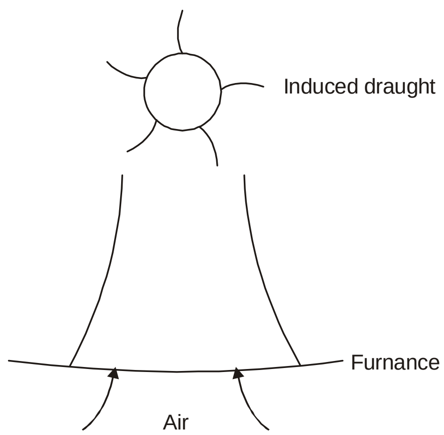
116. The partial vacuum created by the fan in the furnace and flues, draws the products of the combustion from the main flue and allows them to pass up to the chimney. Such a draught is called

(a) Balanced draught (b) Forced draught

(c) Induced draught (d) Artificial draught

Ans. **(c)**

Sol.



Induced draught fans discharge gases essentially at atmospheric pressure and place the system under negative gauge pressure in upstream side.

117. Which of the following are applied (used) ways of compounding steam turbines?

1. Pressure compounding
2. Temperature compounding
3. Velocity compounding

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

Ans. **(d)**

Sol. There are three types of compoundings used in steam turbines which are:

(1) Pressure compounding
(2) Velocity compounding
(3) Pressure-Velocity compounding

118. A steam ejector which removes air and other non-condensable gases from the condenser is known as

(a) Wet air pump (b) Dry air pump
(c) Centrifugal pump (d) Circulating pump

118.

Ans. **(b)**

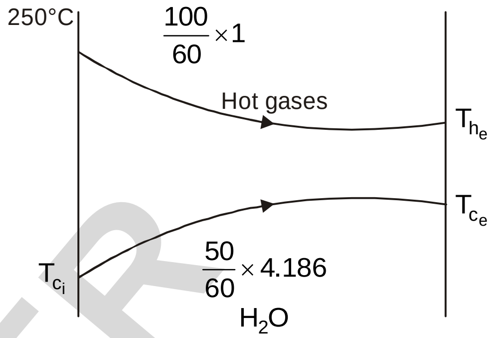
Sol. Air pumps are provided to maintain a desired vacuum in the condenser by extracting the air and other non-condensable gases. Dry air pump which removes air and non-condensable gases. Wet air pump which removes condensate and gases.

119. In a heat exchanger, 50 kg of water is heated per minute from 50°C to 110°C by hot gases which enter the heat exchanger at 250°C. The value of C_p for water is 4.186 kJ/kg.K and for air is 1 kJ/kg.K. If the flow rate of gases is 100 kg/min, the net change of enthalpy of air will be nearly

(a) 17.6 MJ/min (b) 15.0 MJ/min
(c) 12.6 MJ/min (d) 10.0 MJ/min

Ans. **(c)**

Sol.



By heat balancing in heat exchanger

$Q_{exchanged}$ by Air (Hot) = $Q_{exchanged}$ by H_2O

$Q_{exchanged}$ by Hot air = $\dot{m}_w \times c_w \times (T_{ce} - T_{ci})$

$$= \frac{50}{60}\times 4.186 \times (110-50)$$

= 209.3 kJ/s = 12.558 MJ/min

≈ 12.6 MJ/min

120. The phenomenon that enables cooling towers to cool water to a temperature below the dry bulb temperature of air is termed as

(a) Chemical dehumidification
(b) Adiabatic evaporative cooling
(c) Cooling and dehumidification
(d) Sensible cooling

Ans. **(b)**

Sol. The cooling tower utilizes the phenomenon of evaporative cooling to cool the warm water below the DBT of air. However, water never reaches the minimum temperature i.e. WBT since an excessively large cooling tower would then be required.

121. The angle through which the Earth must turn to bring the meridian of a point directly in line with the Sun's rays is called

(a) Altitude angle
(b) Hour angle
(c) Solar azimuth angle
(d) Zenith angle

Ans. **(b)**

Sol. **Hour angle:** The hour angle at any moment is the angle through which the earth must turn to bring the meridian of the observer directly in line with sun's rays.

122. In which type of collector is solar radiation focused into the absorber from the top, rather than from the bottom ?

(a) Fresnel lens

(b) Paraboloidal

(c) Concentrating

(d) Compound parabolic

Ans. **(a)**

Sol. In linear Fresnel lens collector and circular Fresnel lens concentrator solar radiation focused into the absorber from the top, rather than from the bottom.

123. A flat plate collector is 150 cm wide and 180 cm high and is oriented such that it is perpendicular to the sun rays. Its active area is 90% of the panel size. If it is in a location that receives solar insolation of 1000 W/m^2 peak, the peak power delivered to the area of the collector will be

(a) 1.23 kW (b) 2.43 kW

(c) 4.46 kW (d) 6.26 kW

Ans. **(b)**

Sol. Area of the flat plate = 150 × 180 = 27000 cm^2

= 27000 cm^2

= 2.7 m^2

Solar insolation = 1000 W/m^2

= 1000 × 2.7 × 0.90

= 2700 × 0.90

= 2.43 kW

124. A surface having high absorptance for short-wave radiation (less than 2.5 μm) and a low emittance of long-wave radiation (more than 2.5 μm), is called

(a) Absorber (b) Emitter

(c) Selective (d) Black

Ans. **(c)**

Sol. A surface having high absorption for short-wave radiation and a low emittance of long-wave radiation is called selective surface.

125. In a solar tower power system, each mirror is mounted on a system called

(a) Regenerator (b) Linear Fresnel

(c) Dish (d) Heliostat

Ans. **(d)**

Sol. A heliostat is composed of a reflective surface mirror, mirror support structure, pedestal, foundation and control and drive mechanisms.

126. The ratio of PV cell's actual maximum power output to its theoretical power output is called

(a) Quantum factor

(b) Fill factor

(c) Quantum efficiency

(d) PV factor

Ans. **(b)**

Sol. $$\text{Fill factor} = \frac{\text{Maximum power}}{\text{Theoretical power}}$$

- These power output of both the open circuit voltage and short circuit current together.
- Fill factor measure the quality of the solar cell.

127. With respect to the wind turbine blades, TSR means

(a) Tip Swift Ratio (b) Tip Sharp Ratio

(c) Tip Speed Ratio (d) Tip Swing Ratio

Ans. **(c)**

Sol.

$$\text{TSR} = \text{Tip speed ratio}$$

$$= \frac{\text{blade tip speed}}{\text{wind speed}}$$

128. For a wind turbine 10 m long running at 20 rpm in 12.9 kmph wind, the TSR will be nearly

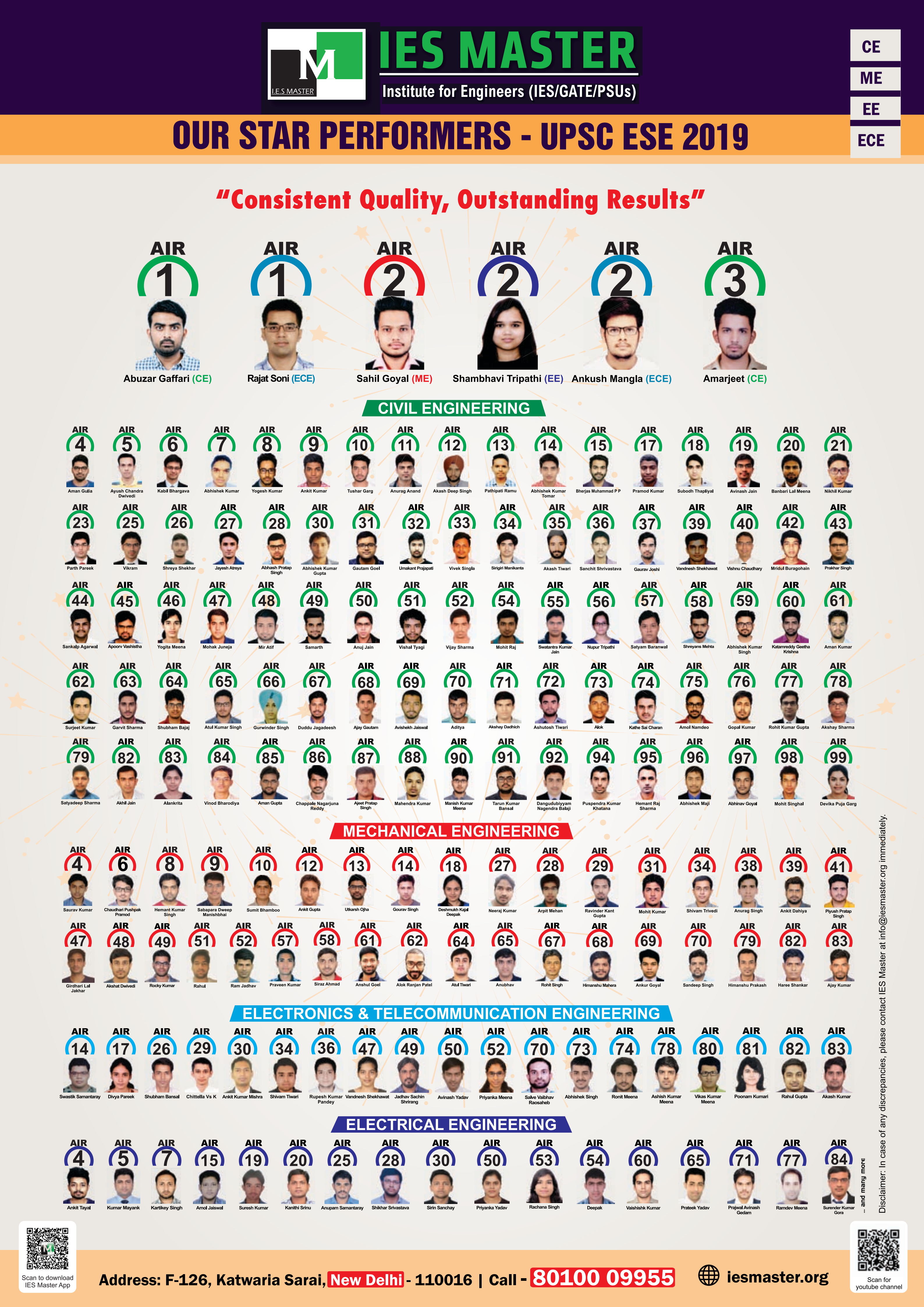
(a) 3.6 (b) 5.8

(c) 7.6 (d) 9.8

Ans. **(b)**

Sol. Given:

$$\text{Wind speed} = 12.9 \text{ kmph} = 12.9 \times \frac{5}{18} \text{m/s}$$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Blade tip speed = $\frac{\pi DN}{60}$

$$= \frac{\pi \times (10 \times 2) \times 20}{60} \text{ m/s}$$

$$\text{TSR, } \lambda = \frac{\text{blade tip speed}}{\text{wind speed}}$$

$$= \frac{\pi \times 20 \times 20 \times 18}{60 \times 12.9 \times 5}$$

$$\boxed{\lambda = 5.8}$$

129. Which one of the following is an enclosure or housing for the generator, gear box and any other parts of the wind turbine that are on the top of the tower?

(a) Turbine blade (b) Nacelle

(c) Turbine head (d) Gear box

Ans. **(b)**

Sol. The nacelle houses the generator, the gear box, the hydraulic system and yawing of wind turbine that are on the top of tower.

130. The force required for producing tides in the ocean is

(a) 70% due to Moon and 30% due to Sun

(b) 30% due to Moon and 70% due to Sun

(c) 45% due to Moon and 55% due to Sun

(d) 55% due to Moon and 45% due to Sun

Ans. **(a)**

Sol. The tides are caused by the combined attraction of the sun and the moon on the water of the revolving globe. The effect of moon is 2.6 times more than that of sun, influencing the tides of the ocean.

i.e. $\frac{70}{30} = 2.3 \approx 2.6$

131. Which of the following are related to the Proton Exchange Membrane Fuel Cell (PEMFC)?

1. Polymer electrolyte

2. Hydrogen fuel and oxygen

3. Pure water and small amount of electricity

4. Nitrogen gas

(a) 1 and 3 only

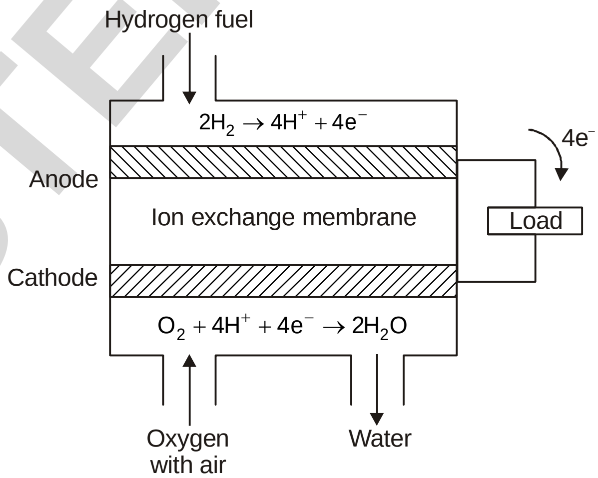
(b) 2 and 4 only

(c) 1 and 2 only

(d) 3 and 4 only

Ans. **(c)**

Sol.



Polymer electrolyte fuel cell

132. Which of the following are the essential functions of fuel cells?

1. The charging (or electrolyser) function in which the chemical AB is decomposed to A and B

2. The storage function in which A and B are held apart.

3. The charge function in which A and B are charged with the simultaneous generation of electricity.

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

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

Ans. **(c)**

Sol. (i) The charging (or electolyser) function in which the chemical AB is decomposed to A and B.

(ii) The discharge (or fuel cell) function, in which A and B are re-united, with the simultaneous generation of electricity.

133. The position of centroid can be determined by inspection, if an area has

(a) Single axis of symmetry

(b) Two axes of symmetry

(c) An irregular shape

(d) Centre axes of symmetry

Ans. **(b)**

Sol. If an area has two axes of symmetry, the position of the centroid can be determined by inspection.

In case of center of symmetry, area is symmetric about a point. It has no axes of symmetry but there is a point such that every line drawn through that point contacts the area in asymmetrical manner.

134. Which of the following statements of D'Alembert's principle are correct?

1. The net external force F actually acting on the body and the inertia force F_t together keep the body in a state of fictitious equilibrium

2. The equation of motion may be written as F + (ma) = 0 and the fictitious force (– ma) is called an inertia force

3. It tends to give solution of a static problem an appearance akin to that of a dynamic problem.

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

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

Ans. **(b)**

Sol. D'Alembert principle involves statements:

1. The net external force F actually acting on the body and the inertia force F_t together keep the body in a state of fictitious equilibrium.

2. It tends to given the solution procedure of a dynamic problem an appearance akin to that of a static problem.

Hence, statement (3) given is incorrect.

So, correct statement are 1 and 2 only.

135. The linear relationship between stress and strain for a bar in simple tension or compression is expressed with standard notations by the equation

(a) $\sigma = E\varepsilon$ (b) $\sigma = E\nu$

(c) $\sigma = G\nu$ (d) $\sigma = G\varepsilon$

Ans. **(a)**

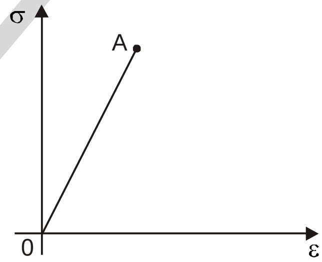
Sol. According to Hooke's law,

Stress α strain

$\sigma \,\alpha\, \varepsilon$

$$\boxed{\sigma = E\varepsilon}$$

where E = Young's modulus of elasticity



where A = proportional limit

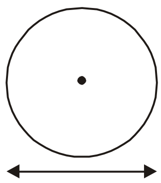
136. A punch is used for making holes in steel plates with thickness 8 mm. If the punch diameter is 20 mm and force required for creating a hole is 110 kN, the average shear stress in the plate will be nearly

(a) 139 MPa (b) 219 MPa

(c) 336 MPa (d) 416 MPa

Ans. **(b)**

Sol. In punching operation,



force required = F = $\tau \times t \times L$

where L = length of shearing region

t = thickness = 0.008 m

F = force = 110 kN

F = $\tau \times t \times \pi d$

$$110 \times 10^3 = \tau \times (8 \times 10^{-3}) \times \pi \times 20 \times 10^{-3}$$

$$\tau = \frac{110 \times 10^3 \times 10^6}{8 \times \pi \times 20}\text{Pa}$$

$$\tau = \frac{110 \times 100}{16 \times 3.14} \text{MPa} = 218.83 \text{ MPa}$$

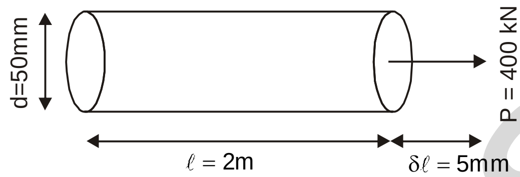
137. A rod of length 2 m and diameter 50 mm is elongated by 5 mm when an axial force of 400 kN is applied. The modulus of elasticity of the material of the rod will be nearly

(a) 66 GPa (b) 72 GPa

(c) 82 GPa (d) 96 GPa

Ans. **(c)**

Sol.



As we know, under axial load,

Change in axial length = $\frac{PL}{AE}$

$$\delta L = \frac{P \times L \times 4}{\pi d^2 \times E}$$

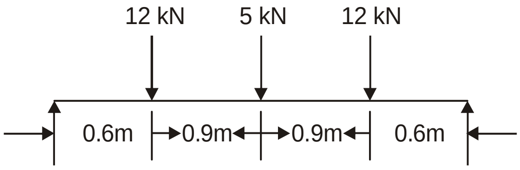
$$E = \frac{4 \times P \times L}{(\delta L) \times \pi \times d^2}$$

$$= \frac{4 \times 400 \times 10^3 \times 2}{5 \times 10^{-3} \times 3.14 \times 50^2 \times 10^{-6}}$$

$$E = \frac{4 \times 400 \times 1000 \times 2}{5 \times 2500 \times 3.14} \text{GPa}$$

$$\boxed{E = 81.48 \text{ GPa} \approx 82 \text{ GPa}}$$

138. A beam of span 3 m and width 90 mm is loaded as shown in the figure. If the allowable bending stress is 12 MPa, the minimum depth required for the beam will be

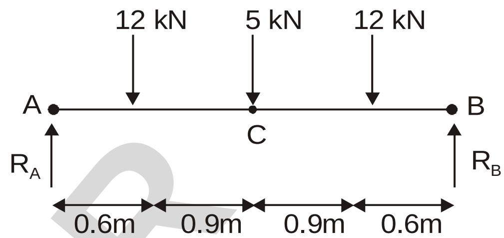


(a) 218 mm (b) 246 mm

(c) 318 mm (d) 346 mm

Ans. **(b)**

Sol.



$$\sigma_{max} = \left(\frac{M}{Z}\right)$$

To find reactions, $\Sigma M_A = 0$

$12 \times 0.6 + 5 \times 1.5 + 12 \times 2.4 - R_B \times 3 = 0$

$R_B = 14.5$ kN

$R_A + R_B = 29$ kN $\Rightarrow$ $R_A = R_B = 14.5$ kN

Bending moment is maximum at point C because shear force changes its sign at point C.

$M_c = 14.5 \times 1.5 - 12 \times 0.9 = 10.95$ kNm

$$\sigma_{max} = 12 \times 10^6 = \frac{10.95 \times 10^3}{\left(\frac{bd^2}{6}\right)} = \frac{10.95 \times 10^3 \times 6}{0.09 \times d^2}$$

d = 246.6 mm

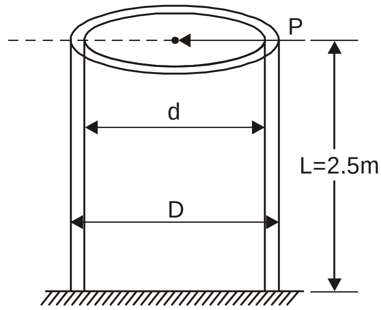
139. A vertical hollow aluminium tube 2.5 m high fixed at the lower end, must support a lateral load of 12 kN at its upper end. If the wall thickness is $\frac{1}{8}$th of the outer diameter and the allowable bending stress is 50 MPa, the inner diameter will be nearly

(a) 186 mm (b) 176 mm

(c) 166 mm (d) 156 mm

Ans. **(d)**

Sol.



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$$t = \frac{D}{8}$$

$$\sigma_{Allow} = 50 \text{ Mpa}$$

$$d = D - 2t$$

$$d = D - \frac{2\times D}{84} = \frac{3D}{4}$$

$$k = \frac{d}{D} = \frac{3}{4}$$

$$M_{max} = P \times L$$

$$\sigma_{max} = \frac{M}{Z} = \frac{32\times P\times L}{\pi D^3 (1-k^4)}$$

$$\sigma_{max} = \frac{32\times 12\times 10^3 \times 2.5}{\pi(D)^3\left[1-(0.75)^4\right]}$$

$$= 50 \times 10^6$$

$$D = 0.207 \text{ m}$$

$$d = D_i = 0.207 \times 0.75$$

$$= 0.15525 \approx 156 \text{ mm}$$

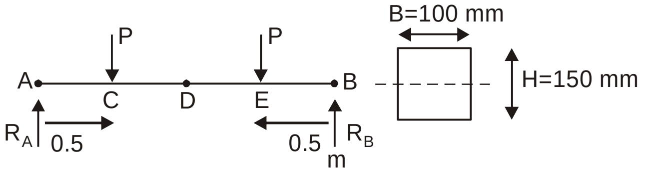
140. A wooden beam AB supporting two concentrated loads P has a rectangular cross-section of width = 100 mm and height = 150 mm. The distance from each end of the beam to the nearest load is 0.5 m. If the allowable stress in bending is 11 MPa and the beam weight is negligible, the maximum permissible load will be nearly

(a) 5.8 kN (b) 6.6 kN

(c) 7.4 kN (d) 8.2 kN

Ans. **(d)**

Sol.



$$\sigma_{max} = 11 \text{ MPa}$$

By symmetry,

$$R_A = R_B = P$$

$$\sigma_{max} = \frac{M_{max}}{Z}$$

$$M_{max} = P \times 0.5 = M_C = M_D = M_E$$

$$Z = \frac{BH^2}{6}$$

$$\sigma_{max} = 11\times 10^6 = \frac{P\times 0.5\times 6}{(0.1)(0.15)^2}$$

$$\boxed{P = 8.25 \text{ kN}}$$

141. Which of the following statements regarding thin and thick cylinders, subjected to internal pressure only, is/are correct?

1. A cylinder is considered thin when the ratio of its inner diameter to the wall thickness is less than 15.

2. In thick cylinders, tangential stress has highest magnitude at the inner surface of the cylinder and gradually decreases towards the outer surface

(a) 1 only (b) 2 only

(c) Both 1 and 2 (d) Neither 1 nor

Ans. **(b)**

Sol. A cylinder is considered as thin when ratio of diameter and thickness is greater than 20.

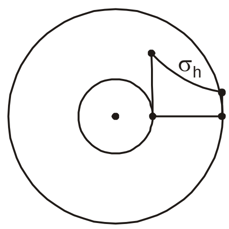
$$\boxed{\frac{d}{t} > 20}$$

Hence, statement (1) is wrong.

Hoop stress is tangential

$$\sigma_h = \frac{b}{r^2} + a$$

$$(\sigma_h)_{max.\ at\ r=R_i} = \frac{b}{R_i^2} + a$$



As shown in the stress profile, tangential stress is maximum at inner radius and decreases towards outer radius.

Hence, statement 2 is only correct.

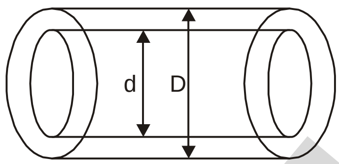
142. A cylindrical storage tank has an inner diameter of 600 mm and a wall thickness of 18 mm. The transverse and longitudinal strains induced are 255×10^{-6} mm/mm and 60×10^{-6} mm/mm, and if G is 77 GPa, the gauge pressure inside the tank will be

(a) 2.4 MPa (b) 2.8 MPa

(c) 3.2 MPa (d) 3.6 MPa

Ans. **(d)**

Sol.



Given: d = 600 mm, t = 18 mm

$$\varepsilon_\ell = 60 \times 10^{-6} \text{ mm/mm}$$

$$\varepsilon_{hoop} = \varepsilon_{transverse} = 255 \times 10^{-6} \text{ mm/mm}$$

We know that,

$$\varepsilon_\ell = \frac{Pd}{4tE}(1-2\mu) \quad \text{...(i)}$$

$$\varepsilon_{hoop} = \frac{Pd}{4tE}(2-\mu) \quad \text{...(ii)}$$

Dividing equation (i) by equation (ii),

$$\frac{\varepsilon_\ell}{\varepsilon_{hoop}} = \frac{(1-2\mu)}{(2-\mu)} = \frac{60}{255}$$

$$\Rightarrow \quad \mu = 0.3$$

$$E = 2G(1+\mu)$$

$$= 2 \times 77 \times (1.3) = 200.2 \text{ GPa}$$

Putting the respective values in equation (i),

$$60 \times 10^{-6} = \frac{P \times 600}{4 \times 18 \times 200.2 \times 10^3} \times (1-2\times 0.3)$$

$$P = 3.603 \text{ MPa} \approx 3.6 \text{ MPa}$$

143. A compressed air spherical tank having an inner diameter of 450 mm and a wall thickness of 7 mm is formed by welding. If the allowable shear stress is 40 MPa, the maximum permissible air pressure in the tank will be nearly

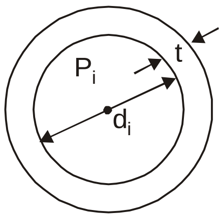
(a) 3 MPa (b) 5 MPa

(c) 7 MPa (d) 9 MPa

Ans. **(b)**

Sol. Given: d_i = 450 mm, t = 7 mm

Spherical tank



$$\sigma_{hoop} = \sigma_{longitudinal} = \frac{P_i d_i}{4t} \text{(for spherical tank)}$$

$$\text{Maximum shear stress } (\tau_{max}) = \frac{\sigma_{hoop}}{2} = \frac{p_i d_i}{8t}$$

$$40 = \frac{P_i \times 450}{8 \times 7}$$

$$P_i = 4.977 \text{ MPa} \approx 5\text{MPa}$$

144. A solid bar of circular cross-section having a diameter of 40 mm and length of 1.3 m is subjected to torque of 340 N.m. If the shear modulus of elasticity is 80 GPa, the angle of twist between the ends will be

(a) 1.26° (b) 1.32°

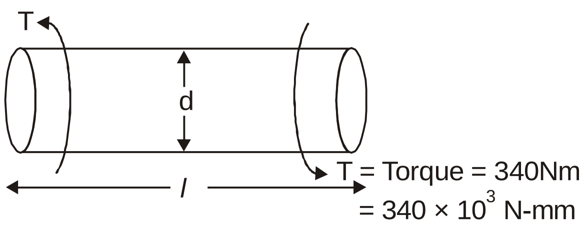
(c) 1.38° (d) 1.44°

Ans. **(a)**

Sol. Given: d = 40 mm

l = 1.3 m = 1300 mm

G = 80 GPa = 80×10^3 N/mm²



Torsion equation is given by

$$\frac{\tau}{R_o} = \frac{T}{J} = \frac{G\theta}{L}$$

$$\frac{T}{J} = \frac{G\theta}{L} \Rightarrow \theta = \frac{TL}{GJ}$$

where $J = \frac{\pi}{32}d^4$

$$\theta = \frac{340\times10^3\times1300}{80\times10^3\times\frac{\pi}{32}\times(40)^4} = 0.21983 \text{ rad}$$

$$\theta = 1.2595° \approx 1.26°$$

145. Which of the following statements regarding screw dislocation is correct?

(a) It lies parallel to its Burgers vector

(b) It moves in the direction parallel to its Burgers vector.

(c) It initially requires very less force to move.

(d) It moves very fast as compared to edge dislocation

Ans. **(a)**

Sol.

Relation with burger vector

Dislocation	Position	Direction of movement
Edge	Perpendicular	Parallel
Screw	Parallel	Perpendicular

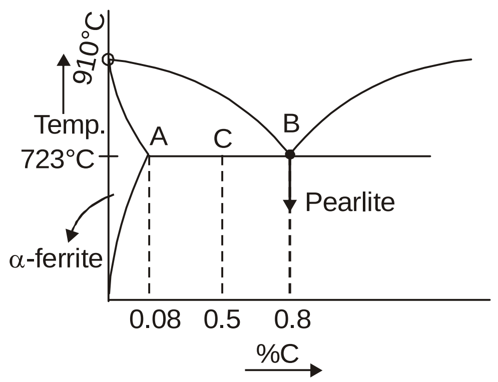
146. The percentage of pearlite in a slowly cooled melt of 0.5% of carbon steel is

(a) 48.5% (b) 52.5%

(c) 58.5% (d) 62.5%

Ans. **(c)**

Sol. Fe – c diagram



Applying lever rule at temp. 723°C i.e. Along line ACB

Mass-fraction of pearlite $= \frac{AC}{AB}\times100$

$$= \left(\frac{W_C - W_A}{W_B - W_A}\right)\times100 = \left(\frac{0.5-0.08}{0.8-0.08}\right)\times100$$

Mass-friction of pearlite $= \frac{42}{72}\times100 = 58.37\%$

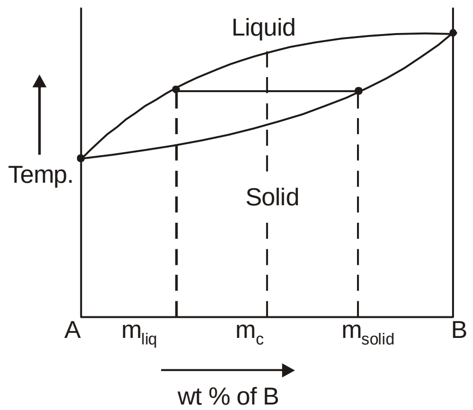
147. In the study of phase diagrams, the rule which helps to calculate the relative proportions of liquid and solid material present in the mixture at any given temperature is known as

(a) Hume-Rothery rule (b) Lever rule

(c) Gibb's phase rule (d) Empirical rule

Ans. **(b)**

Sol.



By Lever Rule

$$\% \text{ liquid} = \left(\frac{m_s - m_c}{m_s - m_\ell}\right)\times100$$

Similarly

$$\% \text{ solid} = \left(\frac{m_c - m_{liquid}}{m_s - m_\ell}\right)\times100$$

148. The phenomenon that artificially increases the dielectric constant of plastics containing fillers is known as

(a) Gamma polarization

(b) Interfacial polarization

(c) Post-forming drawing

(d) Reinforcement drawing

Ans. **(b)**

Sol. **Interfacial polarization** is phenomenon that artificially increases the dielectric strength of plastics containing fillers.

In it under the application of applied field some of defects may migrate through the material towards two electrode that has opposite polarity to their charge. If they reach the electrode and area able to discharge.

149. The addition of alloying element nickel to cast iron will primarily improve

(a) Wear resistance

(b) Toughness

(c) Carbide formation

(d) Machinability

Ans. **(b)**

Sol. The purpose of Nickel in the engineering cast irons is to control the structure by retarding austenite transformation, stabilizing pearlite and maintaining combined carbon at the eutectoid quantity.

Nickel lowers the critical temperature so pearlite forms at lower temperature so pearlite is finer and tougher in this case. Nickel also reduces the carbon content. These factor increases toughness, plasticity and fatigue resistance

150. A unidirectional fibre-epoxy composite contains 65% by volume fibre and 35% epoxy resin. If the relative density of the fibre is 1.48 and of the resin is 1.2, the percentage weight of fibre will be nearly

(a) 70% (b) 75%

(c) 80% (d) 85%

Ans. **(a)**

Sol. We know that, $\rho = \frac{\text{Mass}}{\text{volume}}$

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}}$$

$$\%\text{ volume of fibre} = \frac{V_f}{V_{epoxy} + V_{fibre}} \quad ...(i)$$

$$\%\text{ volume of epoxy} = \frac{V_e}{V_{epoxy} + V_{fibre}}$$

From equation (i) and (ii)

$$\frac{\%\text{ volume of fibre}}{\%\text{ volume of epoxy}} = \frac{V_f}{V_e} = \frac{m_f/\rho_f}{m_e/\rho_e}$$

$$\frac{0.65}{0.35} = \frac{m_f/1.48}{m_e/1.2}$$

$$\frac{m_f}{m_e} = 2.2904 \quad ...(iii)$$

and $m_f + m_e = 100$ ...(iv)

From equation (iii) and (iv)

$$m_f + \frac{m_f}{2.2904} = 100$$

$$m_f = 69.609 \approx 70$$

$$m_f = 70\%$$