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ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

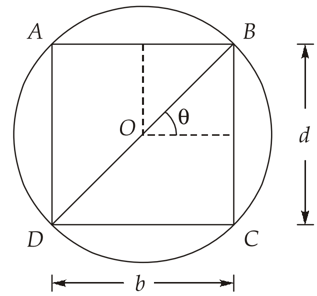
Test 18

Full Syllabus Test-2 : (Paper-II)

Answer Key

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

1. (d)



$$OB = \text{radius} = R$$

Let OB be inclined at θ with the horizontal diameter.

Let $ABCD$ be the rectangular beam to be cut out of the cylindrical log.

$$BC = d = \frac{2D}{2}\sin\theta = D\sin\theta$$

$$AB = b = \frac{2D}{2}\cos\theta = D\cos\theta$$

$$Z = \frac{bd^2}{6} = \frac{(D\cos\theta)(D\sin\theta)^2}{6} = \frac{D^3\cos\theta\sin^2\theta}{6}$$

For beam to be strongest, Z must be maximum $\frac{dz}{d\theta} = 0.$

$$\frac{D^3}{6}\left[-\sin\theta\left(\sin^2\theta\right) + 2\sin\theta\cos\theta\cos\theta\right] = 0$$

$$-\sin^3\theta + 2\sin\theta\cos^2\theta = 0$$

$$\sin\theta\,[2\cos^2\theta - \sin^2\theta] = 0$$

$$\sin\theta = 0$$

or $$\tan^2\theta = 2$$

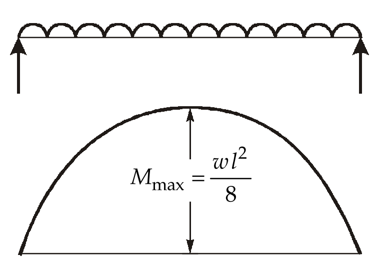
$$\tan\theta = \sqrt{2}$$

$$\sin\theta = \frac{\sqrt{2}}{\sqrt{3}}$$

$$\cos\theta = \frac{1}{\sqrt{3}}$$

$$\frac{d}{b} = \frac{D\sin\theta}{D\cos\theta} = \sqrt{2}$$

2. (b)



We have, $$\frac{M_v}{I} = \frac{\sigma}{y}$$

Let UDL be w kN/m

$$M_{max} = \frac{wl^2}{8} = \frac{w(10)^2}{8} = 12.5\text{ W kN-m}$$

$$1 \text{ kN-m} = 1 \times 10^3 \times 10^3 = 10^6 \text{ N-mm}$$

$$M_{max} = \frac{\sigma \cdot I}{y} = \frac{\sigma \times 1 \times 10^8}{100} = \sigma \times 10^6 \text{ N-mm}$$

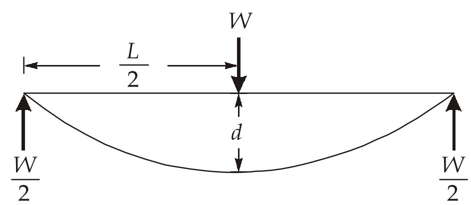
$$M_{max} = 12.5w \times 10^6 \text{ N-mm}$$

$$12.5w \times 10^6 = 150 \times 10^6$$

$$w = 12 \text{ kN/m}$$

3. (c)

Greatest BM occur at the mid-span when point load is at the mid-span.



Let d be the depth at the mid span.

$$M_{max} = \frac{W}{2} \cdot \frac{L}{2}$$

Also, $$M_{max} = \sigma \cdot \frac{bd^2}{6}$$

∴ $$\frac{WL}{4} = \sigma \cdot \frac{bd^2}{6}$$

$$\sigma = \frac{3}{2}\frac{WL}{bd^2}$$

Now, let the point W be placed at a distance x from support.

$$M_{max} = \frac{Wx(L-x)}{L}$$

Bending stress, $$\sigma_x = \frac{6Wx(L-x)}{Lbd_x^2}$$

$$\sigma = \sigma_x \text{ for beam of uniform strength}$$

$$\frac{6Wx(L-x)}{Lbd_x^2} = \frac{3}{2}\frac{WL}{bd^2}$$

$$d_x = \frac{2d}{L}\sqrt{x(L-x)}$$

4. (a)

$$A = \frac{\pi}{4} \times (14)^2 = 154 \text{ mm}^2$$

$$\text{KE of load} = \frac{1}{2}MV^2 = \frac{1}{2}\times 1000\times(1)^2 = 500\text{ N-m}$$

$$U = \frac{\sigma^2}{2E}AL = \frac{\sigma^2\times 154\times 10000}{2\times 2\times 10^5} = \frac{\sigma^2\times 77}{20}$$

$$500\times 10^3 = \sigma^2\times\frac{77}{20}$$

$$\sigma = 360.37\text{ N/mm}^2 \simeq 360\text{ N/mm}^2$$

5. (d)

$$y_B = \left[\frac{PL^3}{3EI}-\frac{ML^2}{2EI}\right]$$

$$= \frac{L^2}{6EI}[2PL-3M]$$

6. (a)

$$G = 1\times 10^5\text{ N/mm}^2$$

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

$$\frac{\delta d}{d} = -\mu\frac{P}{EA}$$

$$\frac{2\times 10^{-3}}{10} = \mu\frac{10\times 10^3}{2G(1+\mu)\times\frac{\pi}{4}(10)^2}$$

$$\frac{2\times 10^{-3}}{10} = \frac{10\times 10^3}{2\times 1\times 10^5\left(\frac{1}{\mu}+1\right)\times\frac{\pi}{4}(10)^2}$$

$$\left(1+\frac{1}{\mu}\right) = \frac{10\times 10^3\times 10}{2\times 10^5\times\frac{\pi}{4}(10)^2\times 2\times 10^{-3}}$$

$$\mu = 0.457 \simeq 0.46$$

7. (a)

$$\alpha L\Delta T - \frac{\sigma L}{E} = a$$

$$\sigma = 0$$

$$\alpha L\Delta T = a$$

$$12\times 10^{-6}\times 20\times\Delta T = 12\times 10^{-3}$$

$$\Delta T = \frac{12 \times 10^{-3}}{12 \times 10^{-6} \times 20} = 50°C$$

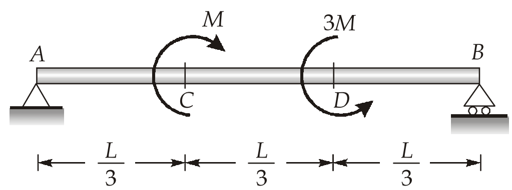
$$T_f - T_i = 50$$

$$\therefore \quad T_f = 60°C$$

8. (d)

For ductile material, though distortion energy theory is quite in agreement with the experimental results, maximum shear stress theory is most widely used for its simplicity.

9. (a)

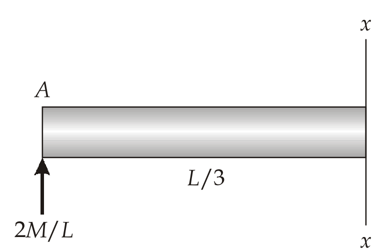


Calculating reactions at the supports,

$$\therefore \quad R_A \times L + M = 3M$$

$$\therefore \quad R_A = \frac{2M}{L}$$

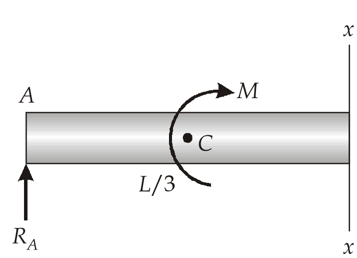
For portion $AC \left(0 \le x < \frac{L}{3}\right)$



$$BM = \frac{2M}{L}(x)$$

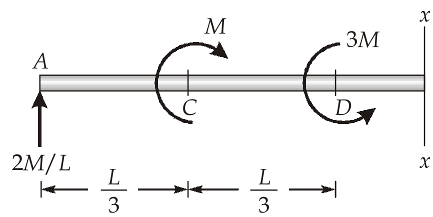
For portion $CD \left(\frac{L}{3} \le x < \frac{2L}{3}\right)$

$$BM = \frac{2M}{L}x + M$$



$$BM_C = \frac{2M}{L}\frac{L}{3} + M = \frac{5M}{3}$$

For portion DB $\left(\frac{2L}{3} \le x < L\right)$



$$BM = \frac{2M}{L}x + M - 3M$$

$$= \frac{2M}{L}x - 2M$$

$$BM_D = \frac{2M}{L} \times \frac{2L}{3} - 2M = \frac{4M}{3} - 2M = \frac{-2M}{3}$$

Therefore, option (a) is the right answer.

10. (c)

Simple theory of bending, based on following assumption:

1. Material is linearly elastic and follows Hooke's law.
2. Plane sections remains plane and normal to the neutral axis after bending.
3. Beam material is homogeneous and isotropic.
4. Beam is initially straight and has a constant cross-section.

11. (b)

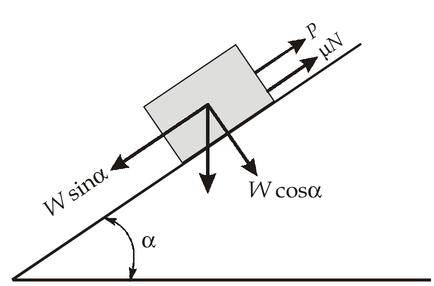
Total load = 50 kg

Moment about A = 20 × 2.3 + 30 × 8.6

= 304 kg cm

Point at which rod will balance = $\frac{304}{50} = 6.08$ cm

12. (c)



For equilibrium,

$$P + \mu N = W\sin\alpha$$
$$\mu = \tan\phi$$
$$\phi = \text{Friction angle}$$
$$P + \tan\phi\, W\cos\alpha = W\sin\alpha$$
$$P = W[\sin\alpha - \tan\phi\,\cos\alpha]$$
$$= W\left[\sin\alpha - \frac{\sin\phi}{\cos\phi}\cos\alpha\right] = W\left[\frac{\sin\alpha\cos\phi - \cos\alpha\sin\phi}{\cos\phi}\right]$$
$$P_{\min} = W\left[\frac{\sin(\alpha-\phi)}{\cos\phi}\right]$$

13. (c)

14. (c)

Distance travelled for 1 revolution $= 2\pi r$

Total distance travelled for 70 revolution = $70 \times 2\pi r$

$$= 70 \times \pi \times 1 = 70\,\pi\,\text{m}$$
$$\text{Friction force} = \mu N$$
$$= 0.3 \times 10 = 3\text{ N}$$
$$F = ma$$
$$a = \frac{-3}{110}\ \text{m/s}^2$$

For initial,
$$v^2 - u^2 = 2as$$
$$u^2 = 2 \times a \times s \qquad \text{(Retardation)}$$
$$u = \sqrt{2 \times \frac{3}{110} \times 70 \times \pi}$$
$$u = 2\sqrt{3}$$

15. (c)

16. (c)

17. (c)

We know,
$$Q = \sqrt{\frac{2DC_0}{C_h}} = \sqrt{\frac{2 \times 100 \times 200}{0.04}}$$
$$Q = 1000\text{ units}$$
$$\text{Length of cycle} = \frac{1000}{100} = 10\text{ days}$$

As the lead time is 13 days and cycle length is 10 days, reordering should occur when the level of inventory is sufficient to satisfy the demand for 13 – 10 = 3 days

$$\text{Reorder point} = 100 \times 3 = 300 \text{ units}$$

18. (c)

The benefits of using PERT (Program Evaluation and Review Technique) in project management.

1. Improved project scheduling.
2. Identification of critical path.
3. PERT helps to identify potential risks and uncertainties.
4. Resource allocation.
5. Reduced project duration.
6. Better project monitoring.

19. (c)

$$\text{Arrival rate, } \lambda = \frac{15}{8 \times 60} = \frac{1}{32} \text{ units/minute}$$

$$\text{Service rate, } \mu = \frac{1}{20} \text{ units/minute}$$

Number of jobs ahead of the set bought in = Average number jobs in the system

$$L_s = \frac{\lambda}{\mu - \lambda} = \frac{\frac{1}{32}}{\frac{1}{20} - \frac{1}{32}} = \frac{5}{3}$$

$$L_s = \frac{5}{3}$$

20. (c)

Exponential smoothing is designed to smooth out fluctuations, but it doesn't explicitly account for seasonal patterns.

Exponential smoothing gives more weight to recent observations and less weight to older observations. This is what allows it to adopt to changes in demand.

21. (d)

BMTS is based on the complete movements of body members and following factors are taken into account:

1. Distance moved during any activity.
2. Amount of muscular control required to stop or slow down the motion.
3. Degree of precision required in grasping and positioning.
4. Degree of freedom.
5. Simultaneous motions, ex: time for reach and move may be affected if performed simultaneously.

22. (c)

Batch production have more flexibility than mass production as it uses general purpose machine tools.

23. (c)

One of the limitations of eddy current method is its limited depth of penetration.

24. (c)

$$\text{Revenue} = \text{Fixed cost} + \text{Variable cost} + \text{Profit}$$

$$\text{For breakeven profit} = 0$$

$$\text{Revenue} = \text{FC} + \text{VC}$$

Let the breakeven be x

$$x \cdot [10] = 40000 + x(5)$$

$$5x = 40000$$

$$x = 8000 \text{ units}$$

25. (b)

Gating element should be designed in such a way that

1. No air aspiration effect is there.
2. Molten metal enters the mould cavity with optimum velocity without turbulence and splashing.
3. Molten metal enter the mould cavity without any slag particles and impurities.
4. Casting yield should be maximum.
5. Molten metal enters into the mould cavity without eroding gating elements and mould cavity.

26. (c)

Power source, $$6V + 2I = 480$$

$$3V + I = 240$$

$$I = 240 - 3V$$

$$\text{Power, } P = VI$$

$$= V(240 - 3V)$$

$$P = 240\text{V} - 3V^2$$

For maximum power, $$\frac{dP}{dV} = 0 = \frac{d\left(240V - 3V^2\right)}{dV}$$

$$6V = 240$$

$$V = 40 \text{ Volts}$$

27. (b)

In soldering and brazing, the composition of the filler material is intentionally designed to be different from that of the base metal for several reasons:

1. Lower melting point than the base metal, allowing it to melt and flow into the joint without melting the base metal.
2. Improved flow and wetting, ensuring a strong bond between the two.
3. Reduced oxidation, increased strength, corrosive resistance.

The filler metal in soldering must have low surface tension and high wetting capability.

28. (a)

$$\frac{N_{max}}{N_{min}} = (r)^{n-1}$$

$$\frac{1200}{120} = (r)^{9-1}$$

$$10 = (r)^8$$

For spindle speed 5th one

$$\frac{N_{max}}{N_{min}} = (r)^{5-1} = (r)^4$$

$$\frac{N_{max}}{120} = (r)^4$$

$$N_5 = 120 \times \sqrt{10}$$

$$N_5 = 379.47 \simeq 378$$

29. (d)

$$D_B = 50 \text{ mm, Thickness } (t) = 5 \text{ mm}$$

$$\text{Clearance} = 10\% \text{ of sheet thickness}$$

$$= \frac{10}{100} \times 5 = 0.5 \text{ mm}$$

$$\text{Punch diameter} = 50 - (2 \times 0.5) = 49 \text{ mm}$$

$$\text{Die diameter} = \text{Blank diameter} = 50 \text{ mm}$$

30. (a)

$L = 100$ mm $\Rightarrow$ $\sin\theta = \frac{h}{L}$

$\theta = 30°$

$$h = L\sin\theta$$

$$h = 100 \times \sin 30°$$

$$h = 50 \text{ mm}$$

31. (c)

Interference fit makes it more difficult to disassemble the bearing, not easier.

32. (b)

Diffusion : At elevated temperatures during sintering, atoms move within the solid material. This diffusion process allows atoms to migrate from areas of high concentration to areas of low concentration (like voids or pore spaces), reducing the void volume and increasing density.

Grain growth : As sintering progresses, smaller, grains tend to coalesce into larger grains, contributing to densification.

33. (d)

$$\text{Radius of gyration} = 0.5 \times 6 = 3 \text{ m}$$

$$\text{Moment of Inertia, } I = mk^2 = (4 \times 20) \times (3)^2 = 80 \times 9$$

$$\text{Angular speed, } \omega = \frac{2 \times \pi \times N}{60} = \frac{2 \times 22 \times 420}{7 \times 60}$$

$$\omega = 44 \text{ rad/sec}$$

$$\text{Couple, } C = I\omega\omega_p$$

$$= (80 \times 9) \times 44 \times 1$$

$$C = 31.68 \text{ kNm}$$

34. (d)

$$f_n = 5 \text{ Hz}$$

$$\omega_n = 2\pi f_n = 2 \times \pi \times 5$$

$$\omega_n = 10\pi$$

$$N = \frac{\omega_n \times 60}{2\pi} = \frac{10\pi \times 60}{2\pi} = 300 \text{ rpm}$$

35. (d)

$$\frac{x_4}{x_o} = \frac{1}{16}$$

$$\frac{x_0}{x_4} = 16$$

$$\frac{x_0}{x_1} \cdot \frac{x_1}{x_2} \cdot \frac{x_2}{x_3} \cdot \frac{x_3}{x_4} = 16$$

$$e^{4\delta} = 16$$

$$4\delta = \ln 16$$

$$\delta = \frac{\ln 16}{4} = \frac{\ln(2)^4}{4}$$

$$\delta = \frac{4 \ln 2}{4} = \ln 2$$

$$\delta = \ln 2$$

36. (d)

Effects of partial balancing in locomotics:

1. Hammer blow
2. Variation of tractive force
3. Swaying couple

37. (c)

Oldham's Coupling is used to connect the two parallel shafts when distance between their axes is small.

38. (a)

	Action	Arm	Pinion	Gear
1.	Fixed arm	0	1	$-\frac{T_P}{T_G}$
2.	x rotate	0	x	$-x\frac{T_P}{T_G}$
3.	y	y	$y+x$	$y-x\frac{T_P}{T_G}$

A gear is fixed, $N_G = 0$

$$y - x\frac{T_P}{T_G} = 0$$

$$y = \frac{x}{4}$$

$$x = 4y$$

For 1 revolution of arm;

$$y = 1; \quad x = 4 \text{ revolution}$$

$$N_P = x + y$$

$$N_P = 4 + 1$$

$$N_P = 5 \text{ rev.}$$

39. (d)

A planetary or epicyclic gear train is used in a differential because it allows for the following:

1. Speed differentiation : Enables the wheels on either side of the axle to rotate at different speeds, which is essential for smooth turns.
2. Torque distribution : The gear train distributes the torque evenly between the two wheels.
3. Compact design.

40. (d)

All the three statements are correct. An isochronous governors infinite sensitivity refers to its ability to respond to infinitesionally small changes in speed without oscillating. In other words, its sensitivity is perfectly balanced to eliminate hunting.

41. (a)

42. (c)

$$V_r = (\omega_o + \omega_c)\, r$$

$$= (3+4) \times \frac{10}{1000} = \frac{7}{100}$$

$$V_r = 0.07 \text{ m/sec}$$

43. (c)

LVDT gives an a.c. voltage output proportional to the distance of the transformer core to the windings.

44. (c)

$$G_F = 4.2$$

When the piezo-resistive effect is neglected, the gauge factor is given by

$$G_F = 1 + 2\mu$$

$$4.2 = 1 + 2\mu$$

$$\mu = \frac{4.2 - 1}{2} = 1.6$$

45. (b)

Reproducibility : It relates to the closeness of the output readings for the same input when there are changes in the method of measurement, observer, measuring instrument, location, condition of use and time of measurement.

Threshold : It defines the smallest measurable input.

Resolution : It defines the smallest measurable input.

46. (a)

Programmable Logic Controllers (PLCs) are industrial control devices specifically designed for harsh environments where reliability and quick decision-making are critical. They are typically programmed using ladder logic and are made to be robust against electrical noise and interference. Importantly, PLCs are built with a small and efficient instruction set, optimized only for control tasks like logic, timing, and counting, rather than having a large general-purpose instruction set.

47. (d)

Stepper motors are electromechanical devices that move in discrete, precise angular steps, making them ideal for applications requiring accurate positioning and control. They can rotate in both directions, move in small fixed angles, and provide holding torque when stationary. However, they operate through digital pulse signals rather than analog signals. Therefore, the idea that a stepper motor can be controlled with analog circuits is incorrect, as stepper motors fundamentally require digital control.

48. (a)

$$\text{Number of bits required} = \frac{\log\left(1 + \frac{R}{Q}\right)}{\log 2}$$

$$n = \frac{\log\left(1 + \frac{5}{0.005}\right)}{\log 2} = \frac{\log 1001}{\log 2}$$

$$\simeq \frac{3}{0.3} \simeq 10 \text{ bits}$$

49. (a)

$$\%\text{Linearity} = \frac{\text{Deviation}}{\text{Maximum displacement}}$$

$$= \frac{\pm 0.0045}{1.8} \times 100 = \pm 0.25\%$$

50. (b)

51. (a)

RISC microprocessors are usually faster than conventional microprocessor.

52. (a)

The PIC16F84 generally operates on a regulated 5V supply but has an operable range from 2V to 6V. Its power consumption is minimal and hence can be operated with dry cells for long hours. The PIC16F84 is available as an 18-pin dual-in-line package.

53. (b)

Vacuum grippers : It is used to grasp large flat objects. These grippers are mainly "Suction grippers" that uses a vacuum pump or a venturi jet to generate vacuum between a suction cup and the gripping plane.

54. (c)

Spline : It is the smooth function that passes through the set of knot points.

Trajectory generation : It is the act of computing the trajectory as a time sequence of values in real time, using the trajectory planning algorithm based on the spatial and temporal constraints.

Path update rate : The rate at which the trajectory points are computed at run time is called path update rate.

55. (b)

$$\text{Total heat removed in 10 hours} = mc(\Delta T) + m(\text{L.H})$$

$$= 500 \times 1.25(30) + 500 \times 100$$

$$\text{Total heat} = 68750 \text{ kJ}$$

$$\text{Total heat removed in 1 minute} = \frac{68750}{10 \times 60} \text{ kJ/min}$$

$$= 114.58 \text{ kJ/min} \simeq 115 \text{ kJ/min}$$

56. (a)

- Electrolux refrigerator has NH_3, H_2 and H_2O as working substance.
- Electrolux refrigeration system has no liquid pump, as it uses a capillary tube or a thermostatic expansion valve to control the flow of refrigerant.
- The function of a compressor in a vapour absorption system is performed by absorber, pump and generator.

57. (c)

$$T_H = 273 + 27 = 300 \text{ K},$$
$$T_L = 273 - 23 = 250 \text{ K}$$
$$\text{COP} = 0.5 \times \frac{T_L}{T_H - T_L} = 0.5 \times \frac{250}{300 - 250} = 2.5$$
$$2.5 = \frac{\text{Refrigeration effect}}{\text{Work input}} = \frac{0.5 \times 3.5}{\text{Work input}}$$
$$\text{Work input} = 0.7 \text{ kW}$$
$$\text{Heat rejected} = 0.7 + 0.5 \times 3.5 = 2.45 \text{ kW}$$
$$\Delta h_{\text{condenser}} = \frac{2.45}{0.01}$$
$$(\Delta h)_{\text{cond.}} = 245 \text{ kJ/kg}$$

58. (c)

Properties of a good refrigerant are:

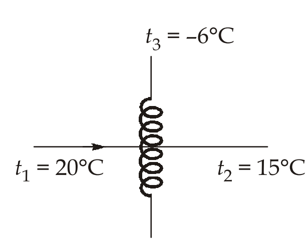
1. High latent heat of vapourization and low freezing point.
2. Specific heat should be less in liquid form and high in vapour form.
3. Thermal conductivity should be high in both liquid and vapour phase.
4. Critical pressure should be high.
5. Viscosity should be low.
6. Critical temperature should be high.

59. (d)

Given : P_{vs} = 3.325 kPa

$$\phi = \frac{P_v}{P_{vs}}$$
$$0.6 = \frac{P_v}{3.325}$$
$$P_v = 1.995 \text{ kPa}$$
$$\text{Specific humidity, } \omega = \frac{0.622 \times P_v}{P_t - P_v} = \frac{0.622 \times 1.995}{101.325 - 1.995}$$
$$= 0.0125 \text{ kg/kg of dry air}$$

60. (d)



$$\text{Bypass factor, BPF} = \frac{t_2 - t_3}{t_1 - t_3} = \frac{15-(-6)}{20-(-6)} = \frac{15+6}{20+6}$$
$$= 0.8077 \simeq 0.8$$

61. (a)

$$T_1 = 300 \text{ K}$$
$$T_2 = 240 \text{ K}$$
$$\text{COP} = \frac{240}{300-240} = 4$$
$$\text{COP} = \frac{\text{Refrigeration effect}}{\text{Work input}}$$
$$4 = \frac{10}{\text{Work input}}$$
$$\text{Work input} = \frac{10}{4} = 2.5 \text{ tonnes}$$
$$\text{Heat rejected} = \text{Refrigeration effect + Work input}$$
$$= 10 + 2.5 = 12.5 \text{ tonnes}$$
$$\text{We know 1 ton of refrigeration} = 210 \text{ kJ/min}$$
$$12.5 \text{ tonnes} = 12.5 \times 3.5 \text{ kJ/sec}$$
$$\text{Heat rejected} = 43.75 \text{ kJ/sec} \simeq 44 \text{ kW}$$

62. (c)

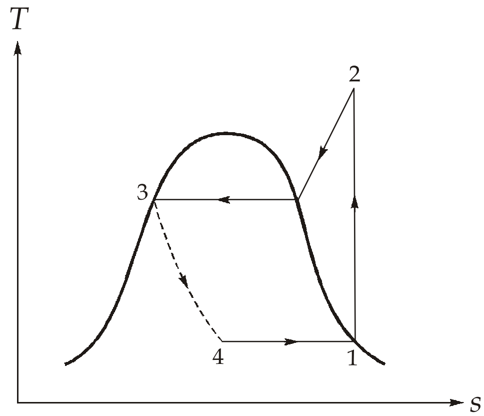
For VARS,
$$\text{COP} = \left(\frac{T_g - T_a}{T_g}\right) \times \left(\frac{T_e}{T_a - T_e}\right)$$

Given,
$$\text{COP} = 2 \text{ and } T_g - T_a = T_a - T_e$$
$$\text{COP} = \frac{T_e}{T_g}$$
$$\frac{T_e}{T_g} = 2$$

63. (d)

Cooling tower is a heat rejection device which is used to cool the water stream by evaporating some of the water flow into an air stream.

64. (b)



VCRS cycle

1 - 2 → Isentropic compression

2 - 3 → Const. pressure heat rejection

3 - 4 → Iso-enthalpic expansion

4 - 1 → Const. pressure heat absorption

65. (b)

Hermetic seated compressors are sealed and are designed to avoid leakage problems. Hermetic compressors are completely sealed units where the motor and compressor are enclosed in the same casing. This sealing prevents refrigerant leakage, which is the major advantage. They are not particularly easy to service because they are sealed.

66. (c)

Subcooling increases refrigeration effect without increasing the compressor work, resulting in higher COP.

67. (b)

$$\text{Solidity} = \frac{Nb}{2\pi R} = \frac{24 \times 0.35}{2 \times \pi \times 3} \times 100$$

$$= 44.58\% \simeq 44.6\%$$

68. (a)

The absorber plate of a flat plate solar collector must be thin enough to quickly absorb heat but strong enough to hold its structure. Typically, metal sheets (like copper or aluminum) of thickness 0.2 mm to 1 mm are used for good heat transfer and mechanical stability.

69. (d)

flat plate Air heating collector has following advantages over a liquid flat-plate collector:

- It is compact, simple in construction and requires little maintenance.
- The need to transfer thermal energy from the working fluid to another fluid is eliminated as air is used directly as the working fluid.

- Corrosion is completely eliminated.
- Leakage of air from the duct is less severe.
- Possibility of freezing of working fluid is also eliminated.
- The pressure inside the collector does not become very high.

70. (c)

It has a high acceptance angle and needs to be adjusted intermittently.

71. (c)

As the insolation keeps on varying throughout the day, it is important to observe its effects on PV characteristics. If the spectral content of the radiation remains unaltered, and temperature and all other factors remain same, both I_{sc} and V_{oc} increase with increasing the intensity of radiation. The photo-generated current depends directly on insolation. Therefore, the short-circuit current depends linearly while the open-circuit voltage depends logarithmically on the insolation.

72. (a)

We know that,
$$\eta = \frac{V_{max} \times I_{max}}{P_{in}}$$
$$V_{max} = \frac{\eta \times P_{in}}{I_{max}} = \frac{0.3 \times 0.9 \times 0.9 \times 10^{-3}}{0.6 \times 10 \times 10^{-3}}$$
$$V_{max} = 0.0405\,\text{V}$$
$$\text{Fill factor, } FF = \frac{I_{max} \times V_{max}}{V_{oc} \times I_{sc}} = \frac{0.6 \times 10 \times 0.9 \times 10^{-3} \times 0.0405}{0.3 \times 0.9 \times 10 \times 10^{-3}}$$
$$FF = 0.09$$

73. (d)

Dry matter produced by two cows = 3 × 2 = 6 kg/day

Dry matter content in cow dung is only 18%

$$\therefore \quad \text{Cow dung produced} = \frac{6}{0.18} = 33.33 \text{ kg/day}$$

Equal amount of water is added to make the slurry.

Hence, the amount of slurry produced per day = 33.33 + 33.33 = 66.66 kg/day

74. (b)

$$\text{Power at any point of time, } P = \frac{\rho Q H'}{75} \times \eta \times 0.736 \text{ kW}$$
$$= \frac{1025 \times 400 \times 6 \times 0.8 \times 0.736}{75}$$
$$= 19.31 \text{ MW}$$

75. (d)

Latent Heat Storage (Storage in Phase Change Materials) :

In this class of storage, energy is stored by virtue of latent heat of change of phase of the storage medium. Phase change materials have considerably higher thermal energy storage densities as compared to sensible heat storage materials and are able to absorb or release large quantities of energy at a constant temperature. Therefore, these systems are more compact but more expensive than sensible heat-storage systems. Various phase changes that can occur are

- Solid-solid (lattice change)
- Solid-gas
- Solid-liquid
- Liquid-gas

Solid-gas and liquid-gas transformations are not employed in spite of large latent heats as large changes in volume make the system complex and impracticable. In solid-solid transition, heat is stored as the material is transformed from one crystalline form to another. These transitions involve small volume changes, however, most of them have small latent heats.

The solid-liquid transformations include storage in salt hydrates. Certain inorganic salts, which are soluble in water and form crystalline salt hydrates, are employed.

76. (d)

The term air mass is defined as the ratio of the path length through the atmosphere, which the solar beam actually traverses up to the ground to the vertical path length through the atmosphere.

i.e.
$$\text{Air mass} = \frac{\text{Path length traversed by beam radiation}}{\text{Vertical path length of atmosphere}}$$

77. (a)

Anemometers work on one of the following principles:

1. The oldest and simplest anemometer is a swinging plate hung vertically and hinged along its top edge. Wind speed is indicated by the angle of deflection of the plate with respect to the vertical.
2. A cup anemometer consists of three or four cups mounted symmetrically about a vertical axis. The speed of rotation indicates wind speed.
3. Wind speed can also be recorded by measuring the wind pressure on a flat plate.
4. A hot-wire anemometer measures the wind speed by recording cooling effect of the wind on a hot wire. The heat is produced by passing an electric current through the wire.
5. An anemometer can also be based on sonic effect. Sound travels through still air at a known speed. However, if the air is moving, the speed decreases or increases accordingly.
6. The other more novel techniques include the laser anemometer, the ultrasonic anemometer and the SODAR Doppler anemometer.

78. (b)

S.No.	Fuel cell	Operating temperature
1	PEMFC	40 - 60°C
2	AFC	90°C
3	PAFC	150 - 200°C
4	MCFC	600 - 700°C
5	SOFC	600 - 1000°C

79. (b)

Heisler's charts are used for solving transient heat conduction problems in solids. These charts provide temperature distribution and heat transfer calculations for different geometrics (slabs, cylinders and spheres). Heisler's charts use Fourier number and reciprocal of Biot number.

80. (d)

The maximum temperature occurring at the centre (r = 0) of sphere is given by

$$t_{\max} = T_w + \frac{q_G R^2}{6k}$$

For $R = 2R$

$$t_{\max} = T_w + \frac{2 q_G R^2}{3k}$$

81. (a)

Fin effectiveness improves with

1. High thermal conductivity.
2. Higher perimeter to cross-sectional area ratio.
3. Low heat transfer coefficient.

82. (d)

The rate of heat transfer by convection,

$$Q_c = h_c\, A(\Delta T)$$
$$h_c = 2(\Delta T)^{1/4}\ \text{W/m}^2\text{K}$$
$$= 2(101 - 20)^{1/4}$$
$$= 6\ \text{W/m}^2\text{K}$$
$$Q_c = 6 \times 1 \times (101 - 20)$$
$$Q_c = 486\ \text{W}$$

83. (b)

$$Q = hA(\Delta T)$$
$$= h\pi DL\,(T_w - T_\infty)$$
$$= 70 \times \pi \times 0.04 \times (50 - 20)$$
$$= 263.76\ \text{W}$$

84. (c)

Equivalent thermal resistance can be written as

$$R_{th} = \frac{L}{k_1 A} + \frac{L}{k_2 A}$$

$$\Rightarrow \quad \frac{2L}{k_{eq} \cdot A} = \frac{L}{k_1 A} + \frac{L}{k_2 A}$$

$$\Rightarrow \quad \frac{2}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2}$$

$$\Rightarrow \quad k_{eq} = \frac{2k_1 \cdot k_2}{k_1 + k_2}$$

85. (a)

$$Q = k_b A \frac{200 - T}{L} = k_s A \frac{T - 0}{L}$$

$$\frac{k_b}{k_s}(200 - T) = (T - 0)$$

$$3(200 - T) = T$$

$$600 - 3T = T$$

$$T = 150°\text{C}$$

86. (c)

Hydrophobic coatings inhibit the wetting of surfaces which helps in promoting dropwise condensation.

87. (c)

Energy balance in spherical shell of thickness dr at distance r is

$$Q = -k4\pi r^2 \frac{dT}{dr}$$

$$\frac{Q}{k4\pi} \int_{r=r_1}^{r=\infty} r^{-2}\, dr = -\int_{T_1}^{0} dT$$

$$\frac{Q}{4\pi k}\left[-\frac{1}{r}\right]_{r_1}^{\infty} = -(0, -T_1)$$

$$\frac{Q}{4\pi k}\left[\frac{1}{r_1}\right] = T_1$$

$$Q = 4\pi k T_1 r_1$$

$$T_1 = \frac{100}{4\pi \times 0.8 \times 0.4}$$

$$= 24.88°\text{C} \simeq 25°\text{C}$$

88. (d)

Given : H_1 = 4 m; T_w = 200°C; T_∞ = 27°C; Q_1 = 8 kW

We know

$$\text{Nu} \propto (\text{GrPr})^{1/4}$$

$$\frac{hL}{k} = \left(\frac{g\beta\Delta T L^3\rho^2}{\mu^2}\cdot\frac{\mu C_p}{k}\right)^{1/4}$$

$$h \propto (L)^{\frac{3}{4}}\cdot L^{-1}$$

$$h \propto (L)^{-\frac{1}{4}}$$

$$Q = hL(\Delta T)$$

$$Q \propto (L)^{1-\frac{1}{4}}$$

$$Q \propto L^{3/4}$$

$$\frac{Q_1}{Q_2} = \left(\frac{L_1}{L_2}\right)^{3/4}$$

$$(8)^{4/3} = \frac{4}{L_2}$$

$$L_2 = 0.25 \text{ m}$$

89. (b)

90. (a)

With datum at the tail race, the total head across the turbine is

$$H = \frac{P_1}{\rho g} + y_1 + \frac{V_1^2}{2g}$$

$$= 36 + (1+3) + \frac{5^2}{2\times 9.81} = 41.27 \text{ m}$$

91. (b)

For similar turbines,

$$\left(\frac{H}{N^2D^2}\right)_m = \left(\frac{H}{N^2D^2}\right)_p$$

$$N_p = N_m \times \frac{D_m}{D_p}\times\left(\frac{H_p}{H_m}\right)^{\frac{1}{2}}$$

$$N_p = 320\times\frac{1}{6}\times\left(\frac{6}{1.5}\right)^{\frac{1}{2}} = 320\times\frac{1}{6}\times 2$$

$$= 106.67 \text{ rpm}$$

92. (c)

Loss of head in the pipeline is

$$h_f = \frac{f\,LQ^2}{12.1 d^5}$$

$$= \frac{4 \times 0.01 \times 80 \times (0.03)^2}{12.1 \times (0.1)^5}$$

$$h_f = 23.80 \text{ m}$$

The head against which the pump is working = 23.80 + 20 = 43.80 m

93. (a)

The basic characteristics of the ramjet engine can be summarized as follows:

(i) It is a simple engine and should be adaptable for mass production at relatively low cost.

(ii) It is independent of fuel technology and a wide range of liquid, and even solid fuels can be used.

(iii) Its fuel consumption is comparatively very large for its application in aircraft propulsion or in missiles at low and moderate speeds.

(iv) Its fuel consumption decreases with flight speed and approaches reasonable values when the flight Mach number is between 2 and 5 and therefore, it is suitable for propelling supersonic missiles.

94. (d)

$$\text{Thrust, } F = \dot{m}_a \left(c_j - c_i\right)$$

$$= 80 \times (2600 - 1300)$$

$$= 104 \text{ kN}$$

$$\text{Thrust power} = F \times C_i$$

$$= 104 \times 1300 = 135.2 \text{ MW}$$

$$\eta_P = \frac{2\alpha}{1+\alpha}$$

$$\alpha = \frac{C_i}{C_j} = \frac{1300}{2600} = 0.5$$

$$\therefore \quad \eta_P = \frac{2 \times 0.5}{1 + 0.5} = 0.6667 \text{ or } 66.67\%$$

95. (b)

Power available from the turbine shaft,

$$P = \rho g Q H \times \eta_0$$

$$735 \times 10^3 = 1000 \times 9.81 \times Q \times 40 \times 0.8$$

$$\therefore \quad Q = \frac{735 \times 1000}{1000 \times 9.81 \times 40 \times 0.8}$$

$$= 2.34 \text{ m}^3/\text{sec}$$

96. (a)

Spraying thin layers of erosion resistance metal in place where cavitation is most likely to occur.

97. (b)

Given : D = 10 cm = 0.1 m, W = 100 N, l = 0.12 m, $C = 2 \times 10^{-3}$ cm

$$\text{Viscous shear stress, } \tau = \mu \frac{du}{dy} = \frac{\mu u}{t}$$

$$\text{Viscous resistance} = \text{Shear stress} \times \text{Area}$$

$$= \frac{\mu u}{t} \times \pi d l$$

$$= \mu \times \frac{5}{2 \times 10^{-5}} \times \pi \times 0.1 \times 0.12 = 9424.8\ \mu\text{N}$$

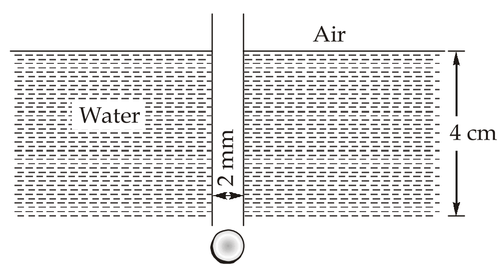
Newton's second law, ΣF = Mass × Acceleration

$$100 - 9424.8\,\mu = \frac{100}{10} \times (-0.5)$$

$$105 = 9424.8\,\mu$$

$$\mu = 0.011\ \text{Ns/m}^2$$

98. (b)



Gauge pressure inside the bubble,

$$P_i = 500\ \text{N/m}^2$$

Gauge pressure outside the bubble,

$$P_o = wh = 10^3 \times 9.81 \times 0.04$$

$$= 392.4\ \text{N/m}^2$$

$$P_i - P_o = 500 - 392.4 = 107.6$$

For bubble, $$P_i - P_o = \frac{4\sigma}{d}$$

$$107.6 = \frac{4\sigma}{0.002}$$

$$\sigma = 0.0538\ \text{N/m}$$

99. (d)

$$\text{Total force on the disc, } F = wA\bar{x}$$

$$= 9810 \times 7 \times 5 = 343350\ \text{N}$$

$$\text{Depth of centre of pressure, } x_{cp} = \bar{x} + \frac{I_{CG}}{A\bar{x}}$$

$$x_{cp} = 5 + \frac{4}{7 \times 5}$$

$$x_{cp} - \bar{x} = \frac{4}{35}$$

Torque on the disc = Force × Force arm

$$= 343350 \times \frac{4}{35} = 39240 \text{ Nm}$$

100. (b)

Let A and h denote the cross-section area and height of the block.

$$\rho_w \times A \times h = \rho_{\text{water}} A(h - 0.1) = \rho_{\text{glycerine}} A(h - 0.15)$$

$$h - 0.1 = 1.35(h - 0.15)$$

$$h - 0.1 = 1.35h - 0.2025$$

$$0.1025 = 0.35h$$

$$h = 29.3 \text{ cm}$$

101. (b)

- Streamlines do not cross, otherwise the fluid particle will have two velocities at the point of intersection and that is physically impossible.
- Streamlines may, however, intersect at isolated points of zero velocity or infinite velocity.
- Streamline spacing varies inversely as the velocity; convergent of streamlines in any particular direction shows accelerated flow in that direction.

102. (d)

The streamlines are defined as

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

$$\frac{dx}{ax} = \frac{dy}{-ay}$$

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

$$\Rightarrow \quad \ln x = -\ln y + \ln c$$

$$\ln xy = \ln c$$

$$\Rightarrow \quad xy = c \quad ; \quad x = 1, y = 1$$

That gives constant $c = 1$

$$xy = 1$$

103. (c)

Flow rate is given by,

$$Q = \int v.dA = \int_0^R 2\left(1-\frac{r^2}{R^2}\right)2\pi r.dr$$

$$= 4\pi\int_0^R\left(r-\frac{r^3}{R^2}\right)dr = 4\pi\left[\frac{r^2}{2}-\frac{r^4}{4R^2}\right]_0^R$$

$$= 4\pi\left[\frac{R^2}{2}-\frac{R^2}{4}\right] = 4\pi\left[\frac{R^2}{4}\right]$$

$$= \pi R^2$$

104. (c)

Potential function exists only for irrotational flow, as it requires the flow to have zero vorticity.

105. (d)

The friction factor in fully developed turbulent flow in rough pipes, depends upon the roughness and is independent of Reynolds number.

By Karman-Prandtl resistance equation for turbulent flow in rough pipes is

$$\frac{1}{\sqrt{4f}} = 1.74 + 2.00\log_{10}\frac{R}{\in}$$

106. (b)

The attachment/detachment of flow to surface is governed by value of velocity gradient

(i) $\frac{\partial u}{\partial y} = \frac{2}{\delta} - 2\left(\frac{y}{\delta}\right) = \frac{2}{\delta}$ at $y = 0$ Flow is attached

(ii) $\frac{\partial u}{\partial y} = -\frac{1}{\delta} + 2\times 3\left(\frac{y}{\delta}\right)^2 + 4\times 4\left(\frac{y}{\delta}\right)^3 = -\frac{1}{\delta}$ at $y = 0$

Flow is separated

(iii) $\frac{\partial u}{\partial y} = -2\left(\frac{y}{\delta}\right) - 5\times 4\left(\frac{y}{\delta}\right)^3 = 0$ Flow is in verge of separation

(iv) $\frac{\partial u}{\partial y} = \frac{1}{\delta} - 4\times 2\left(\frac{y}{\delta}\right) = \frac{1}{\delta}$ at $y = 0$ Flow is attached

107. (c)

Considering force only due to gravity,

$$\frac{1}{2}mV_2^2 + mgz_2 = \frac{1}{2}mV_1^2 + mgz_1$$

$$V_2 = \sqrt{2gz_1 + V_1^2}$$

$$= \sqrt{2 \times 10 \times 20 + 10^2}$$

$$= \sqrt{400 + 100} = 10\sqrt{5}$$

108. (c)

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

$$P_1 = 20 \text{ bar}; V_1 = 0.04 \text{ m}^3; V_2 = 0.08 \text{ m}^3$$

$$P_1V_1^{1.4} = P_2V_2^{1.4}$$

$$20 \times (0.04)^{1.4} = P_2(0.08)^{1.4}$$

$$P_2 = 20 \times \left(\frac{1}{2}\right)^{1.4} = 7.58 \text{ bar}$$

$$W = \frac{(20 \times 0.04) - (7.58 \times 0.08)}{0.4} \times 10^2$$

$$= 48.4 \text{ kJ}$$

109. (a)

$$Q = \Delta U + W$$

$$Q_{1\text{-}2} = U_2 - U_1 + W_{1\text{-}2}$$

$$-30 = (U_2 - U_1) + \int_1^2 PdV$$

$$-30 = (U_2 - U_1) + 0.1 \times 10^3 (0.1 - 0.2)$$

$$-30 = (U_2 - U_1) - 10$$

$$-30 + 10 = U_2 - U_1$$

$$U_2 - U_1 = -20 \text{ kJ}$$

110. (b)

The factor z_c is called compressibility factor, and for a gas obeying van der Waal's equation of state,

$$z_c = \frac{p_c v_c}{RT_c} = \frac{3}{8}$$

111. (b)

$$T_1 = 200 \text{ K}, P_1 = 2 \text{ bar}, V_1 = 80 \text{ m/s}$$

$$P_2 = 1 \text{ bar}, V_2 = 240 \text{ m/s}$$

$$h_1 + \frac{V_1^2}{2} + gz_1 + \dot{Q} = h_2 + \frac{V_2^2}{2} + gz_2 + \dot{W}$$

$$\dot{m} = \rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

$$T_2 = \frac{P_2}{P_1}\cdot\frac{A_2}{A_1}\cdot\frac{V_2}{V_1}\cdot T_1$$

$$= \frac{1}{2}\times\frac{240}{80}\times 200 = 300\text{ K}$$

112. (a)

$$\text{Entropy change in working fluid} = \frac{+100}{273+200} = +0.211\text{ kJ/K}$$

113. (d)

Internal irreversibility occurs due to dissipative effects within the system that prevent it from returning to its original state without external intervention.

114. (c)

During recovery, metal is heated to a temperature of 10% of melting point temperature.

The following objectives are achieved:

1. Internal stresses developed during cold working are relieved.
2. Distortion in lattice is reduced.
3. Electrical resistivity is reduced.
4. Ductility and elastic limit are improved.
5. Dislocations rearrange themselves.
6. Surplus point defects as vacancies are reduced.

115. (d)

- The increase in stress required to cause slip because of previous deformation is known as strain hardening.
- The generation of dislocation due to Frank-Read source by which a large amount of slip could be produced by a single dislocation.

116. (b)

- Edge dislocation is a type of crystallographic defect in materials where an extra half plane of atoms is inserted into a crystal structure.
- In an edge dislocation, Burger vector is perpendicular to the edge dislocation line.
- When shear stress is applied, the dislocation moves along a specific crystallographic plane known as the slip plane.

117. (b)

The plane EDFG intercepts are $\left(\frac{1}{\infty}, 1, \frac{1}{\infty}\right)$

The miller indices are, reciprocal of intercepts (0, 1, 0)

The require miller indices of plane EDFG are (0 1 0)

118. (c)

$$Fe = 99.6\%$$
$$C = 0.4\%$$
$$\text{Fraction of total ferrite, } F_\alpha = \frac{6.67 - 0.4}{6.67 - 0.022} = 0.943$$

119. (c)

In hypereutectoid steel (carbon content > 0.8%), when cooled just below the eutectoid temperature (around 850°C), the structure consists of:

- Austenite grains
- Cementite (Fe_3C) forming along the grain boundaries.

Thus, the correct microstructure observed is "Austenite grains with cementite growth on the grain boundaries."

120. (b)

Spheroidizing, Fe_3C coalesces to form spheroids. The material will become workable and soft.

121. (c)

The factors influencing corrosion include microstructural defects, stress conditions, and environmental exposure. Slab inclusions are non-metallic impurities trapped in the metal during manufacturing. These inclusions do not significantly impact corrosion resistance.

122. (b)

Invar, steel with composition of Ni 36% and Fe 64% has a very low coefficient of thermal expansion, making it ideal for precision-measuring instruments and survey tapes.

123. (b)

The bottom-up approach builds nanomaterials atom by atom or molecule by molecule, CVD is a widely used bottom-up method for growing thin films and nanostructures.

124. (a)

$$P = 0.707\, hl\tau$$
$$100 \times 10^3 = 0.707 \times 10(l) \times 70$$
$$l = 202 \text{ mm}$$
$$l_1 y_1 = l_2 y_2$$
$$l_1 \times (200 - 71) = (202 - l_1) \times 71$$
$$l_1 \times (200 - 71) = 71 \times 202 - 71 l_1$$
$$200\, l_1 = 71 \times 202$$
$$l_1 = 71.71$$

125. (b)

Given : $P = 50$ kW; $n = 500$ rpm; $d_i = 0.5\, d_o$; $\tau = 80$ N/mm^2

$$M_t = \frac{P \times 60}{2\pi n} = \frac{50 \times 10^6 \times 60}{2\pi \times 500} = 954929.66 \text{ Nmm}$$

$$\tau = \frac{16M_t}{\pi d_o^3\left(1-c^4\right)} = \frac{16\times 954929.66}{\pi\times d_0^3\left(1-0.5^4\right)}$$

$$d_o^3 = \frac{16\times 955414.0127}{\pi\times 0.242\times 80}$$

$$d_o = 40.17 \text{ mm}$$

126. (c)

127. (c)

Muff couplings are not suitable for applications that require frequent disassembly because they are difficult to remove. To disassemble, the sleeve must be slide of the shaft, or the shafts must be moved axially, which is not quick or convenient.

128. (a)

Both Statement (I) and Statement (II) are true and Statement (II) is the correct explanation of Statement (I). In drum brakes, the enclosed design traps heat, leading to thermal expansion of components and reducing friction (brake fade). Disc brakes, on the other hand, are exposed to air, allowing heat dissipation and maintaining consistent braking performance.

129. (b)

Given : c = 30 kN; L_{10h} = 8000 hr, n = 300 rpm

$$L_{10} = \frac{60\times 300\times 8000}{10^6} = 144 \text{ million rev.}$$

$$c = P(L_{10})^{3/10}$$

$$P = \frac{30000}{(144)^{0.3}} = 6754.8 \text{ N}$$

130. (c)

Oil as a lubricant has several advantages over grease. It is more effective in carrying away frictional heat due to its better thermal conductivity. Oil can also enter more easily into the small contact areas of a bearing and is more effective in flushing out dirt and foreign particles. However, grease generally stores better over longer periods without degradation compared to oil. Therefore, statements 1, 3, and 4 are correct, and the answer is (c).

131. (d)

Needle bearings use very long and thin rollers, resembling needles. The length-to-diameter ratio of these rollers is typically more than four. This high ratio ensures a greater surface area for load distribution while keeping the diameter small, allowing the bearing to handle higher loads efficiently.

132. (a)

Given : k_t = 1.35, q = 0.85

$$k_f = 1 + q(k_t - 1); \quad q = \left[\frac{k_f - 1}{k_t - 1}\right]$$

$$= 1 + 0.85(1.35 - 1)$$
$$k_f = 1.2975$$
$$k_d = 0.77$$

133. (d)

Fatigue life of component is

$$\frac{\alpha_1}{N_1} + \frac{\alpha_2}{N_2} + \frac{\alpha_3}{N_3} = \frac{1}{N}$$
$$\frac{0.85}{100000} + \frac{0.12}{30000} + \frac{0.03}{6000} = \frac{1}{N}$$
$$N = 57143$$

134. (b)

Given : $P = 1$ kN, $s_{ut} = 200$ N/mm^2|; $f_s = 4$

$$\text{Permissible tensile stress, } \sigma_{max} = \frac{s_{ut}}{f_s} = \frac{200}{4} = 50 \text{ N/mm}^2$$
$$\text{Tensile stress at hole section, } \sigma_o = \frac{P}{(b-d)t} = \frac{1000}{(40-20)t} = \frac{1000}{20t} = \frac{50}{t}$$
$$\sigma_{max} = k_t \sigma_o = 2 \times \frac{50}{t} = \frac{100}{t}$$
$$\text{Thickness of plate, } \frac{100}{t} = 50$$
$$t = 2 \text{ mm}$$

135. (b)

136. (c)

Gears heat up during operation, they expand. Backlash ensures that this expansion does not cause jamming or excessive friction.

137. (d)

Electrostatic Precipitators: It has two sets of electrodes, insulated from each other that maintain an electrostatic field between them at high voltage. The flue gases are made to pass between these two sets of electrodes. The electric field ionises the dust particle; that pass through it attracting them to the electrode of opposite charge. The other electrode is maintained at a negative potential of 30,000 to 60,000 volts. The dust particles are removed from the collecting electrode by rapping the electrode periodically. The electrostatic precipitator is costly but has low maintenance cost and is frequently employed with pulverised coal fired power stations for its effectiveness on very fine ash particles and is superior to that of any other type.

138. (b)

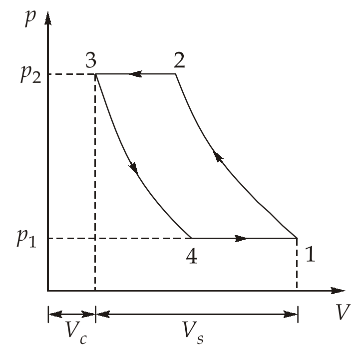
$$[\eta_{Brayton}]_{max\ work} = 1 - \sqrt{\frac{T_{min}}{T_{max}}} = 1 - \sqrt{\frac{300}{1200}}$$

$$= 1-\sqrt{\frac{1}{4}} = 1-\frac{1}{2} = \frac{1}{2} = 0.5$$

$$\eta_{carnot} = 1-\frac{T_{min}}{T_{max}} = 1-\frac{300}{1200} = 1-\frac{1}{4} = 0.75$$

$$\therefore \quad \text{Required ratio} = \frac{\eta_{Brayton}}{\eta_{Carnot}} = \frac{0.5}{0.75} = 0.67$$

139. (c)



$$V_3 = V_c = 0.05V_s$$
$$= 0.05 \times 2000$$
$$= 100 \text{ cm}^3$$
$$V_1 = V_c + V_s = 2100 \text{ cm}^3$$

For process 3 - 4

$$P_3V_3^n = P_4V_4^n$$

$$V_4 = V_3 \times \left(\frac{P_3}{P_4}\right)^{1/n} = 100 \times (8)^{\frac{1}{1.5}} = 100 \times (8)^{\frac{2}{3}} = 100 \times 4$$
$$= 400 \text{ cm}^3$$

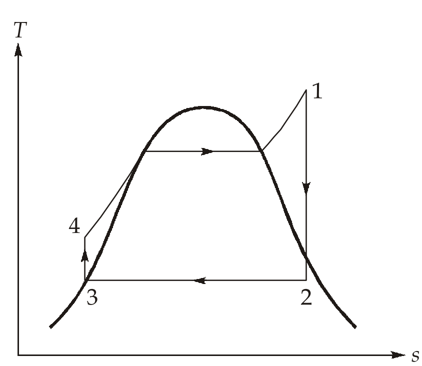
$$\text{Volumetric efficiency} = \frac{V_1 - V_4}{V_s} \times 100 = \frac{1700}{2000} \times 100 = 85\%$$

140. (d)

$$\text{Power required to drive the blower} = \dot{V}(p_2 - p_1) = \frac{\dot{m}RT_1}{p_1}(p_2 - p_1)$$

$$= \frac{1 \times 0.29 \times 343}{101.325} \times 101.325 = 99.47 \text{ kW}$$

141. (c)



$$x = 0.9$$
$$h_1 = 3165.54 \text{ kJ/kg} \qquad \text{[at 360°C]}$$

$$h_2 = (h_f)_{\text{at 0.08 bar}} + x(h_{fg})_{\text{at 0.08 bar}}$$
$$= 173.88 + 0.9 \times 2403.1$$
$$= 2336.67 \text{ kJ/kg}$$

Work done by turbine, $W_T = h_1 - h_2$

$$= 3165.54 - 2336.67$$
$$= 828.87 \text{ kJ/kg}$$

142. (c)

The various advantages of steam turbine are as follows:

(i) It requires less space.

(ii) Absence of various links such as piston, piston rod, cross head etc. make the mechanism simple. It is quiet and smooth in operation,

(iii) Its over-load capacity is large.

(iv) It can be designed for much greater capacities as compared to steam engine. Steam turbines can be built in sizes ranging from a few horse power to over 200,000 horse power in single units.

(v) The internal lubrication is not required in steam turbine. This reduces to the cost of lubrication.

(vi) In steam turbine the steam consumption does not increase with increase in years of service.

(vii) In steam turbine power is generated at uniform rate, therefore, flywheel is not needed.

(viii)It can be designed for much higher speed and greater range of speed.

(ix) The thermodynamic efficiency of steam turbine is higher.

143. (a)

In a bent tube boiler, the tubes were so bent that they entered and left the drums radially.

144. (c)

At maximum efficiency, for reaction turbine

$$\rho_{\text{opt}} = \cos\alpha = \frac{V_b}{V_1}$$

or
$$V_1 = \frac{V_b}{\cos\alpha} = 44.72\left(\frac{(\Delta h_s)_{stage}}{2}\right)^{1/2}$$

∴
$$\Delta h_{\text{stage}} = 2\left(\frac{V_b}{44.72\cos\alpha}\right)^2$$

145. (c)

$$\alpha_1 = 30°,\ \beta_1 = \beta_2,\ k = 0.85$$

$$(\eta_b)_{\max} = \frac{\cos^2\alpha_1}{2}\left[1 + k\frac{\cos\beta_1}{\cos\beta_2}\right]$$

$$= \frac{\cos^2 30}{2}[1 + 0.85] = 0.6937 \text{ or } 69.37\%$$

146. (d)

Absolute pressure in the condenser,

$$P = (1035 - 965) \times 10^{-2} \times 1000 \times 9.81$$
$$= 6867 \text{ N/m}^2 = 6.86 \text{ kPa}$$

Partial pressure of steam in condenser = Saturation pressure of steam corresponding to 35°C = 5.62 kPa

$$\text{Partial pressure of air, } P_a = P_t - P_s$$
$$P_a = 6.86 - 5.63 = 1.23 \text{ kPa}$$

Mass of air per m^3 of condenser volume,

$$m_a = \frac{P_a V}{RT} = \frac{1.23 \times 1}{0.287 \times (273 + 35)}$$
$$= 0.0139 \text{ kg/m}^3 \simeq 0.014 \text{ kg/m}^3$$

147. (d)

148. (b)

We know that,
$$h_w = 353H\left\{\frac{1}{T_a} - \left(\frac{m+1}{m}\right)\frac{1}{T_g}\right\} \text{ mm of water}$$

$$20 = 353H\left\{\frac{1}{300} - \left(\frac{18+1}{18}\right)\frac{1}{570}\right\}$$

$$H = 38.24 \text{ m}$$

149. (b)

150. (d)

The steam air ejectors uses high pressure steam in a series of nozzle to create a vacuum higher than that in the condenser.

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