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ESE

Prelims Exam

Paper - II

2021

MECHANICAL ENGINEERING

Detailed Solution

(SET-A)

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Detailed Solution

1. In various solar energy storage systems, pumped hydro-electric storage system falls under which one of the following categories?

- (a) Thermal energy storage
- (b) Electrical energy storage
- (c) Mechanical energy storage
- (d) Electromagnetic energy storage

Ans. (c)

Sol. Mechanical energy storage

Energy can be stored in various forms and the storage methods are classified on the basis of the form in which it is stored.

1. Mechanical storage
 - (a) Pumped storage
 - (b) Compressed air storage
 - (c) Flywheel storage
2. Chemical energy storage
 - (a) Batteries storage
 - (b) Hydrogen storage
 - (c) Reversible chemical reaction storage
3. Electromagnetic energy storage
4. Electrostatic energy storage
5. Thermal energy storage
6. Biological storage

2. What is the standard value of solar constant adopted by World Radiation Centre?

- (a) 1192 W/m² (b) 1084 W/m²
- (c) 1927 W/m² (d) 1367 W/m²

Ans. (d)

Sol. Solar constant value adopted by world Radiation centre is 1367 W/m².

The solar constant is defined as the energy received from the sun per unit time, on a unit area of surface perpendicular to the direction of propagation of the radiation at the top of the atmosphere and at the earth's mean distance from the sun.

3. What is the tip speed ratio of savonius wind turbine rotor?

- (a) 1 (b) 3
- (c) 5 (d) 7

Ans. (a)

Sol. Tip-speed ratio λ is defined as

$$\lambda = \frac{\text{speed of the rotor blade}}{\text{speed of incoming air}} = \frac{R\omega}{u_0}$$

Rotor Type Tip speed ratio

- | | |
|------------------------------|--------|
| 1. Propeller
(1-3 Blades) | 6 – 20 |
| 2. Sailwing | 4 |
| 3. Chalk multiblade | 3 - 4 |
| 4. American multiblade | 1 |
| 5. Dutch type | 2 - 3 |
| 6. Savonius | 1 |
| 7. Darrieus | 5 - 6 |
| 8. Musgrove and Evan | 3 - 4 |

4. What is the solidity of American multiblade wind turbine rotor?

- (a) 0.4 (b) 0.7
- (c) 0.9 (d) 1

Ans. (b)

Sol.

Rotor Type Solidity

- | | |
|---------------------|-----|
| Savonius rotor | 1 |
| American multiblade | 0.7 |

Solidity is defined as the ratio of the projected area of the rotor blades on the rotor plane to the swept areas of the rotor.

5. The energy density of Bio-ethanol is

- (a) 8.3 MJ/kg (b) 14.6 MJ/kg
- (c) 26.9 MJ/kg (d) 34.7 MJ/kg

Ans. (c)

6. The percentage of hydrogen in producer gas is

- (a) 34% (b) 27%
- (c) 18% (d) 8%

Ans. (c)

Typical gas composition of producer gas is 19 percent CO, 18 percent H₂, 1 Percent CH₄, 11 percent CO₂ and the rest N₂.

Detailed Solution

7. In single basin, double effect scheme, power is generated
- (a) during filling. (b) during emptying.
(c) on ebb only. (d) on both flood and ebb.

Ans. (d)

Sol. In single basin, double effect scheme, power is generated on both flood and ebb. Two-way (reversible) hydraulic turbines are used.

In single effect scheme, power is generated either during filling or emptying the basin.

8. The operating temperature of alkaline fuel cell is
- (a) 39°C (b) 90°C
(c) 127°C (d) 192°C

Ans. (b)

Sol. The operating temperature of alkaline fuel cell is 90°C

Cell type	Operating temperature
Phosphoric Acid fuel cell	150 – 200°C
Alkaline fuel cell	90°C
Solid polymer fuel cell	40 – 60 °C
Direct methanol fuel cell	50 – 120 °C
Molten Carbonate fuel cell	600 – 700 °C
Solid oxide fuel cell	600 –1000°C

9. The ideal emf produced by polymer electrolyte membrane fuel cell at 25°C is
- (a) 3.57 V (b) 2.94 V
(c) 1.23 V (d) 0.73 V

Ans. (c)

Sol. Polymer electrolyte membrane fuel cell (PEMFC) or solid polymer fuel cell (SPFC) operates at 40 – 60°C. The ideal emf produced is 1.23 V at 25°C.

10. Which one of the following fuel cells has highest efficiency?
- (a) PAFC (b) MCFC
(c) PEMFC (d) AFC

Ans. (d)

Sol. Characteristics of various fuel cells

Fuel Cell	Operating temp.	Fuel	Efficiency
1. PEMFC	40-60°C	H ₂	48-58%
2. AFC	90°C	H ₂	64%
3. PAFC	150-200°C	H ₂	42%
4. MCFC	600-700°C	H ₂ & Co	50%
5. SOFC	600-1000°C	H ₂ & Co	60-65%

11. How many kilograms of steam per day is produced by 15 m diameter community solar cooker developed by Centre for Scientific Research, Auroville (Puducherry)?

- (a) 100 kg (b) 300 kg
(c) 600 kg (d) 1000 kg

Ans. (c)

Sol. A 15 m diameter community solar cooker has been developed at the Centre for Scientific Research (CSR), Auroville. Around 600 kg of steam per day could be generated from this bowl.

12. In a solar passive space heating system, the south-facing thick wall is called

- (a) Vent wall (b) Trombe wall
(c) Damper wall (d) Ventilation wall

Ans. (b)

Sol. The south facing thick wall in a solar passive heating system, called Trombe wall is made of concrete, adobe, stone or composites of brick blocks and sand, designed for thermal storage.

13. All power plants use superheated steam due to which of the following advantages?

1. Superheating is mostly done from waste heat of boiler without additional cost of fuel.
2. The plant efficiency increases due to higher temperature of steam.
3. There is less corrosion and erosion of equipment due to absence of moisture in the steam.

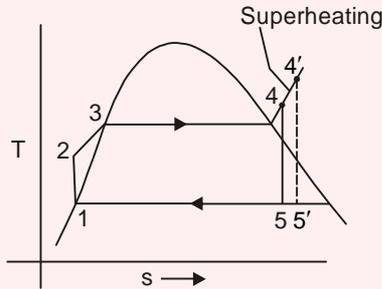
Select the correct answer using the code given below:

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

Detailed Solution

Ans. (d)

Sol.



- 1 – 2 – 3 – 4 – 5 is normal Rankine cycle
- 1–2–3–4'–5' is superheated Rankine cycle

Because of superheating mean temperature (T_m) of heat addition \uparrow .

As $\eta = f(T_m)$

So, $\eta \uparrow$ for superheated cycle

- at point 5', dryness fraction is more than at 5, so moisture content is less after the turbine exit, so less erosion and corrosion is there in superheated Rankine cycle than Rankine cycle.
- Superheaters (CSH) are placed after the reheater and before the economizer which uses waste heat releasing to the stack. Further superheated steam for convective superheater (CSH) goes to desuperheater and then to radiant superheater (again uses radiating energy waste) and then pendent superheater (PSH_t) and final superheated steam supplied to the turbine.

14. What are the effects of regenerative feedwater heating for the same turbine output?

1. It significantly increases the cycle efficiency and reduces the heat rate.
2. It increases the steam flow rate.
3. It increases the steam flow to the condenser.
4. If there is no change of boiler output, the turbine output drops.

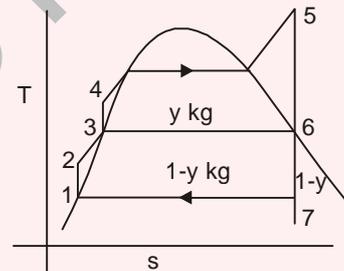
Select the correct answer using the code given below:

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

Ans. (b)

Sol. Effect of regeneration:

- $\eta \uparrow$ & Heat rate \downarrow Due to \uparrow in mean temperature of heat addition.
- For the same turbine output steam flow \uparrow (bigger boiler is required) due to bleeding of steam to heat the feed water.
- Steam flow rate in Condenser is reduces as each stage of regeneration, steam is bleeding off because of this less amount of steam condense in condenser.
- If boiler size is fixed and same amount of steam is produced then because of bleeding, less amount of steam available at turbine at each stage leads to \downarrow in turbine output.



- Due same boiler output

$$\eta = \frac{W_T \rightarrow \text{reduced}}{Q \rightarrow \text{more reduced}}$$

- Since the amount of heat input in the boiler reduced significantly compared to work lost, the efficiency \uparrow .

15. Which of the following are the advantages of pulverized coal firing?

1. Higher boiler efficiency.
2. Fast response for no load changes.
3. Ability to use low preheated air reducing internal losses.
4. Ability to release large amounts of heat enabling it to generate about 2000 t/h of steam in one boiler.

Select the correct answer using the code given below:

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

Detailed Solution

Ans. (c)

Sol. Pulverized coal firing system has following advantages:

- It has better and far response over firing with load variation.
- Ability to use high preheated air reducing exhaust losses.
- Ability to release large amount of heat enabling it to generate about 2000 t/h of steam or more in one boiler.

16. A fuel consists of 92% carbon, 7% hydrogen and remaining residual matter by mass. Working from first principles, the higher calorific value of the fuel is

- (a) 40176 kJ/kg (b) 41176 kJ/kg
(c) 40876 kJ/kg (d) 41678 kJ/kg

Ans. (b)

Sol. Heat released by carbon is combustion

$$= \frac{C_{kg} \times 407000}{12}$$

$$= \frac{0.92 \times 407000}{12}$$

$$= 31203.64 \text{ kJ/g}$$

Heat released by hydrogen in combustion

$$= 143000 \times 0.07$$

$$= 10010 \text{ kJ/kg}$$

So, HHV = 31203.64 × 10010

$$= 41213.64 \text{ kJ/kg} \approx 41176$$

17. In order to burn a fuel completely, which of the following basic conditions must be fulfilled?

1. Supply enough air for complete combustion of fuel.
2. Secure low turbulence for thorough mixing of fuel and air.
3. Maintain a furnace temperature high enough to ignite the incoming fuel air mixture.
4. Provide a furnace volume large enough to allow time for combustion to be completed.

Select the correct answer using the code given below:

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

Ans. (c)

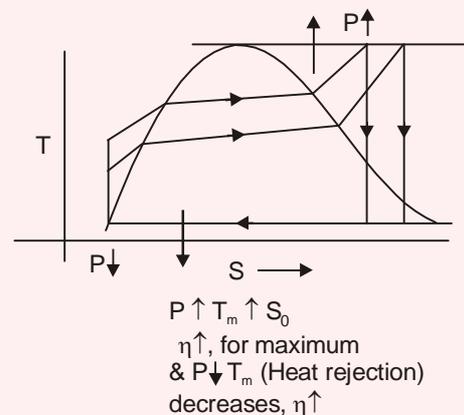
Sol. More turbulence is required for the proper mixing of fuel and air due to better surface contact.

18. The efficiency of any cycle increases with

- (a) the decrease of maximum pressure and the constant of exhaust pressure.
- (b) the decrease of maximum pressure and the decrease of exhaust pressure.
- (c) the increase of maximum pressure and the decrease of exhaust pressure.
- (d) the increase of maximum pressure and the constant of exhaust pressure.

Ans. (c)

Sol.



19. In a power plant, the efficiencies of the electric generator, turbine (mechanical), boiler, cycle and the overall plant are 0.97, 0.95, 0.92, 0.42 and 0.33, respectively. What is the efficiency of auxiliaries?

- (a) 98.14% (b) 92.68%
(c) 83.41% (d) 75.14%

Ans. (b)

Sol.

$$\eta_g = 0.97$$

$$\eta_m = 0.95$$

$$\eta_{\text{boiler}} = 0.92$$

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$$\eta_{isen} = 0.42$$

$$\eta_{overall} = 0.33$$

$$\eta_{aux} = ?$$

$$\eta_{overall} = \eta_g \times \eta_m \times \eta_{boiler} \times \eta_{ism} \times \eta_{aux}$$

$$\eta_{aux} = \frac{0.33}{0.97 \times 0.95 \times 0.92 \times 0.42}$$

$$\approx 92.68\%$$

20. Consider the following statements for analysis of steam cycles:

- (1) A steam power plant continuously converts the energy stored in fossil fuels or fissile fuels into shaft work.
- (2) Steam power plants work on Brayton cycle.
- (3) In supercritical steam cycle, steam is generated in a 'once-through' boiler at a pressure above the critical point of 27.5 bar.
- (4) Deaerator is used for the purpose of deaerating the feedwater.

Which of the above statements are correct?

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

Ans. (c)

- Sol.**
- Steam power plant works on Rankine cycle.
 - A steam power plant continuously converts the energy stored in fossil fuels on fissile fuels into shaft work.
 - Deaerator is used for the purpose of removal of air (deaerating) the feed water entering to the boiler.
 - Critical point of water is 22.12 MPa or 220 bar and 373.14°C.

21. Consider the following statements for solid fuels:

- (1) Peat is the first stage in the formation of coal from wood.
- (2) The average calorific value of bituminous coal is 1524 kJ/kg.
- (3) Anthracite is very hard coal and has a shin-

ing black lustre.

- (4) Wood charcoal is obtained by destructive distillation of wood.

Which of the above statements are correct?

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

Ans. (b)

- Sol.**
- Anthracite is the highest grade of coal, it is a shiny black dense, hard, brittle coal that borders on graphite.
 - The calorific value of coals range from 25600 to 32600 kJ/kg
 - Peat is considered as the first geological step in coal's formation.
 - Wood charcoal is obtained by destructive distillation of wood.

22. Consider the following statements for fluidized bed boilers:

- (1) Fluidized bed boilers produce steam from fossil and waste fuels by using a technique called fluidized bed combustion.
- (2) Cyclone separators are gas cleaning devices that utilize the centrifugal force created by a spinning gas stream to separate particles from a gas.
- (3) In a pressurized fluidized bed boiler, the combustion process takes place in a pressurized environment resulting in a compact furnace and improved combustion efficiency.

Which of the above statements are correct?

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

Ans. (d)

Sol. All statements are correct as per their definition.

23. Consider the following statements for steam turbines:

- (1) The ratio of actual enthalpy drop to isentropic enthalpy drop is known as mechanical efficiency.
- (2) The ratio of enthalpy drop in moving blades to enthalpy drop in the stage is known as de-

Detailed Solution

gree of reaction.

- (3) Rateau turbine is the example of reaction turbine.
- (4) Curtis turbine is the example of impulse turbine.

Which of the above statements are correct?

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

Ans. (a)

Sol.

- Rateau turbine is a pressure compounding multistage impulse turbine.
- Curtis turbine is velocity compounding multistage impulse turbine.

$$R = \frac{(\Delta h)_{\text{moving blade}}}{(\Delta h)_{\text{moving blade}} + (\Delta h)_{\text{fixed blade}}}$$

$$= \frac{(\Delta h)_{\text{moving blade}}}{(\Delta h)_{\text{stage}}}$$

$$\eta_{\text{isen}} = \frac{\text{Actual enthalpy drop}}{\text{isentropic enthalpy drop}} = \frac{(\Delta h)_{\text{act}}}{(\Delta h)_{\text{isen}}}$$

24. Consider the following statements for cooling towers:

- (1) Cooling tower is an artificial device used to cool the hot cooling water coming out of condenser more effectively.
- (2) The amount of water usually lost with induced draft cooling tower ranges from 5% to 6% by evaporation.
- (3) The amount of water usually lost with induced draft cooling tower ranges from 7% to 8% by drift losses.
- (4) The rate of evaporation of water and its cooling effect on the remaining water depends upon the relative humidity of air passing through the tower.

Which of the above statements are correct?

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

Ans. (a)

Sol. The amount of water usually lost with induced draft cooling towers ranges from 1 to 2% by evaporation and 0.5 to 2% by drift losses.

25. A single-acting reciprocating pump, running at 50 rpm delivers 0.00736 m³/s of water. The diameter of the piston is 200 mm and stroke length is 300 mm. What is the percentage slip of the pump?

- (a) 5.29% (b) 6.29%
- (c) 7.29% (d) 8.29%

Ans. (b)

Sol. Single acting reciprocating pump

$$N = 50 \text{ rpm}$$

$$Q = 0.00736 \text{ m}^3/\text{s}$$

$$D = 200 \text{ mm}$$

$$L = 300 \text{ mm}$$

$$\% \text{ slip} = ?$$

$$\% \text{ slip} = \frac{Q_{\text{th}} - Q_{\text{act}}}{Q_{\text{th}}} \times 100$$

$$Q_{\text{th}} = \frac{ALN}{60} = \frac{\pi}{4} (0.20)^2 \times 0.30 \times \frac{50}{60}$$

$$= 0.00785 \text{ m}^3/\text{s}$$

$$\% \text{ slip} = \frac{0.00785 - 0.00736}{0.00785} \times 100$$

$$= 6.25\%$$

26. A pump discharges a liquid into a tank at the rate of 0.032 m³/s. The tank, 1.5 m in diameter and 4.20 m in height, can hold 3500 kg of liquid. The density of the liquid and mass flow rate of the liquid handled by the pump are respectively,

- (a) 471.57 kg/m³ and 16 kg/s
- (b) 471.57 kg/m³ and 15 kg/s
- (c) 481.57 kg/m³ and 16 kg/s
- (d) 481.57 kg/m³ and 15 kg/s

Ans. (b)

Sol. Assuming the tank to be cylindrical,

$$\text{Volume of the tank} = \frac{\pi}{4} d^2 \times h$$



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31. A turbine develops 800 kW when running at 1000 rpm. The head on the turbine is 30 m. If the head is reduced to 18 m, what is the speed developed by the turbine?
- (a) 67.46 rpm (b) 95.24 rpm
(c) 54.67 rpm (d) 77.46 rpm

31.

Ans. (d)

Sol.

$$P_1 = 800 \text{ kW}$$

$$N_1 = 1000 \text{ rpm}$$

$$H_1 = 30 \text{ m}$$

if $H_2 = 18 \text{ m}; N_2 = ?$

$$N_u = \frac{N}{\sqrt{H}}$$

$$\Rightarrow \frac{N_2}{N_1} = \sqrt{\frac{H_2}{H_1}}$$

$$\Rightarrow N_2 = N_1 \sqrt{\frac{H_2}{H_1}} = 1000 \times \sqrt{\frac{18}{30}} = 774.60 \text{ rpm}$$

None of the given option is correct

[There seems a typographical error in the options and if 77.46 rpm is read as 774.6 rpm, option (d) may be marked as correct.

32. The steam turbine can be governed by the following methods except
- (a) Reaction governing
(b) Throttle governing only
(c) Nozzle control governing only
(d) Combination of throttle and nozzle control governing.

Ans. (a)

Sol. Steam turbine is governed by

- (i) Throttle governing
(ii) Nozzle control governing
(iii) Combination of throttle and nozzle governing.
- Reaction governing is done to increase the efficiency of turbine by the use of reaction blade.

33. In a gas turbine plant, heat supplied is 667.2 kJ/kg, and heat rejected is 391.43 kJ/kg. What is the thermal efficiency of the plant?
- (a) 57.29% (b) 72.51%
(c) 41.33% (d) 32.83%

Ans. (c)

Sol. $\eta = \frac{667.2 - 391.43}{667.2} = 41.33\%$

34. The constant pressure gas turbine works on
- (a) Stirling Cycle (b) Atkinson Cycle
(c) Rankine Cycle (d) Brayton Cycle

Ans. (d)

Sol. Brayton a cycle is constant pressure gas cycle on which gas turbine works.

35. In hydraulic turbines, if the energy available at inlet is only kinetic energy, energy, then that type of turbine is
- (a) Reaction turbine
(b) Impulse turbine
(c) Francis turbine
(d) Kaplan turbine

Ans. (b)

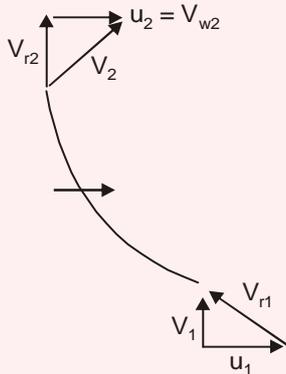
Sol. In impulse turbines, the energy at the entrance to the runner is in the form of kinetic energy only. The pressure remains atmospheric throughout the runner.

36. A centrifugal pump has an impeller of 30 cm outer diameter. The vane tips are radial at the outlet. For a rotative speed of 1450 rpm, what is the manometric head developed? (Assume a manometric efficiency of 82% and take $g = 9.81 \text{ m/s}^2$)
- (a) 37.24 m
(b) 43.38 m
(c) 29.46 m
(d) 32.88 m

Ans. (b)

Sol.

Detailed Solution



$D_2 = 30 \text{ cm}$

Vane tips are radial at outlet

$N = 1450 \text{ rpm}$

$\eta_{\text{mano}} = 82\%$

$H_m = ?$

$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.30 \times 1450}{60} = 22.765 \text{ m/s}$

$\eta_{\text{mano}} = \frac{gH_m}{V_{w2} u_2} = \frac{gH_m}{u_2^2}$

$\eta_{\text{mano}} = 0.82 = \frac{9.81 \times H_m}{(22.765)^2}$

$\Rightarrow H_m = 43.32 \text{ m}$

37. Lenoir cycle is used for

- (a) Gas turbines
- (b) Pulse jet engines
- (c) S.I engines
- (d) C.I engines

Ans. (b)

Sol.

Gas turbine \rightarrow Brayton cycle

S.I. engine \rightarrow Otto cycle

C.I engine \rightarrow Diesel cycle

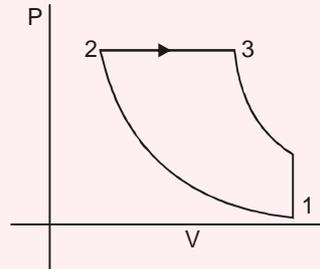
Pulse jet engine \rightarrow Lenoir cycle.

38. A diesel engines has a compression ratio of 20 and cut-off takes place at 5% of the stroke. What is the cut-off ratio

- (a) 1.21
- (b) 1.47
- (c) 1.73
- (d) 1.95

Ans. (d)

Sol.



$\frac{V_1}{V_2} = 20 = r$

$V_3 - V_2 = \frac{5}{100} (V_1 - V_2)$

$\frac{V_3}{V_2} - 1 = \frac{5}{100} \left(\frac{V_1}{V_2} - 1 \right)$

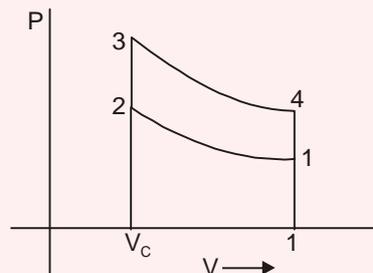
or $\frac{V_3}{V_2} = \frac{1}{20} (20 - 1) + 1 = \frac{19}{20} + 1 = 1.95$

39. The cubic capacity of a four-stroke over-square spark-ignition engine is 275 cc. The clearance volume is 25 cc. What is the compression ratio of the engine?

- (a) 8
- (b) 10
- (c) 12
- (d) 14

Ans. (c)

Sol.



$V_s = 275 = V_1 - V_2 = V_1 - V_c \dots(i)$

$V_c = 25 = V_2 \dots(ii)$

So from (i) & (ii) $V_1 = V_s + V_c = 275 + 25 = 300$

$r = \frac{V_1}{V_2} = \frac{300}{25} = 12$

40. The mechanical efficiency of a single-cylinder four-stroke engine is 60%. The frictional power is estimated to be 30 kW. What is the indicated power?

- (a) 120 kW
- (b) 75 kW

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- (c) 150 kW (d) 130 kW

Ans. (b)

Sol.

$$\eta_m = \frac{bp}{ip} = 0.6$$

or $bp = 0.6 ip$
or, $ip - fp = 0.6 ip$

$$ip = \frac{fp}{0.4} = \frac{30}{0.4} = 75 \text{ kW}$$

41. A four-stroke petrol engine at full load delivers 100 kW. It requires 10 kW to rotate it without load at same speed. What is the mechanical efficiency at half load?

- (a) 67.82% (b) 70.24%
(c) 77.32% (d) 83.33%

Ans. (d)

Sol. $bp = 100 \text{ kW}$ at full load

$$bp' = \frac{100}{2} = 50 \text{ kW at half load}$$

$$fp = \text{constant} = 10 \text{ kW}$$

So, $\eta'_m = \frac{bp'}{ip'} = \frac{50}{50 + 10} = 83.33\%$

42. Freon-12 is used in a simple saturation cycle, with suction saturation temperature of -10°C and condensing saturation temperature of 30°C . If the clearance volume is 6% of the stroke volume, what is the volumetric efficiency? (Consider specific volume at suction and discharge to be $0.07815 \text{ m}^3/\text{kg}$ and $0.025 \text{ m}^3/\text{kg}$ respectively)

- (a) 87.24% (b) 71.31%
(c) 64.85% (d) 55.43%

Ans. (a)

Sol. Volumetric efficiency (η_v)

$$= 1 + C - C \frac{v_{\text{suction}}}{v_{\text{discharge}}}$$

$$C = \text{Clearance factor} = \frac{\text{Clearance volume}}{\text{Swept volume}}$$

Stroke volume = Clearance Volume + Swept Volume

$$= 0.06 \times \text{stroke volume} + \text{swept volume}$$

$$\therefore \text{Swept volume} = (0.94 \times \text{stroke volume})$$

$$C = \frac{\text{Clearance volume}}{\text{Swept volume}} = \frac{0.06 \times \text{stroke volume}}{0.94 \times \text{stroke volume}}$$

$$= \frac{3}{47}$$

$$v_{\text{suction}} = 0.07815 \text{ m}^3/\text{kg}$$

$$v_{\text{discharge}} = 0.025 \text{ m}^3/\text{kg}$$

$$\therefore \eta_v = \left(1 + \frac{3}{47} - \frac{3}{47} \times \frac{0.07815}{0.025} \right)$$

$$= 0.86429 = 86.43\% \approx 87.24\%$$

Alternately

Considering stroke volume = swept volume

$$C = 0.06$$

$$\therefore \eta_v = 1 + C - C \left(\frac{v_{\text{suction}}}{v_{\text{discharge}}} \right)$$

$$= 1 + 0.06 - \left(0.06 \times \frac{0.07815}{0.025} \right)$$

$$= 0.8724 = 87.24\%$$

43. Relative ozone destruction efficiency of R-12 is

- (a) 0.29 (b) 0.86
(c) 0.05 (d) 0.57

Ans. (b)

Sol. The relative ozone destruction efficiency of R-12 ranges in 0.82 – 0.86.

44. An air cooled condenser has 6 m^2 of surface with a removal of $50 \text{ kJ hr}^{-1} \cdot \text{m}^{-2} \cdot ^\circ\text{C}^{-1}$. What is the refrigerant temperature to dissipate 5235 kJ/hr, if the room temperature is 25°C ?

- (a) 24.31°C (b) 35.82°C
(c) 42.45°C (d) 56.94°C

Ans. (c)

Detailed Solution

Sol. The removal rate of condenser = $50 \frac{\text{kJ}}{\text{hr} \cdot \text{m}^2 \cdot \text{C}}$

Area = 6 m²

∴ Total removal rate = $(50 \times 6) \frac{\text{kJ}}{\text{hr} \cdot \text{C}}$

= $300 \frac{\text{kJ}}{\text{hr} \cdot \text{C}}$

Heat to be removed = 5235 kJ/hr

∴ $\Delta t = \frac{5235}{300} \text{C} = 17.45\text{C}$

$(t - t_{\text{room}}) = 17.45\text{C}$

$t = (17.45 + 25) = 42.45\text{C}$

45. The actual and theoretical COP of rolling piston compressor are 3.6 and 4.7 respectively. What is the relative COP?

(a) 8.3

(b) 16.92

(c) 1.3

(d) 0.76

Ans. (d)

Sol. Relative COP = $\frac{\text{Actual COP}}{\text{Theoretical COP}}$

= $\frac{3.6}{4.7} = 0.76$

46. In an absorption type refrigeration system, heating in generator, refrigeration in evaporator and cooling by cooling water in condenser, take place at 95°C, -5°C and 30°C respectively. What is the maximum COP of the system?

(a) 1.17

(b) 1.35

(c) 1.52

(d) 1.78

Ans. (b)

Sol.

Temperature of evaporator (T_E) = -5°C = 268 k

Temperature of generator (T_G) = 95°C = 368 k

Temperature of surrounding (T_o) = 30°C = 303k

Maximum COP = $\frac{T_E(T_G - T_D)}{T_G(T_o - T_E)}$

= $\frac{268 \times (368 - 303)}{368 \times (303 - 268)} = 1.352$

47. Consider the following statements for sensible heat factor:

1. Sensible heat factor will be negative if sensible heat and latent heat are both negative.
2. Sensible heat factor will be negative if sensible heat is negative and latent heat is positive.
3. Sensible heat factor will be negative if sensible heat is positive and latent heat is negative.
4. Sensible heat factor will be negative if sensible heat and latent heat are both positive.

Which of the above statements are correct?

(a) 2 and 3 only

(b) 1 and 2 only

(c) 1 and 3 only

(d) 2 and 4 only

Ans. (a)

Sol.

Sensible heat factor (SHF)

= $\frac{\text{Sensible Heat (SH)}}{\text{Sensible Heat (SH)} + \text{Latent Heat (LH)}}$

(1) when SH is -ve & LH is -ve SHF → +ve

(4) when SH → +ve & LH is +ve SHF → +ve

Hence, statement 1 & 4 are incorrect and statement 2 & 3 are correct.

48. If the air initially at dry bulb temperature 35°C and wet bulb temperature 26.1°C as it enters an air washer which has a humidifying efficiency of 85%, then what is the final dry bulb temperature of air washed with recirculated spray water?

(a) 26.81°C

(b) 27.43°C

(c) 32.83°C

(d) 30.49°C

Ans. (b)

Sol. Humidifying efficiency = $\frac{\text{DBT} - T_{\text{out}}}{\text{DBT} - \text{WBT}}$

$0.85 = \frac{35 - T_{\text{out}}}{(35 - 26.1)}$

Detailed Solution

$$\Rightarrow T_{out} = 35^\circ - 0.85 (35^\circ - 26.1^\circ) = 27.435^\circ$$

49. Consider the following statements for Nucleate boiling:

1. For water, the critical heat flux does not exceed 1 MW/m².
2. Nucleate boiling is the most desirable boiling regime in practice because of high heat transfer rates.
3. Heat flux increases at a higher rate with increase in temperature

Which of the above statements is/are correct?

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

Ans. (b)

Sol.

- For water, critical heat flux > 1 Mw/m²
- From heat transfer point of view, nuclear boiling regime is the most desirable range to operate.
- Heat transfer rate increase at a lower rate as ΔT_e increases.

50. In drop-wise condensation, the heat transfer rate is

- (a) 5 times less than that in film-wise condensation.
- (b) 15 times less than that in film-wise condensation
- (c) 25 times more than that in film-wise condensation.
- (d) 10 times more than that in film-wise condensation.

Ans. (d)

Sol. In drop-wise condensations, the vapours condense on the surface on drops, which drips down the surface. A continuous films of liquid is not formed on the surface. Thus, more of the base area at temperature T_s is always exposed to the vapours. Therefore, heat transfer rate is higher (up to 10 times) in drop-wise condensation as compared to the value in film-wise condensation.

51. 1 kg of water falls from an altitude of 1000 m above ground level. What is the change in the temperature of water at the foot of the fall, if there are no losses during the fall ? (Take specific heat of water as 1 kcal. kg⁻¹. K⁻¹ and g = 9.81 m/s²)

- (a) 3.35°C (b) 2.35°C
(c) 3.32°C (d) 4.12°C

Ans. (b)

Sol. Since total energy is conserved
Loss of potential energy = Gain in thermal energy

$$mgh = mc_p \Delta T$$

$$1 \times 9.81 \times 1000 = \frac{1 \times 1000 \times 4.18 \text{ J}}{\text{kg K}} \times \Delta T$$

$$\Delta T = 2.346889952 \text{ }^\circ\text{C}$$

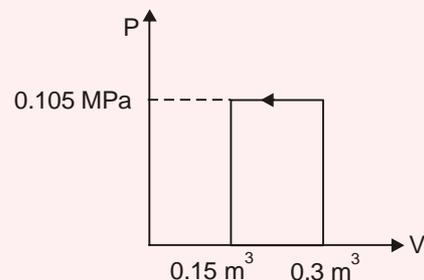
$$\Delta T = 2.35^\circ\text{C}$$

52. A stationary mass of gas is compressed without friction from an initial state of 0.3 m³ and 0.105 MPa, the pressure remaining constant during the process. There is a transfer of 40 kJ of heat from the gas during the process. How much does the internal energy of the gas change ?

- (a) -24.25 kJ (b) -19.62 kJ
(c) -15.91 kJ (d) -12.72 kJ

Ans. (a)

Sol.



$$\text{Work done} = P \Delta V$$

$$= -(0.105 \times 0.15) \times 10^3 \text{ kJ}$$

$$= -15.75 \text{ kJ}$$

$$Q = -40 \text{ kJ}$$



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Detailed Solution

First law of thermodynamics :

$$Q = w + \Delta u$$

$$-40 = -15.75 + \Delta u$$

$$\Delta u = (-40 + 15.75) \text{ kJ} = -24.25 \text{ kJ}$$

53. The state of a simple compressible pure substance can be fixed by specifying

- (a) one independent property.
- (b) two independent properties.
- (c) three independent properties.
- (d) four independent properties.

Ans. (b)

Sol.

The state of pure substance of a given mass can be fixed by specifying two independent intensive properties provided the system is in equilibrium. This is known as 2-properties rule. Temperature and specific volume, for example, are always independent properties, and together they can fix the state of a simple compressible system.

54. In a thermoelectric thermometer for $t^\circ\text{C}$ temperature, the emf is given as: $E = 0.003t - 5 \times 10^{-7} t^2 + 0.5 \times 10^{-3}$ volts. Thermometer is having reference junction at ice point and is calibrated at ice point and steam point. What is the temperature shown by the thermometer for a substance at 30°C ?

- (a) 33.23°C
- (b) 36.28°C
- (c) 41.23°C
- (d) 46.28°C

Ans. (a)

Sol. $E = 0.003t - 5 \times 10^{-7} t^2 + 0.5 \times 10^{-3}$

At ice point, when $t = 0^\circ\text{C}$,

$$E = 0.5 \times 10^{-3}$$

At steam point $t = 100^\circ\text{C}$

$$\begin{aligned} E &= 0.003 \times 100 - 5 \times 10^{-7} \times (100)^2 \\ &\quad + 0.5 \times 10^{-3} \\ &= 0.2955 \text{ V} \end{aligned}$$

At 30°C

$$E = 0.003 \times 30 - 5 \times 10^{-7} \times (30)^2$$

$$+ 0.5 \times 10^{-3}$$

$$= 0.09005 \text{ V}$$

- When the gas thermometer reads 30°C the thermocouple will read

$$= \frac{100}{0.2955} \times 0.09005$$

$$= 30.44^\circ\text{C}$$

The nearest answer is 33.23°C .

55. Consider the following statements for comparison of heat and work:

1. Both heat and work are transient phenomena.
2. Both heat and work are boundary phenomena.
3. Both heat and work are path functions and inexact differentials.

Which of the above statements are correct ?

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

Ans. (b)

Sol. • Both heat and work are interactions between a system and its surroundings. They have following similarities:

- Both are recognized only as they cross the boundary of a system, i.e. both are boundary phenomena.
- Systems possess energy, but not heat or work. That is, heat and work are transient phenomena.
- Both are path functions.

56. A tank containing a fluid is stirred by a paddle wheel. The work input to the paddle wheel is 5090 kJ. The heat transfer from the tank is 1500 kJ. What is the change in internal energy of this control mass ? (Consider the tank and the fluid inside a control surface)

- (a) -3590 kJ
- (b) $+3590 \text{ kJ}$
- (c) $+4590 \text{ kJ}$
- (d) -4590 kJ

Ans. (b)

Sol. $\Delta Q = \Delta U + \Delta W$

$$\Delta U = \Delta Q - \Delta W = -1500 - (-5090)$$

Detailed Solution

= 3590

57. During the charging of a storage battery, the current is 20 A and the voltage is 12.8 V. The rate of heat transfer from the battery is 10W. At what rate is the internal energy increasing?

- (a) - 256 J/s (b) + 246 J/s
(c) + 256 J/s (d) - 246 J/s

Ans. (b)

Sol.

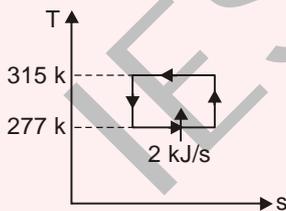
$$\begin{aligned} \Delta Q &= \Delta U + \Delta W \\ -10 &= \Delta U - IR \\ -10 &= \Delta U - 20 \times 12.8 \\ \Delta U &= 246 \text{ J/sec} \end{aligned}$$

58. A refrigerator operates on Reversed Carnot cycle. What is the power required to drive the refrigerator between temperatures of 42°C and 4°C, if heat at the rate of 2 kJ/s is extracted from the low temperature region ?

- (a) 0.174 kW (b) 0.374 kW
(c) 0.274 kW (d) 0.474 kW

Ans. (c)

Sol.



$$\begin{aligned} \text{COP} &= \frac{\dot{Q}_{in}}{\text{Power}} = \frac{T_L}{T_H - T_L} \\ &= \frac{277}{(315 - 277)} \end{aligned}$$

$$\dot{Q}_{in} = 2 \text{ kW}$$

$$\therefore \frac{2}{\text{Power}} = \frac{277}{38}$$

$$\text{Power} = \left(\frac{2 \times 38}{277} \right) \text{ kW} = 0.274 \text{ kW}$$

59. Entropy generated (S_{gen}) can be taken as a criterion to indicate feasibility of process. Which of the following conditions are correct?

1. If $S_{gen} = 0$, then the process is a reversible process.
2. If $S_{gen} > 0$, then the process is an irreversible process.
3. If $S_{gen} < 0$, then the process is impossible.

Select the correct answer using the code given below:

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

Ans. (d)

Sol. All the statements are correct.

- when $\dot{S}_{gen} > 0 \rightarrow$ Irreversible process
 $\dot{S}_{gen} = 0 \rightarrow$ Reversible process
 $\dot{S}_{gen} < 0 \rightarrow$ Impossible process

60. What is the critical radius of insulation for asbestos (thermal conductivity = 0.17 W.m⁻¹. °C⁻¹) surrounding a circular pipe and exposed to room air at 20°C with heat transfer coefficient 3 W.m⁻². °C⁻¹?

- (a) 7.21 cm (b) 6.37 cm
(c) 5.67 cm (d) 6.93 cm

Ans. (c)

Sol.

$$\begin{aligned} h &= 3 \text{ Wm}^{-2}\text{C}^{-1} \\ k &= 0.1700 \text{ Wm}^{-1}\text{C}^{-1} \end{aligned}$$

$$\begin{aligned} \text{Critical radius of insulation} &= \frac{k}{h} \\ &= \left(\frac{0.17}{3} \times 1000 \right) \text{ mm} \\ &= 5.667 \text{ mm} \end{aligned}$$

61. Water is flowing through a pipe of diameter

Detailed Solution

200 mm with a velocity of 3 m/s. What is the head loss due to friction for a length of 5 m if the coefficient of friction is given by $f =$

$0.02 + \frac{0.09}{Re^{0.3}}$, where Re is Reynolds number?

(Take the kinematic viscosity of water as 0.01 stoke, $g = 9.81 \text{ m/s}^2$ and $(6 \times 10^5)^{0.3} = 54.13$)

- (a) 0.993 m of water (b) 0.783 m of water
- (c) 0.685 m of water (d) 0.552 m of water

Ans. (a)

Sol.

$$Re = \frac{VD}{\nu} = \frac{3 \times 0.2}{0.01 \times 10^{-4}} = 6 \times 10^5$$

$$\Rightarrow f = 0.02 + \frac{0.09}{(6 \times 10^5)^{0.3}} = 0.02 + \frac{0.09}{54.13}$$

$$f = 0.02166$$

$$\Rightarrow \text{Friction factor} = 4f = 4 \times 0.02166$$

$$\text{Head loss due to friction} = h_f = \frac{(4f)lV^2}{2gD}$$

$$\Rightarrow h_f = \frac{4 \times 0.02166 \times 5 \times (3)^2}{2 \times 9.81 \times 0.2} = 0.993 \text{ m}$$

62. Water is flowing through a horizontal pipe of diameter 200 mm at a velocity of 3 m/s. A circular solid plate of diameter 150 mm is placed in the pipe to obstruct the flow. What is the loss of head due to obstruction in the pipe if $C_c = 0.62$? (Take $g = 9.81 \text{ m/s}^2$)

- (a) 3.311 m (b) 4.211 m
- (c) 5.211 m (d) 6.211 m

Ans. (a)

Sol. Head loss due to obstruction in pipe

$$= h_L = \frac{V^2}{2g} \left[\frac{A}{C_c(A-a)} - 1 \right]^2$$

V = Velocity in pipe

A = Area of pipe

a = max. area of obstruction

C_c = Coefficient of contraction

$$\Rightarrow h_L = \frac{(3)^2}{2 \times 9.81} \left[\frac{(0.2)^2}{0.62[(0.2)^2 - (0.15)^2]} - 1 \right]^2$$

$$h_L = 3.311 \text{ m}$$

63. Three pipes of length 800 m, 500 m and 400 m and of diameters 500 mm, 400 mm and 300 mm respectively are connected in series. These pipes are to be replaced by a single pipe of length 1700 m. What is the diameter of the single pipe ?

- (a) $(0.007118)^{0.2} \text{ m}$ (b) $(0.003609)^{0.3} \text{ m}$
- (c) $(0.003609)^{0.2} \text{ m}$ (d) $(0.007118)^{0.3} \text{ m}$

Ans. (a)

Sol.



$$l_1 = 800 \text{ m} \quad l_2 = 500 \text{ m} \quad l_3 = 400 \text{ m}$$

$$d_1 = 500 \text{ mm} \quad d_2 = 400 \text{ mm} \quad d_3 = 300 \text{ mm}$$



$$l_1 = 1700 \text{ m}$$

$$d = ?$$

Since the two pipes are to be equivalent, hence the discharge and head loss must be same in the two. Assuming same friction factor in the two sets of pipes

$$\frac{f l Q^2}{12.1 d^5} = \frac{f l_1 Q^2}{12.1 d_1^5} + \frac{f l_2 Q^2}{12.1 d_2^5} + \frac{f l_3 Q^2}{12.1 d_3^5}$$

$$\Rightarrow \frac{1700}{d^5} = \frac{800}{(0.5)^5} + \frac{500}{(0.4)^5} + \frac{400}{(0.3)^5}$$

$$= 239037.1785$$

$$\Rightarrow d^5 = 0.0071118$$

$$d = (0.0071118)^{0.2} \text{ m}$$

64. The head of water at the inlet of a pipe 2000 m long and 500 mm diameter is 60 m. A nozzle of diameter 100 mm at its outlet is fitted to the pipe. What is the velocity of water at the outlet of the nozzle if $f = 0.01$ for the

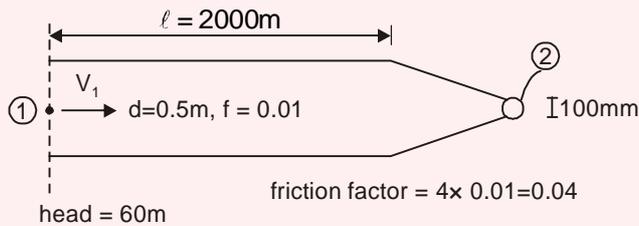
Detailed Solution

pipe ? (Take $g = 9.81 \text{ m/s}^2$)

- (a) 30.61 m/s (b) 34.81 m/s
(c) 36.52 m/s (d) 38.36 m/s

Ans. (a)

Sol. For



$$\text{Head loss in 2000 m length of pipe} = \frac{f l Q^2}{12.1 d^5}$$

Applying energy equation between (1) & (2)

$$60 = \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g} + h_f$$

[Neglecting loss in nozzle]

$$60 = \frac{V_2^2}{2g} + \frac{f l V_1^2}{2g d}$$

$$V_1 \times \frac{\pi}{4} (0.5)^2 = V_2 \times \frac{\pi}{4} (0.1)^2 \quad \text{[Continuity eqn]}$$

$$V_1 = \frac{V_2}{25}$$

$$\Rightarrow 60 = \frac{V_2^2}{2 \times 9.81} \left[1 + \frac{f l}{d \times 625} \right]$$

$$= \frac{V_2^2}{2 \times 9.81} \left[1 + \frac{0.04 \times 2000}{0.5 \times 625} \right]$$

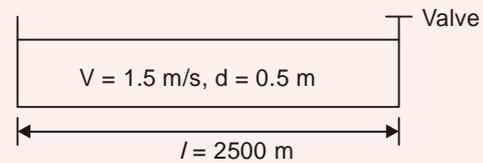
$$\Rightarrow \boxed{V_2 = 30.61 \text{ m/s}}$$

65. Water is flowing with a velocity of 1.5 m/s in a pipe of length 2500 m and of diameter 500 mm. At the end of the pipe, a valve is provided. What is the rise in pressure if the valve is closed in 25 seconds ? (Take the value of C as 1460 m/s)

- (a) 12 N/cm² (b) 15 N/cm²
(c) 16 N/cm² (d) 18 N/cm²

Ans. (b)

Sol.



Time of closure of valve = $t_0 = 25 \text{ sec}$

$$\text{Critical time } (t_c) = \frac{2l}{C} = \frac{2 \times 2500}{1460} \text{ sec} = 3.42 \text{ sec}$$

$$\Rightarrow t_0 > t_c$$

\Rightarrow it is a slow closure case

$$\Rightarrow \Delta P = \frac{\rho V L}{t_0} = \frac{1000 \times 1.5 \times 2500}{25} \frac{\text{N}}{\text{m}^2}$$

$$\Rightarrow \Delta P = 15 \times 10^4 \frac{\text{N}}{\text{m}^2} = 15 \frac{\text{N}}{\text{cm}^2}$$

66. If a submerged body is in unstable equilibrium, then

- (a) the centre of buoyancy is below the centre of gravity.
(b) the centre of buoyancy is above the centre of gravity.
(c) meta-centre is below the centre of buoyancy.
(d) meta-centre is above the centre of buoyancy.

Ans. (a)

Sol. For unstable equilibrium of submerged body centre of gravity should be above centre of Buoyancy.

67. How much of concrete with $\gamma = 25 \text{ kN/m}^3$ must be attached to a beam having a volume of 0.1 m³ and specific gravity 0.6 to cause both to sink in water ? (Take $g = 9.81 \text{ m/s}^2$)

- (a) 0.825 kN (b) 0.745 kN
(c) 0.525 kN (d) 0.645 kN

Ans. (d)

Sol. For Sinking of both beam & the attached concrete, the weight should be greater than or equal to the Buoyant force.

$$\text{Weight} = [V_{\text{conc}} \times 25 + 0.1 \times (0.6 \times 9.81)] \text{ kN}$$

$$\text{Buoyant force} = (V_{\text{conc}} + 0.1) \times 9.81 \text{ kN}$$

Hence

Detailed Solution

$$(V_{\text{conc}} \times 25) + (0.1 \times 0.6 \times 9.81) \geq V_{\text{conc}} \times 9.81 + 0.981$$

$$\Rightarrow V_{\text{conc}} \geq 0.02583 \text{ m}^3$$

$$\Rightarrow \text{Wt of concrete} \geq 0.02583 \times 25 = 0.6458 \text{ kN}$$

$$\Rightarrow (\text{Wt of concrete to be attached})_{\text{min}} = 0.6458 \text{ kN}$$

68. A liquid has a specific gravity of 1.9 and a kinematic viscosity of 6 stokes. What is the dynamic viscosity ?

- (a) 1.14 Ns/m² (b) 2.44 Ns/m²
(c) 3.40 Ns/m² (d) 11.40 Ns/m²

Ans. (a)

Sol. Dynamic viscosity (μ) = $\nu\rho$

$$\mu = (6 \times 10^{-4}) \text{ m}^2/\text{s} \times (1.9 \times 1000) \text{ kg/m}^3$$

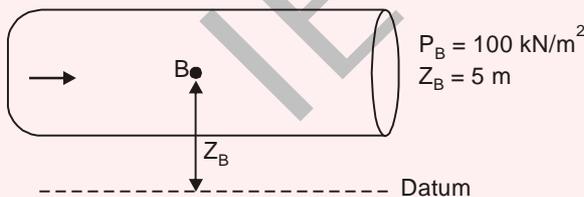
$$\mu = 1.14 \text{ Ns/m}^2$$

69. Oil of specific gravity 0.8 flows through a 0.2 m diameter pipe under a pressure of 100 kN/m². If the datum is 5 m below the centerline of the pipe and the total energy with respect to the datum is 35 Nm/N, the discharge is (Take $g = 9.81 \text{ m/s}^2$)

- (a) 0.58 m³/sec (b) 0.47 m³/sec
(c) 0.31 m³/sec (d) 0.22 m³/sec

Ans. (a)

Sol.



$$\frac{P_B}{\gamma} + Z_B + \frac{V_B^2}{2g} = 35 \text{ m}$$

$$\frac{P_B}{0.8\gamma_w} + Z_B + \frac{V_B^2}{2g} = 35 \text{ m}$$

$$\Rightarrow \frac{100}{0.8 \times 9.81} + 5 + \frac{V_B^2}{2 \times 9.81} = 35$$

$$\Rightarrow V_B = 18.401 \text{ m/s}$$

$$\Rightarrow Q = V_B \frac{\pi d^2}{4} = 18.401 \times \frac{\pi (0.2)^2}{4}$$

$$= 0.578 \frac{\text{m}^3}{\text{s}}$$

70. Bernoulli's equation is obtained by

- (a) integrating the Euler's equation of motion.
(b) differentiating the Euler's equation of motion.
(c) differentiating the Navier-Stokes equations.
(d) integrating energy equation.

Ans. (a)

71. Which one of the following is not the methodology of control separation of flow from boundary in the application of aerofoils ?

- (a) Streamlining of blunt body shapes
(b) Fluid ejection from the boundary layer
(c) Suction of fluid from the boundary layer
(d) Creating a motion of the boundary wall

Ans. (b)

Sol. The various methods adopted for controlling the boundary layer separation are

1. streamlining the object
2. Fluid injection into Boundary layer
3. Suction of retarded fluid form Boundary layer
4. Creating a motion of boundary wall thereby giving energy to the retarded fluid.

Hence answer should be (b) in which in place of injection it is given as ejection.

72. What is the value of mass of the air in a room of size 4 m × 5 m × 6 m at 100 kPa and 25°C? (Take $R = 0.287 \text{ kPa} \cdot \text{m}^3 \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$).

- (a) 150 kg (b) 180 kg
(c) 140 kg (d) 130 kg

Ans. (c)

Sol. $P = \rho RT$

$$\rho = \frac{P}{RT} = \frac{100 \text{ kPa}}{0.287 \text{ kPa} \frac{\text{m}^3}{\text{kg} \cdot \text{K}} \times (273 + 25) \times}$$

$$\rho = 1.169235 \text{ kg/ms}$$

$$\begin{aligned} \Rightarrow \text{Mass of air} &= \rho(\text{Volume}) \\ &= 1.169235 \times (4 \times 5 \times 6) \text{ kg} \\ &= 140.308 \text{ kg} \end{aligned}$$

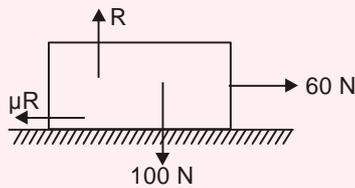
Detailed Solution

73. A body of weight 100 N is placed on a rough horizontal plane. what is the coefficient of friction if a horizontal force of 60 N just causes the body to slide over the horizontal plane ?

- (a) 0.4 (b) 0.5
(c) 0.6 (d) 0.9

Ans. (c)

Sol.



$$R = 100 \text{ N}$$

$$\Rightarrow 60 = \mu \times 100$$

$$\Rightarrow \mu = 0.6$$

74. A body is moving with a velocity of 2 m/s. After 4 seconds, the velocity of the body becomes 5 m/s. The acceleration of the body is

- (a) 0.55 m/s² (b) 0.65 m/s²
(c) 0.75 m/s² (d) 0.45 m/s²

Ans. (c)

Sol.

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

$$V_f = 5 \text{ m/s}$$

$$\Delta t = 4 \text{ sec}$$

$$\text{Acceleration} = \frac{V_f - V_i}{\Delta t} = \frac{3}{4} = 0.75 \text{ m/s}^2$$

75. The principal stresses at a point in an elastic material are 60 N/mm² tensile, 20 N/mm² tensile and 50 N/mm² compressive. What is the volumetric strain by considering Young's Modulus as $100 \times 10^3 \text{ N/mm}^2$ and $\mu = 0.3$?

- (a) 1.20×10^{-4} (b) 1.06×10^{-5}
(c) 1.30×10^{-3} (d) 1.12×10^{-2}

Ans. (a)

Sol.

$$\epsilon_v = \epsilon_x + \epsilon_y + \epsilon_z = \frac{(\sigma_x + \sigma_y + \sigma_z)}{E} (1 - 2\mu)$$

$$\epsilon_v = \frac{(60 + 20 - 50)}{100 \times 10^3} \times (1 - 2 \times 0.3)$$

$$\epsilon_v = 1.2 \times 10^{-4}$$

76. A man whose weight is 650 N, standing on the ground, raises a load of 3000 N by means of single string system of pulleys. There are six light pulleys in each block. The thrust of the man on the ground is

- (a) 120 N (b) 135 N
(c) 150 N (d) 175 N

Ans. (c)

Sol.

In single string system of pulleys:

$$\text{Velocity ratio} = n$$

where, n = number of strings between fixed pulley block and movable pulley block.

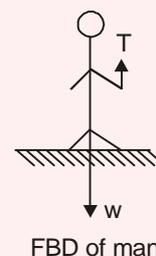
Considering 100% efficiency:

$$\begin{aligned} \text{Mechanical advantage} &= \text{Velocity ratio} \\ &= n = 6 \end{aligned}$$

$$\text{Mechanical advantage} = \frac{\text{Weight}}{\text{Tension}} = 6$$

$$\therefore \text{Tension} = \frac{\text{Weight}}{6} = \frac{3000}{6} = 500 \text{ N}$$

$$\begin{aligned} \text{So, thrust of man on ground} &= w - T \\ &= (650 - 500) \\ &= 150 \text{ N} \end{aligned}$$



77. A particle starts with an initial velocity of 200 cm/s and moves with a uniform retardation of 10 cm/s². If it describes 1500 cm in time t, what is/are the possible value(s) of t ?



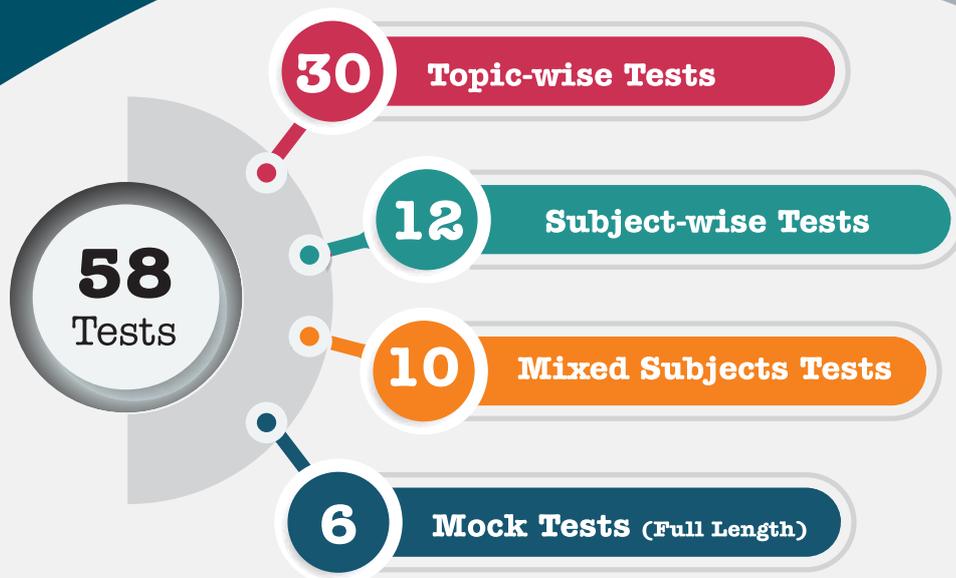
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Detailed Solution

- (a) 10 sec only (b) 10 sec and 30 sec
(c) 30 sec only (d) 5 sec and 10 sec

Ans. (b)

Sol.

$$u = 200 \text{ cm/s}$$

$$g = -10 \text{ cm/s}^2$$

$$S = 1500 \text{ cm}$$

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

$$1500 = 200t - 5t^2$$

$$\Rightarrow t^2 - 40t + 300 = 0$$

$$t_1 = 10 \text{ sec and } t_2 = 30 \text{ sec.}$$

78. Consider the following statements for system of forces:

- Two or more forces that act at the same point are called coplanar forces.
- Two or more forces whose directed arrows lie in same plane are called concurrent forces.
- Varignon's theorem states that the moment of several concurrent coplanar forces about any point O in their plane equals the moment of their resultant about the point O'.
- Lami's theorem states that if a body is in equilibrium under the action of three forces, each force is proportional to the sine of angle between the other forces.

Which of the above statements are correct ?

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

Ans. (c)

79. Consider the following statements related to stress and strain:

- Shear stress is always tangential to the area over which it acts.
- Shear stresses on the transverse pair of faces are known as complimentary shear stresses.
- Shear strain is defined as the change in the right angle of the element measured in radians.
- Modulus of rigidity is the ratio of shear strain to shear stress.

Which of the above statements are correct ?

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

Ans. (d)

Sol. Statements 1, 2 and 3 are correct.

$$\text{Modulus of rigidity} = \frac{\text{Shear stress}}{\text{Shear strain}}$$

80. Consider the following statements for stress and strain analysis:

- The stress components on any inclined plane can easily be found with the help of a geometrical construction known as Mohr's stress circle.
- The ratio of longitudinal strain to lateral strain is known as Poisson's ratio.
- When a body is acted upon by three mutually perpendicular forces, there is change in the volume of the body which is referred to as dilation of the material.
- The ratio of original volume to increase in volume is known as volumetric strain.

Which of the above statements are correct ?

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

Ans. (a)

Sol. Statement 1 and 3 are correct

$$\text{Poisson's ratio} = \frac{\text{lateral strain}}{\text{longitudinal strain}}$$

$$\text{Volumetric strain} = \frac{\text{Change in volume}}{\text{Original volume}}$$

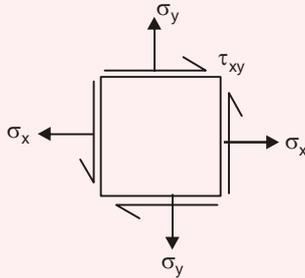
81. The stresses on two perpendicular planes through a point in a body are 160 MPa and 100 MPa, both compressive, along with a shear stress of 80 MPa. What is the normal stress on a plane inclined at 30° to the plane of 160 MPa stress ?

- (a) -42.4 MPa (b) -75.7 MPa
(c) -59.1 MPa (d) -86.3 MPa

Ans. (b)

Detailed Solution

Sol.



$$\sigma_x = -160 \text{ MPa}, \sigma_y = -100 \text{ MPa}, \tau_{xy} = 80 \text{ MPa}$$

$\sigma'_2 \rightarrow$ Normal stress on a plane inclined at 30° to the plane of 160 MPa stress.

Case-I when the plane is in anticlockwise direction

$$\sigma'_x = \frac{\sigma_x + \sigma_y}{2} + \left(\frac{\sigma_x - \sigma_y}{2} \right) \cos 2\theta + \tau_{xy} \sin 2\theta$$

$$\sigma'_2 = \frac{-160 - 100}{2} + \left(\frac{-160 + 100}{2} \right) \cos (2 \times 30) + 80 \sin (2 \times 60)$$

$$\sigma'_x = -75.71 \text{ MPa}$$

Case-II When the plane is in clockwise direction i.e., θ is negative

$$\sigma'_2 = \frac{-160 - 100}{2} + \left(\frac{-160 + 100}{2} \right) \cos (-60) + 80 \sin (-60)$$

$$\sigma'_x = -214.28 \text{ MPa}$$

82. Consider the following statements regarding types of supports and beams:

1. When both supports of beams are roller supports, the beam is known as simply supported beam.
2. A beam with one end fixed and the other end free is known as fixed beam.
3. A beam with both ends fixed is known as cantilever beam.
4. A beam with one end fixed and the other simply supported is known as propped cantilever.

Which of the above statements is/are correct ?

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

Ans. (b)

83. Consider the following statements regarding stress in beam:

1. If a member is subjected to equal and opposite couples acting in the same longitudinal planes, the member is said to be in pure bending.
2. The internal stresses developed in the beam are known as flexural stresses.
3. There is an intermediate surface known as neutral surface, at which the stress is zero.
4. An axis obtained by intersection of the neutral surface and a cross-section is known as neutral axis.

Which of the above statements are correct ?

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

Ans. (d)

84. Consider the following statements for the symmetric beam under pure bending:

1. In the elastic range, the normal stress varies linearly with the distance from the neutral surface.
2. As long as the stresses remain in the elastic range, the neutral axis passes through the centroid of the section.
3. If stresses are in the plastic range, the neutral axis passes through the centroid of the section.

Which of the above statements is/are correct ?

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

Ans. (c)

Sol. As long as the stresses remain in the linear elastic range, neutral axis passes through the centroid and normal stress varies linearly with the distance from the neutral axis.

Detailed Solution

→ If stresses are in the plastic range, it is not necessary to pass neutral axis through centroid.

85. The volume of FCC unit cell in terms of the atomic radius R is

(a) $V_c = 16R^3\sqrt{3}$ (b) $V_c = 8R^3\sqrt{2}$

(c) $V_c = 16R^3\sqrt{2}$ (d) $V_c = 8R^3\sqrt{3}$

Ans. (c)

Sol.

For FCC crystal, $a = 2\sqrt{2}R$
 Volume of unit cell is
 $= (a)^3 = (2\sqrt{2}R)^3$
 $= 16R^3\sqrt{2}$

86. Which one of the following alloying ingredients increases the hardenability and forms carbides for wear resistance ?

- (a) Chromium (b) Molybdenum
 (c) Nickel (d) Manganese

Ans. (b)

Sol.

Carbide forming tendency in Chromium is greater than Manganese (Mn) but lesser than tungsten (W). Hardenability increases moderately.

Manganese has consider formation tendency greater than iron (Fe) in steel but lesser than chromium. Manganese increases hardenability moderately.

Nickel leads to formation graphite that it has negative effect on carbide formation but it stabilized the Austenite.

Molybdenum leads to formation of carbide more than chromium and increases hardenability strongly.

87. Which one of the following related to the most stable arrangement of atoms in a crystal is not correct ?

- (a) Preserves electrical neutrality
 (b) Maximizes strong ion-ion repulsion
 (c) Satisfies discreteness of all covalent bonds

(d) Packs the atoms as closely as possible

Ans. (b)

Sol. Stability of atoms in crystal depends on :

- Electrical neutrality
- Atoms should have greater atomic packing factor.
- The ease of formation of the positive and negative ions from respective neutral atoms.
- Satisfies discreteness of all the covalent bonds.
- As many anions as possible to surround the cation for maximum reduction in electrostatic energy.

88. The dielectric constant of rubber varies between

- (a) 0.5 and 1.0 (b) 1.0 and 1.5
 (c) 1.5 and 2.0 (d) 2.5 and 5.0

Ans. (d)

Sol.

- Dielectric Constant :
- Rubber - 2 to 4
 - Nylon - 3.4 to 22.4
 - Air - 1 to 1
 - Backelite - 5 to 22
 - Glass - 3.8 to 14.5

89. Consider the following statements for ductile fracture:

1. The material undergoes substantial plastic deformation with high energy absorption before fracture.
2. Presence of cracks on the surface of material initiates this type of failure.
3. Fracture occurs due to necking.

Which of the above statements is/are correct ?

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

Ans. (d)

Sol.

Ductile fracture occurs often prolonged plastic deformation and is accompanied by necking. It

Detailed Solution

require higher strain energy.

- Ductile fracture begin at the central region then propagates to the periphery of the necked region.
- Crack at surface influence fatigue failure.

90. The TTT diagram shows the times required for isothermal transition from

- (a) austenite to pearlite
- (b) austenite to ferrite
- (c) ferrite to pearlite
- (d) martensite to pearlite

Ans. (a)

Sol. Time Temperature Transformation (TTT) diagram is used to indicate time and temperature transformation of austenitic stainless steel to pearlite at eutectoid temperature. This transformation of austenite is time dependent.

91. Iron at 20°C is BCC with atoms of atomic radius 0.124 nm. What is the lattice constant 'a' for the cube edge of the iron unit cell ?

- (a) 0.2864 nm (b) 0.1496 nm
- (c) 0.2173 nm (d) 0.1756 nm

Ans. (a)

Sol.

$$r = 0.124 \text{ nm}$$

$$4r = \sqrt{3} a$$

$$4 \times 0.124 = \sqrt{3} \times a$$

or $a = 0.286365 \approx 0.2864 \text{ nm}$

92. Copper has the FCC crystal structure and a unit cell with a lattice constant of 0.361 nm. What is the interplanar spacing 'd₂₂₀' ?

- (a) 0.085 nm (b) 0.174 nm
- (c) 0.206 nm (d) 0.128 nm

Ans. (d)

Sol.

$$d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

or, $d_{220} = \frac{0.361}{\sqrt{2^2 + 2^2 + 0}}$

$$= 0.12763 \approx 0.128 \text{ nm}$$

93. Which one of the following is not a step of lever rule of determination of phase amounts?

- (a) A tie line is constructed across the two-phase region at the temperature of the alloy.
- (b) The overall alloy composition is located on the tie line.
- (c) Perpendiculars are dropped from these intersections to the horizontal composition axis, from which the composition of each of the respective phases is read.
- (d) The fraction of one-phase is computed by taking the length of tie line from the overall alloy composition to the phase boundary for the other phase and dividing by the total tie line length.

Ans. (c)

Sol.

The Lever Rule is used to find the fractions of liquid phase in the binary alloy in the two-phase state. The rule can be obtained by using the law of conservation of mass.

The tie line must be used along with a procedure that is generally termed as lever rule (or the inverse lever rule) which is as follows (same is marked in figure).

- (1) The tie line is constructed across the two phase region at the temperature of the alloy.
- (2) The overall alloy composition is located on the tie line.
- (3) The fraction of one phase is computed by taking the length of tie line from the overall alloy composition to the phase boundary for the other phase and dividing by the total tie line length.
- (4) The fraction of the other phase is determined in the same manner.

94. Consider the following statements regarding polymeric materials :

- 1. A plastic material that requires heat to make it formable (plastic) and upon cooling, retains its shape is known as thermosetting plastic.
- 2. The chemical reaction in which high molecular mass molecules are formed from two or

Detailed Solution

more monomers is called chain polymerization.

3. A polymer chain consisting of two or more types of monomeric units is called copolymer.

Which of the above statements is/are correct ?

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

Ans. (b)

Sol.

- Thermoplastic materials are those which soften on the application of heat with or without pressure, but then require cooling to set them to shape.
- Thermosetting materials are those plastic which require heat and pressure to mold them into shape. They can not be resoftened as once they have set and hardened.

95. As per mechanical properties, which one of the following microconstituents is soft and ductile ?

- (a) Bainite (b) Martensite
- (c) Spheroidite (d) Tempered martensite

Ans. (c)

Sol. Ductility of spheroidite > Coarse pearlite > fine pearlite > bainite > tempered martensite > martensite.

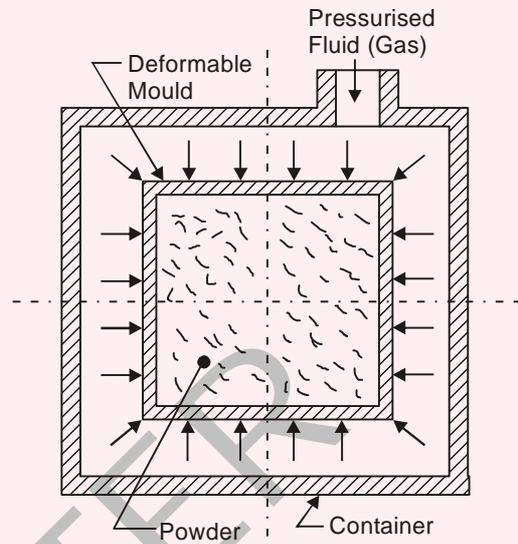
Hardness: Tempered martensite > bainite > fine pearlite > coarse pearlite > spheroidite.

96. The simultaneous compaction and shaping of a ceramic powder (and binder) by pressure applied uniformly in all directions is known as

- (a) Glaze pressing (b) Porcelain pressing
- (c) Slip pressing (d) Isostatic pressing

Ans. (d)

Sol. In isostatic pressing, pressure is applied from all the directions against the powder that are contained in a flexible mould. Hydraulic pressure is used to achieve compaction. Compaction and shaping are completed simultaneously.



97. An electric motor drives a punching press. A flywheel fitted to the press has a radius of gyration of 0.5 m and runs at 250 rpm. The press is capable of punching 800 holes per hour with each punching operation taking 1.5 seconds and requiring 12,000 N-m of work . The energy delivered by the motor during punching operation is

- (a) 2000 N-m (b) 3000 N-m
- (c) 4000 N-m (d) 5000 N-m

Ans. (c)

Sol. Actual punching time, $t_a = 1.5$ sec
Cycle time or time required to complete one rotation, $t_c = 4.5$ sec

$$\left[\because 800 \text{ hole / hr} \right. \\ \left. 1 \text{ hole / 4.5 sec} \right]$$

Energy required per operation,

$$E_{\text{req}} = 12000 \text{ N-m or Joule}$$

$$\therefore P_{\text{motor}} = \frac{E_{\text{req}}}{T_c} = \frac{12000}{4.5} \text{ Joule/sec}$$

\therefore Energy delivered by motor,

$$E = P_{\text{motor}} \times t_a \\ = \frac{12000}{4.5} \times 1.5 \\ = 4000 \text{ Joule}$$

$$\boxed{E = 4000 \text{ N-m}}$$

Detailed Solution

Ans. (b)

Sol. frequency of oscillation:

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

$$\text{Time period} = \frac{2\pi}{\omega_n} = 2\pi\sqrt{\frac{m}{k}}$$

Now, Initially,

$$2 = 2\pi\sqrt{\frac{m}{k}} \quad \dots(i)$$

Later

$$3 = 2\pi\sqrt{\frac{m+2}{k}} \quad \dots(ii)$$

Dividing (ii) by (i)

$$\frac{3}{2} = \sqrt{\frac{m+2}{m}}$$

$$\text{or, } \frac{9}{4} = \frac{m+2}{m}$$

$$\text{or, } 9m = 4m + 8$$

$$\text{or, } 5m = 8$$

$$\text{or, } m = 1.6 \text{ kg}$$

103. What is the critical speed of the shaft if its natural frequency of transverse vibration is 2.85 Hz?

- (a) 171 rpm (b) 285 rpm
(c) 570 rpm (d) 142.5 rpm

Ans. (a)

Sol. The critical speed of the shaft is revolution per second is equal to the natural frequency of transverse vibration is Hz.

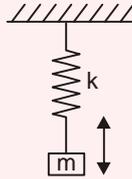
$$\text{Now, } f_n = 2.85 \text{ Hz}$$

$$\therefore N_c = 2.85 \text{ rps}$$

$$N = 60 \times N_c = (60 \times 2.85) = 171 \text{ RPM}$$

104. Consider the following statements regarding gears:

- The ratio of number of teeth on the gear to that on the pinion is known as gear ratio.
- The circle passing through the tips of teeth is called dedendum circle.



- The circle passing through the roots of teeth is called addendum circle.
- Backlash is the difference between the space width and the tooth thickness along the pitch circle.

Which of the above statements are correct?

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

Ans. (b)

Sol. 1 → (Correct)

$$G = \frac{T}{t} = \frac{\text{Teeth on the gear}}{\text{Teeth on the pinion}} \text{ (correct)}$$

2 → (Incorrect)

The circle passing through the tip of teeth is addendum circle

3 → (Incorrect)

The circle passing through the roots of teeth is dedendum circle

4 → (Correct statement) (1 and 4) (b)

105. The number of teeth of a spur gear is 30 and it rotates at 200 rpm. What is the pitch line velocity if it has a module of 2 mm?

- (a) 341.7 mm/s (b) 497.2 mm/s
(c) 628.3 mm/s (d) 758.5 mm/s

Ans. (c)

Sol. Given:

$$T = 30$$

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

$$N = 200 \text{ rpm}$$

$$\text{Pitch line velocity} = \left(\frac{2\pi N}{60} \times r \right)$$

$$r = \frac{mT}{2}$$

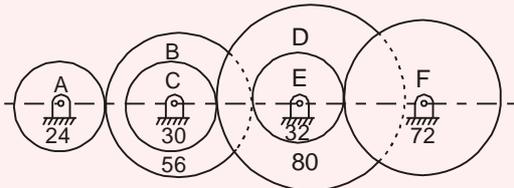
$$\therefore \text{Pitch line velocity} = \left(\frac{2\pi \times 200}{60} \times \frac{2 \times 30}{2} \right) \text{ mm/s.}$$

$$= 628.32 \text{ mm/s}$$

106. The compound gear train shown in the figure below consists of compound gear B-C and D-E. All gears are mounted on parallel shafts. The motor shaft rotating at 800 rpm is

Detailed Solution

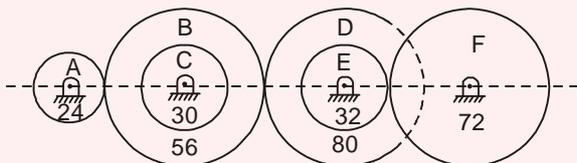
connected to the gear A and the output shaft to the gear F. The number of teeth on gears A, B, C, D, E and F are 24, 56, 30, 80, 32 and 72 respectively. What is the speed of the gear F?



- (a) 57.14 rpm (b) 32.51 rpm
(c) 74.63 rpm (d) 69.72 rpm

Ans. (a)

Sol.



$$N_A = 800 \text{ RPM}$$

$$\frac{N_B}{N_A} = \frac{T_A}{T_B}$$

$$N_B = \left(800 \times \frac{24}{56} \right) \text{ RPM}$$

$$N_B = N_C = \left(800 \times \frac{24}{56} \right) \text{ RPM}$$

$$\frac{N_D}{N_C} = \frac{T_C}{T_D}$$

$$N_D = N_C \frac{T_C}{T_D} = \left(800 \times \frac{24}{56} \times \frac{30}{80} \right) \text{ RPM}$$

$$N_D = N_E = \left(800 \times \frac{24}{56} \times \frac{30}{80} \right) \text{ RPM}$$

$$N_F = N_E \cdot \frac{T_E}{T_F} = 800 \times \frac{24}{56} \times \frac{30}{80} \times \frac{32}{72}$$

$$= \frac{400}{7} \text{ RPM}$$

$$= 57.14 \text{ RPM}$$

107. A quick-return mechanism is to be designed, where the outward stroke must consume 1.2s and the return stroke 0.8s. If the cycle time is 2.0 s/rev, what is the speed at which the

mechanism should be driven?

- (a) 10 rev/s (b) 30 rev/s
(c) 10 rev/min (d) 30 rev/min

Ans. (d)

Sol. Cycle time = 2s

So, basically, the mechanism will rotate one full rotation in 2s.

$$\therefore \text{speed} = \frac{60\text{s}}{2\text{s}} = 30 \text{ RPM}$$

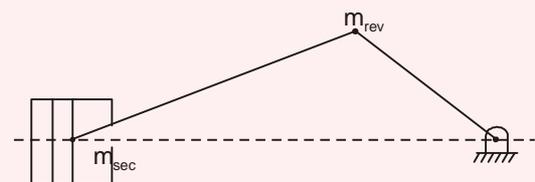
or, 30 rev/s

108. The following data relate to a single-cylinder reciprocating engine : mass of reciprocating parts = 40 kg, mass of revolving parts = 30 kg at crank radius, speed = 150 rpm, stroke = 350 mm. If 60% of the reciprocating parts and all the revolving parts are to be balanced, what is the balance mass required at a radius of 320 mm?

- (a) 15.27 kg (b) 21.43 kg
(c) 24.96 kg (d) 29.53 kg

Ans. (d)

Sol.



Stroke = 2 × crank radius (r) = 350 mm
Mass to be balanced (M) = Revolving mass + 60% of reciprocating mass.

$$= (30 + 0.6 \times 40) \text{ kg}$$

$$= (30 + 24) \text{ kg}$$

$$= 54 \text{ kg}$$

Now,
$$\underbrace{Mw^2 \cdot r}_{\text{Mass to be balanced part}} = \underbrace{mw^2 \times R}_{\text{Balanced mass}}$$

$$\Rightarrow \left(54 \times \frac{0.35}{2} \right) = (m \times 0.32)$$

or,
$$m = \left(\frac{54 \times 0.35}{0.32 \times 2} \right) \text{ kg}$$

$$= 29.53 \text{ kg}$$



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Detailed Solution

109. A leaf spring consists of seven steel plates, each 60 mm wide and 6 mm thick. What is the length of the spring if it is to carry a central load of 3 kN, without the stress exceeding 150 MPa?

- (a) 547 mm (b) 498 mm
(c) 494 mm (d) 504 mm

Ans. (d)

Sol. In case of leaf spring, maximum bending stress is given by:

$$\sigma = \frac{3}{2} \frac{wL}{nbt^2}$$

Now, $\sigma = 150$ MPa

$$w = 3 \text{ kN}$$

$$n = 7$$

$$b = 60 \text{ mm}$$

$$t = 6 \text{ mm}$$

$$\begin{aligned} \therefore L &= \frac{(2nbt^2) \times \sigma}{3w} \\ &= \left(\frac{2 \times 7 \times 60 \times 6^2 \times 10^{-9} \times 150 \times 10^6}{3 \times 3 \times 10^3} \right) \\ &= 0.504 \text{ m} \\ &= 504 \text{ mm} \end{aligned}$$

110. According to maximum shear stress theory, with comparison to yield strength in tension, the yield strength in shear is

- (a) half the yield strength in tension
(b) same as that of yield strength in tension
(c) double the yield strength in tension
(d) 1.33 times that of the yield strength in tension

Ans. (a)

Sol. According to maximum shear stress theory,

$$|\sigma_1 - \sigma_2| \leq S_{yt}$$

But in pure shear state of stress,

$$\sigma_1 = \tau \text{ and } \sigma_2 = -\tau$$

$$\tau - (-\tau) = S_{yt}$$

$$2\tau = S_{yt}$$

When yielding occurs in shear under pure shear state of stress, $\tau = S_{ys}$

$$\frac{S_{ys}}{S_{yt}} = \frac{1}{2}$$

111. In curved beams, normally the nature of stress distribution is

- (a) linear (b) circular
(c) parabolic (d) hyperbolic

Ans. (d)

Sol. In curved beams, normally the nature of stress distribution is hyperbolic.

112. Consider the following statements regarding crack:

1. Crack is more likely to occur in the regions of discontinuity such as oil holes.
2. Crack is more likely to occur in the regions of irregularities in machining operations such as stamp mark.
3. Crack is more likely to occur in the internal cracks due to defects in materials like blow holes.

Which of the above statements are correct?

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

Ans. (d)

Sol. The crack is more likely to occur in the following regions:

- (i) Regions of discontinuity, such as oil holes, keyways, screw threads etc.
- (ii) Region of irregularities in machining operation such as scratches on the surface stamp mark, inspection mark etc.
- (iii) Internal crack due to defects in materials like blow holes.

113. The yield strength of bolt material is 300 MPa and factor of safety is 2.5. What is the maximum principal stress using maximum principal stress theory?

- (a) 750 MPa (b) 120 MPa

Detailed Solution

- (c) 27.38 MPa (d) 10.95 MPa

Ans. (b)

Sol. Given: Yield strength, $\sigma_{yt} = 300$ MPa

Factor of safety, FoS = 2.5

Using maximum principal stress theory,

$$\text{Maximum principal stress, } \sigma_1 = \frac{\sigma_{yt}}{N}$$

$$= \frac{300}{2.5} = 120 \text{ MPa}$$

114. Which one of the following theories gives satisfactory results for brittle materials?

- (a) Maximum principal stress theory
- (b) Maximum shear stress theory
- (c) Distortion energy theory
- (d) Shear stress energy theory

Ans. (a)

115. A cast steel bar having an ultimate strength of 120 MPa is subjected to a reversed, repeated, bending load. The bar will be machined to a rectangular cross-section, 150 mm wide \times 200 mm high. What is the equivalent diameter?

- (a) 14 mm (b) 30 mm
- (c) 140 mm (d) 300 mm

Ans. (c)

Sol. The 'effective' diameter of any non-circular cross-section is the given by,

$$d_e = \sqrt{\frac{A_{95}}{0.0766}} \quad \dots(i)$$

where,

A_{95} = portion of cross-sectional area of the non-cylindrical part that is stressed between 95% and 100% of the maximum stress

d_e = effective diameter of the non-cylindrical part

For a rectangular cross-section having width b and depth h ,

$$A_{95} = 0.05 bh \quad \dots(ii)$$

from equation (i) and (ii),

$$d_e = \sqrt{\frac{0.05bh}{0.0766}} = 0.808 \sqrt{bh}$$

$$= 0.808 \sqrt{150 \times 200} = 140 \text{ mm}$$

116. Consider the following statements regarding typical analysis of bolt failure:

1. 15% failure of bolt occur at the fillet under the head.
2. 50% failure of bolt occur at the end of threads on the shank.
3. 80% failure of bolt occur in the threads that are in contact with the nut.

Which of the above statements is/are correct?

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

Ans. (a)

Sol.

A typical analysis of bolt failures indicate that

- 15% failures of bolt occur at the fillet under the head
- 20% failures of bolt occur at the end of threads on the shank.
- 65% failures of bolt occur in the threads that are in contact with the nut.

117. Which of the following are the functions of lubrication in a bearing unit?

1. To protect the bearing components from corrosion.
2. To absorb heat from the bearing unit.
3. To carry heat away from the bearing unit.

Select the correct answer using the code given below:

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

Ans. (d)

Sol. The lubricants are used in bearings to reduce friction between the rubbing surfaces and to carry away the heat generated by friction. It

Detailed Solution

also protects the bearing against corrosion.

118. Consider the following statements regarding clutches:

1. Dry clutch has higher coefficient of friction compared to wet clutch.
2. The torque capacity of wet clutch is high compared to dry clutch.
3. The engagement in a dry clutch is smoother than in case of wet clutch.

Which of the above statements is/are correct?

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

Ans. (a)

Sol. The difference between dry and wet clutches is as follows:

- (i) A dry clutch has higher coefficient of friction. In wet clutches, the coefficient of friction is reduced due to oil. The coefficient of friction for dry operation is 0.3 or more, while it is 0.1 or less for wet operation.
- (ii) The torque capacity of dry clutch is high compared with the torque capacity of wet clutch of the same dimensions.
- (iii) For dry clutch, it is necessary to prevent contamination due to moisture or nearby lubricated machinery, by providing seals. Such a problem is not serious in wet clutches.
- (iv) Heat dissipation is more difficult in dry clutches. In wet clutches, the lubricating oil carries away the frictional heat.
- (v) Rate of wear is far less in wet clutches compared to dry clutches. The wear rate in wet clutches is about 1% of the rate expected in dry clutches.
- (vi) The engagement in wet clutch is smoother than in the case of dry clutch.
- (vii) In wet clutches, the clutch facings are grooved to provide for passage of lubricant. This reduces the net face area for transmitting torque.

119. Which of the following factors can cause misalignment of the teeth on the pinion relative to those on the gear?

1. Inaccurate gear teeth
2. Misalignment of the axes of shafts carrying gears
3. Thermal distortions during operation

Select the correct answer using the code given below:

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

119.

Ans. (d)

120. Consider the following statements regarding welded and riveted joints:

1. Welded assemblies are tight and leak proof as compared with riveted assemblies.
2. Single-welded V-joint is less reliable than square butt joint.
3. Welding results in a thermal distortion of the parts, thereby inducing residual stresses.

Which of the above statements is/are correct?

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

Ans. (b)

Sol.

- Welded joints are subjected to residual stresses due to non-uniform heating of the parts being joined. There is always a possibility that localised thermal stresses may result from uneven heating and cooling during fusion and subsequent cooling. This also results in distortion.
- Single welded V-joint is more reliable than square butt joint. Single welded V-joint with backing strip is more reliable than single welded V-joint without backing strip. Double welded V-joint is more reliable than single welded V-joint with backing strip. The cost also increases with the reliability of the joint.

121. Which one of the following lubricants is used in forward hot extrusion of steel?

- (a) Molten glass (b) Soap solution
(c) Copper sulphate (d) Vegetable oil

Detailed Solution

Ans. (a)

Sol. Hot extrusion involves prior heating of the billet to a temperature above its recrystallization temperature, lubrication is critical hot extrusion for certain metal's (eg. steels) and special lubricants have been developed that are effective under harsh conditions in hot extrusion. For hot extrusion glass is an excellent lubricants with steels, stainless steels and high temperatures metals and alloys.

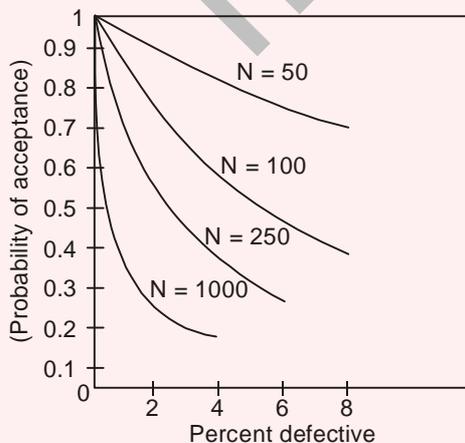
122. Which one of the following statements is not the correct statement regarding operating characteristics (OC) curve for sampling plan?

- (a) It shows ability to distinguish between good and bad lots.
- (b) No sampling plans can give complete protection against acceptance of defectives.
- (c) Larger the sample size, steeper is the slope of the curve
- (d) Acceptance number is zero for ideal sampling plan.

Ans. (d)

Sol.

- Operating curve shows ability to distinguish between good and bad lots.
- No sampling plans can give complete protection against acceptance of defectives.
- Larger the sample size, steeper is the slope of the curve.



- Acceptance number need not be zero for ideal sampling plan.

123. Which one of the following statements is not

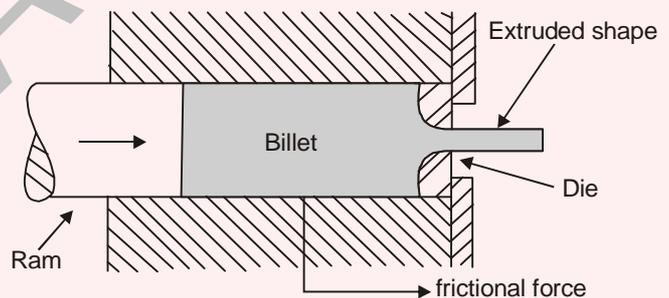
correct for forward or direct extrusion process?

- (a) High friction forces must be overcome.
- (b) High extrusion forces are required but mechanically simple and uncomplicated.
- (c) Low scrap or material waste only 5 – 6% of billet weight.
- (d) Simple, but the material must slide along the chamber wall.

Ans. (c)

Sol.

- A ram drives the entire billet to and through a stationary die and must provide additional power to overcome the frictional resistance between the surface of the moving billet and the confining chamber, Hence material must slide along the chamber wall.
- Huge amount of frictional energy are developed due to which more amount of force are required for extraction.



124. Consider the following statements regarding defects in forgings:

1. Flakes are internal breaks or ruptures occurring in some grades of alloy steel.
2. Die shift is caused by misalignment between the top and bottom forging dies.
3. Fins and rags are small projections or loose metal driven into the surface of the forging.

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.

- Flakes are basically internal ruptures caused by the improper cooling of the large forging.

Detailed Solution

- Die shift is caused by the misalignment of the two die halves, making the two halves of the forging to be of improper shape.
- Fins and rags are small projection of loose metal into the forging surface. The possible cause are improper workmanship, poor die design etc.

125. Consider the following statements regarding desirable properties of cutting fluid:

1. It should get oxidised when left in air.
2. It should react with the materials of machine tool parts.
3. It should wet the surface of cutting tool and workpiece.

Which of the above statements is/are correct?

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

Ans. (b)

Sol.

Cutting fluids are used for decreasing power requirement and increasing heat dissipation. The desirable properties of cutting fluid are

- It should not get oxidised when left in air
- It should not react with the material of machine tools parts
- Easily available
- It should not foam
- Low viscosity
- It should wet the surface of cutting tool and workpiece for better heat dissipation.

126. Consider the following statements regarding limits and fits:

1. Actual size is the standard size of the part and is the same both for the hole and its shaft.
2. Basic size is the dimension as measured on the manufactured part.
3. Deviation is the algebraic difference between a size and the corresponding basic size.

Which of the above statements is/are correct?

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

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

Ans. (a)

Sol.

- Actual size is the actual measured dimension of the part not the standard size of the part and if is not the same f_g both hole and shaft. Hence wrong.
- Basic size is the size of a part to which all limits of variation are applied. Basic dimension is theoretical dimension. Hence wrong.
- Deviation is the algebraic difference between a size (actual max etc) and the corresponding basic size. Hence correct.

127. Which of the following statements is not correct about PERT?

- (a) Network is constructed based on the events.
(b) It does not take uncertainties involved in the estimation of times.
(c) Network deals with uncertainties and hence three time estimations are considered.
(d) As there is no certainty of time, activity duration cannot be reduced.

Ans. (b)

Sol. In case of PERT, three time estimates, optimistic time (t_o), pessimistic time (t_p) and most likely time (t_m) are considered to calculate the average or expected time.

$$t_E = \frac{t_o + 4t_m + t_p}{6}$$

128. Parallel misalignment is present when

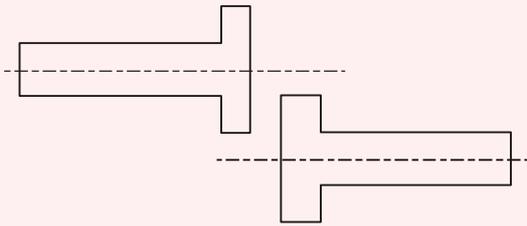
- (a) two shafts are parallel to each other but are not in the same plane.
(b) two shafts are parallel to each other and are in the same plane.
(c) the shafts are not parallel to each other.
(d) the shafts are aligned with each other.

Ans. (b)

Sol.

Parallel misalignment is present when the centre lines of both shafts are parallel but they are offset in same plane.

Detailed Solution



129. The major limitation with displacement or proximity probes is

- (a) Size (b) Time
(c) Accuracy (d) Cost

Ans. (a)

Sol. The sensing range of a proximity probe depends on the type of metal being detected, its shape, its size used in design. Due to above reason proximity probes has distance (size) limitations.

130. Which one of the following contains design data on all products, e.g., their constituent component and parts?

- (a) Engineering data master file
(b) Process data master file
(c) Inventory master file
(d) Sales master file

Ans. (a)

131. Which one of the following is the cutter with a curved tooth outline of the same shape as the profile of the workpiece?

- (a) Plain milling cutter
(b) Face milling cutter
(c) End milling cutter
(d) Profile milling cutter

Ans. (d)

Sol.

- Plain milling, Face milling and End milling cutter are used where the geometry of the machined surface are not related with the tool shape
- Form or profile milling cutter are used where the job profile becomes the replica of the tool form.

132. Which one of the following is a joining process that may employ acetylene, natural gas,

butane in combination with oxygen to supply the heat required to melt the filler rod and diffuse it into the surface of the base metal?

- (a) Furnace brazing (b) Torch brazing
(c) Induction brazing (d) Dip brazing

Ans. (b)

Sol. Heat source that are used for brazing are a molten bath of brazing filler metal, oxy-acetylene torch, controlled atmosphere furnace, electrical resistance heating and inductor heating.

- In torch brazing a reducing flame (oxy-acetylene) is used.
- In dip brazing a molten salt bath is used to supply heat to the base metal.
- In induction heating heat is obtained from the high-frequency current induced in the work.
- In furnace brazing a furnace with a controlled atmosphere is used.

133. Consider the following statements regarding modulation:

1. The modulation is essential in communication systems, where a weak signal is transmitted by the use of a carrier signal.
2. When the frequency of the high frequency signal is varied in accordance with the intensity of the low-frequency weak signal, the modulation is said to be frequency modulation.
3. The process of recovering original baseband signal from the modulated signal is called phase modulation.

Which of the above statements are correct?

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

Ans. (b)

Sol. Modulation is a process of changing the parameters of a high frequency signal called a carrier signal, with respect to the intensity of a given weak signal called an original baseband signal or modulating signal. The high frequency signal is usually a sinusoidal signal. The parameters are simply the amplitude, frequency, and phase. Modulation is essential in communication systems, where a weak signal is

Detailed Solution

transmitted by the use of a carrier signal. The carrier signals are usually sinusoidal in nature. There are many forms of modulation such as Amplitude Modulation (AM), Frequency Modulation (FM), and Phase Modulation (PM). When a high frequency signal has amplitude varied in response to the intensity of a low-frequency weak signal, the modulation is called AM. When the frequency is varied in accordance with the intensity of the weak modulating signal, the modulation is referred to as FM. A similar definition can also be given for PM. The process of recovery of the original baseband signal from the modulated signal is called de-modulation.

Phase modulation is a type of modulation intended for transmitting communication signals. It changes message signal in accordance with the carrier signal due to differences in the immediate phase.

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

- (a) 0.033 V (b) 0.053 V
(c) 0.043 V (d) 0.023 V

Ans. (d)

Sol. The full scale output voltage of 6V will be divided into 2^8 intervals. A change of 1 bit is thus a change in the output voltage of

$$= \frac{6}{2^8} = 0.023 \text{ V}$$

- 135.** Which one of the following is not an application of Hall effect sensor?

- (a) Magnetic switch for electric transducer
(b) Measurement of current
(c) Measurement of acceleration
(d) Measurement of power

Ans. (c)

Sol. Measurement of acceleration

Application of Hall effect sensor

- Hall sensors are used for proximity switching, positioning, speed detection and current sensing application.
- They are used in brushless DC motors to detect the position of the permanent magnet
- It is used as a magnetic switch for electric transducer.
- It is used for the measurement of the position, displacement and proximity.
- It is used for measurement of current.
- It is used for measurement of power.

- 136.** Consider the following statements regarding mechatronics systems:

- The anti-lock brakes on a car are a simple example of a real time computing system.
- The completion of an operation after its deadline is considered useless in soft real time system.
- The hard real time system tolerates lateness and may respond with decreased service quality.

Which of the above statements is/are correct?

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

Ans. (a)

Sol. Real time control and computing is the study of hardware and software systems which are subject to a "real time constraint".

A system is said to be a real time system if there is total correctness of an operation. This depends upon not only the operation's logical correctness, but also the time in which it is performed and used. The antilock brakes on a car are a simple example of a real-time computing system and the real time constraint in the system is the short time in which the brakes must be released to prevent the wheel from locking.

Two types of real time system:

- Hard real time system:** In this completion of an operation after its deadline is considered useless.
- Soft real time system:** It tolerates such lateness and may respond with decreased

Detailed Solution

service quality.

137. Which one of the following materials has least piezoelectric charge sensitivity?

- (a) Quartz
- (b) Barium Titanate
- (c) PZT
- (d) PVDF

Ans. (a)

Sol. Piezoelectric charge sensitivity of following materials:

Quartz - 2.2 pC/N

Barium Titanate - 130 pC/N

Lead zirconate Titanate (PZT) - 265 pC/N

PVDF - 3.10 pC/N

138. The ideal hydraulic rotary actuator provides shaft torque, T, which is

- (a) equal to displaced volume measured.
- (b) inversely proportional to the displaced volume measured.
- (c) proportional to the differential pressure.
- (d) inversely proportional to the differential pressure.

Ans. (c)

Sol. Proportional to the differential pressure rotary actuators are the hydraulic or pneumatic equivalent of electric motors which are used when a twisting or turning motion is required.

A rotary actuator based on the principle of a gear motor. Fluid enters at the top with high pressure, applying force on the gear faces resulting in rotation.

The design and construction of a vane motor is similar to a vane pump. At the entry, a vane has high pressure on one side, whereas on the other side the pressure will be very low due to high pressure of fluid. This difference in pressure exerted on the vane will produce a torque that would result in rotation of vanes.

139. An ammeter requires a change of 3 A in its coil to produce a change in deflection of the pointer by 12 mm. What is the static sensitivity?

- (a) 36 mm/A
- (b) 9 mm/A

- (c) 4 mm/A
- (d) 15 mm/A

Ans. (c)

Sol. The sensitivity is the relationship indicating how much output you get per unit input, i.e. output/ input

$$\text{Sensitivity} = \frac{\text{Change in output}}{\text{Change in input}}$$

$$= \frac{12}{3} = 4 \text{ mm / A}$$

140. What is the force needed to apply to a piston of 2 cm radius in order to result a force of 6000 N at the working piston of radius 6 cm?

- (a) 1334 N
- (b) 333 N
- (c) 1050 N
- (d) 667 N

Ans. (d)

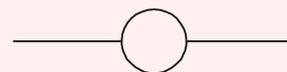
Sol. Pressure will be same

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$\frac{F_1}{\frac{\pi}{4}(2)^2} = \frac{6000}{\frac{\pi}{4}(6)^2}$$

$$F_1 = 666.67 \text{ N}$$

141. The following symbol in the ladder logic represents :



- (a) Normally open contacts
- (b) Normally closed contacts
- (c) Outputs loads
- (d) Special instruction

Ans. (c)

142. The settling time for a unit step response of a second-order system is

- (a) proportional to the natural frequency
- (b) inversely proportional to the natural frequency
- (c) equal to the damping ratio
- (d) proportional to the damping ratio

Ans. (b)



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ASHOK KUMAR



AIR 12 CE
NOOKALA SAIKAS



AIR 13 CE
MRINAL DEWANGAN



AIR 15 CE
SATYAM GUPTA



AIR 16 CE
PRANAV CHOUDHARY



AIR 17 CE
SHAKTI SHEKHAR



AIR 18 CE
ISHANT GEHI



AIR 19 CE
ADITYA UPADHYAY



AIR 20 CE
BHAVYA PARASHAR



AIR 3 ME
SURAJ KUMAR SHAW



AIR 4 ME
SHUBHAM BOTHRA



AIR 5 ME
KAMLESH PARWAR



AIR 6 ME
MOHAMMAD ZUHAIB



AIR 8 ME
VUYYURU SAIKRISHNA REDDY



AIR 9 ME
GANESH KUMAR ADIGAUR



AIR 13 ME
ARPIT JAIN



AIR 14 ME
NIMESH CHANDRA



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Sol. In second order system, the setting time is used as a measure of the time taken for the oscillations to die away.

$$t_s \propto \frac{1}{\xi\omega_n}$$

Here ω_n is natural frequency

ξ is damping ratio

143. A typical wrist mechanism with three rotational joints would be indicated by

- (a) TRL (b) TRT
(c) LLL (d) TRR

Ans. (d)

144. The Analog-to-Digital conversion process involves:

1. Quantizing
2. Sampling
3. Encoding

What is the correct sequence?

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

Ans. (a)

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 and 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.

145. Statement (I): Gravity is the driving force behind flows through open channels.

Statement (II): Gravity stands to reason that the ratio of inertial to gravitational forces will play a major role in open channel flow analysis.

Ans. (b)

146. Statement (I): The viscosity of liquids decreases with the increase of temperature while the viscosity of gases increases with the increase of temperature.

Statement (II): The viscous forces in a fluid are due to cohesive forces and molecular momentum transfer.

Ans. (a)

Sol.

147. Statement (I): If two systems are in thermal equilibrium with a third system, then they are not in thermal equilibrium with each other.

Statement (II): Zeroth law of thermodynamics is the basis for temperature.

Ans. (d)

Sol. When a body A is in the thermal equilibrium with a body B, and separately with body C, then bodies B and C will be in thermal equilibrium with each other. This is known as zeroth law of thermodynamics. It is the basis of the temperature measurement.

148. Statement (I): A thermal energy reservoir is a system that always remains at constant temperature even though the heat is added to or removed from it.

Statement (II): A thermal reservoir that supplies heat energy is called sink and one that absorbs the heat energy is called source.

Ans. (c)

Sol. A thermal reservoir that supplies energy is termed as source and one that absorbs the heat energy is called sink.

Detailed Solution

149. Statement (I): Wear is an issue whenever two components operate with relative motion between them or when liquids or solids impinge on a surface at high velocity.

Statement (II): Wear is often cumulative and can eventually render the components incapable of delivering their expected performance.

Ans. (b)

Sol. Wear is the undesirable removal of solids from a sliding or rolling component. Wear is generally proportional to the applied load and the amount of sliding erosive wear is the cutting of furrows on a surface by hard particles contained in a fluid travelling at high velocity.

It is often cumulative and leads to poor performance of machining parts.

150. Statement (I): Increased productivity, reduced cost of labour and improved quality can be achieved by automation.

Statement (II): Due to automation in process inventory, dependence on operator skills may be increased.

Ans. (b)

Sol.

- Increased productivity, reduced cost of labour, improved qualities can be achieved by automation.
- Due to automation is process inventory, dependence on operator skills may be increased.

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