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Mini GATE Exam: 2017

Centre Based Test (CBT)

ME : MECHANICAL ENGINEERING

TEST : 01 | FULL SYLLABUS

Date: 22-01-2017

Read the following instructions carefully

1. This question paper contains 65 MCQ's & NAQ's. Bifurcation of the questions is given below:

Section: I (General Aptitude Test)

Questions	Ques. Type	No. of Ques.	Marks	Total Marks	Negative Marking
1 to 4	MCQ	4	1 mark	4	0.33
5	NAT	1	1 mark	1	None
6 to 9	MCQ	4	2 marks	8	0.66
10	NAT	1	2 marks	2	None

Note:
NAT : Numerical Answer Type Question
MCQ : Multiple Choice Question.

Physical calculator is not allowed, however you can use virtual online calculator.

Section: II (Technical + Engineering Maths)

Questions	Question Type	No. of Questions	Marks	Total Marks	Negative Marking
1 to 13	MCQ	13	1 mark	11	0.33
14 to 15	MCQ	02	1 mark	02	0.33
16 to 23	NAT	08	1 mark	10	None
24 to 25	NAT	02	1 marks	02	None
26 to 39	MCQ	14	2 marks	26	0.66
40 to 41	MCQ	02	2 marks	04	0.66
42 to 53	NAT	12	2 marks	26	None
54 to 55	NAT	02	2 marks	04	None

Total Questions : 65	**Total Marks : 100**	**Duration : 3 Hours**
Technical Section : 73 Marks	**General Aptitude : 15 Marks**	**Engg Mathematics : 12 Marks**

2. Choose the closest numerical answer among the choices given.

Section -I (General Aptitude)

Multiple Choice Questions : Q. No. 1 to Q. No. 4 carry 1 mark each

Q.1 Which of the following is/are grammatically possible?

1. I fell over
2. I fell myself over.
3. The bicycle fell over.
4. The bicycle fell over it.

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

1. (b)

Q.2 Rajan had not taken any food for the whole day and by the time he got home, he was ______.

(a) Ravenous
(b) Ostentatious
(c) Connotative
(d) Blighted

2. (a)

The word 'ravenous' means very hungry. Meaning of the word 'Ostentatious' is flashy or flamboyant. 'Connotative' means indicative and 'blighted' means ruined or destroyed.

Q.3 Which of the following pair can be used to make a meaningful sentence given below?

If there is nothing to absorb the energy of sound, they travel on _________, but their intensity ______ as they travel away from their source.

(a) erratically, mitigates
(b) forever, increases
(c) indefinitely, diminishes
(d) steadily, stabilizes

3. (c)

The presence of 'but' indicates something to the contrary. If the sound waves are not absorbed means they will continue to travel *indefinitely* BUT their intensity *diminishes* (decreases).

Q.4 What is the number missing from the table?

5	9	15
16	29	?
49	89	147

(a) 45
(b) 48
(c) 51
(d) 54

4. (b)

$$5 \times 3 + 1 = 16$$
$$16 \times 3 + 1 = 49$$
$$9 \times 3 + 2 = 29$$
$$29 \times 3 + 2 = 89$$
$$15 \times 3 + 3 = 48$$
$$48 \times 3 + 3 = 147$$

Numerical Answer Type Question : Q.5 carry 1 mark

Q.5 The number of perfect squares lies between 120 and 300 is ___________.

5. (7)

The squares are 121, 144, 169, 196, 225, 256, 289.

Multiple Choice Questions : Q. No. 6 to Q. No. 9 carry 2 marks each

Q.6 Walking at the speed of 5 km/h a student reaches his school from his house 15 minutes early and walking at 3 km/h, he is late by 9 minutes. The distance between his school and his house is

(a) 2.5 km (b) 2 km

(c) 3 km (d) 4 km

6. (c)

Let distance between house and school is D and he takes t minutes

$$\frac{D}{5}+\frac{15}{60} = t$$

$$\frac{D}{3} = t+\frac{9}{60}$$

$$\frac{D}{3} = \frac{D}{5}+\frac{15}{60}+\frac{9}{60}$$

$$\frac{D}{3}-\frac{D}{5} = \frac{24}{60}$$

$$D = 3 \text{ km}$$

Q.7 Hospitality LLP is a nationwide owner of office space in India with sprawling office buildings in business districts of several cities. They rent this space to individual companies. Hospitality office spaces vary from small offices to large suites with every space having custom-designed wall-to-wall carpeting. Many locations of Hospitality are in need of replacement of the carpet. Jupiter Carpets has submitted the winning bid which is an all inclusive contract with 3 years warranty. Jupiter executives as well as independent consultants they hired felt that Jupiter would be able to perform all these services for far less than their bid price leading to a considerable profit.

Which of the following, if true, will actually counter the argument that Jupiter will make a large profit from this contract with Hospitality?

(a) All the carpets will have to be transported by train from Jupiter in Mirzapur, to Hospitality's locations spread all over India.

(b) Jupiter has already supplied carpets to a number of restaurant chains with some of those spaces are as large as Hospitality's largest office spaces.

(c) Lot of cutting will be required to fit the carpets made in standard size by Jupiter leading to wastage.

(d) Jupiter carpet material degrade rapidly when it comes into contact with standard toner used in most laser printers and photocopiers leading to frequent replacements.

7. (d)

Laser printers and copiers are very commonly used in today's offices occupying space in Hospitality's complexes. The frequent replacement of soiled carpets will add to the cost of maintenance besides incurring huge expenditure in transportation across various locations leading to NOT so high profitability.

Costs detailed in '(a)' and '(c)' have already been factored into Jupiter's costing and '(b)' will actually mean more profits rather than reduced profits.

Q.8 There are three basket of fruits. First basket has twice the number of fruits in the second basket. Third basket has $\frac{3}{4}$th of the fruits in the first. The average of the fruits in all the basket is 30. The number of fruits in the first basket is

(a) 20 (b) 30

(c) 40 (d) 45

8. **(c)**

Let the number of fruits in first basket is x

$$\text{Fruits in 2}^{\text{nd}}\text{ basket} = \frac{x}{2}$$

$$\text{Fruits in 3}^{\text{rd}}\text{ basket} = \frac{3}{4}x$$

$$x + \frac{x}{2} + \frac{3}{4}x = 90$$

$$\frac{9x}{4} = 90$$

$$x = 40$$

Q.9 The traffic lights at three different road crossing change after 24 seconds, 36 seconds and 54 seconds respectively. If they all change simultaneously at 10 : 00 AM, then at what time will they again change simultaneously?

(a) 10 : 16 : 54 AM
(b) 10 : 18 : 00 AM
(c) 10 : 17 : 02 AM
(d) 10 : 22 : 12 AM

9. **(b)**

LCM of 24, 36, 54 is 216.

⇒ The lights change simultaneously after 216 seconds or multiple of 216 seconds.

option (a) = 16 × 60 + 54 = 1014
option (b) = 18 × 60 + 00 = 1080
option (c) = 17 × 60 + 02 = 1022
option (d) = 22 × 60 + 12 = 1332
only option (b) is multiple of 216.

Numerical Answer Type Question : Q.10 carry 2 marks

Q.10 A jar contains a mixture of two liquids *A* and *B* in the ratio of 4 : 1. When 10 litre of the mixture is replaced with liquid *B*, the ratio becomes 2 : 3. The volume of liquid *A* present in the jar earlier was ________ litre.

10. **(16)**

Let the volume of A and B are $4x$ and x respectively.

10 liters of mixture is removed.

$$\text{Volume of } A \text{ removed} = \frac{4}{5} \times 10 = 8$$

$$\text{Volume of } B \text{ removed} = \frac{1}{5} \times 10 = 2$$

$$\frac{4x - 8}{x - 2 + 10} = \frac{2}{3}$$

$$12x - 24 = 2x + 16$$

$$10x = 40$$

$$x = 4$$

⇒ Volume of liquid A = 4 × 4 = 16 litre

❍❍❍❍

Section -II (Technical + Engineering Mathematics)

Multiple Choice Questions : Q.1 to Q.13 carry 1 mark each

Q.1 Under which of the following conditions equation $\frac{p}{\rho g}+\frac{v^2}{2g}+z=C$, will be valid in the whole flow field?

1. Flow is irrotational
2. Flow is rotational
3. Flow is incompressible
4. Flow is laminar
5. Flow is steady

Select the correct answer using the codes given below :

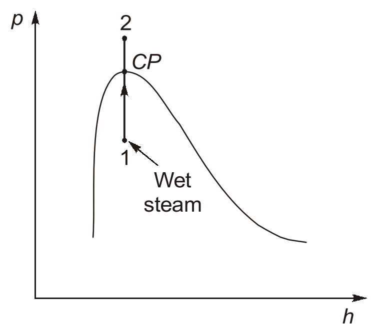
(a) 1, 3 and 5 (b) 2, 3 and 5
(c) 1, 3 and 4 (d) 2, 3 and 4

1. (a)

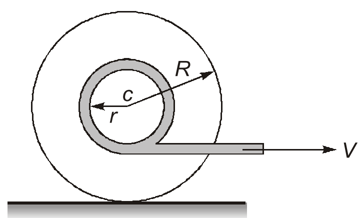
Q.2 If a pure substance contained in a rigid vessel passed through the critical state on heating, its initial state should be

(a) Wet steam (b) Saturated water
(c) Saturated steam (d) Subcooled water

2. (a)

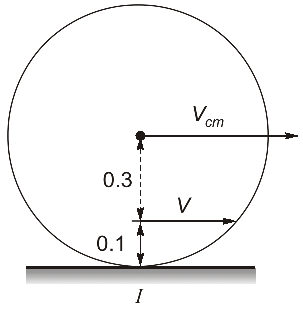


Q.3 A wheel of radius 400 mm is made to roll without slipping by pulling a string with velocity *V*. If the centre of the wheel moves with a velocity of 3 m/s, the velocity of string, which is wound over a drum of radius 0.3 m as shown in figure, will be



(a) 0.75 m/s (b) 2 m/s
(c) 2.5 m/s (d) 3 m/s

3. (a)



$$V_{cm} = 0.4\,\omega$$

$$\omega = \frac{3}{0.4}\text{ rad/s}$$

$$V = 0.1\,\omega = \frac{0.1 \times 3}{0.4}$$

$$V = \mathbf{0.75\ m/s}$$

Q.4 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

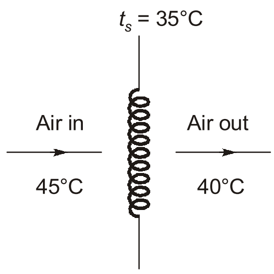
List-I	List-II
A. Drawing	**1.** Soap solution
B. Rolling	**2.** Camber
C. Wire drawing	**3.** Pilots
D. Sheet metal operations using progressive dies	**4.** Crater
	5. Ironing

Codes:

	A	B	C	D
(a)	2	5	1	4
(b)	4	1	5	3
(c)	5	2	3	4
(d)	5	2	1	3

4. (d)

Q.5 The cooling efficiency of the given cooling coil will be



(a) 0.2
(b) 0.8
(c) 0.7
(d) 0.9

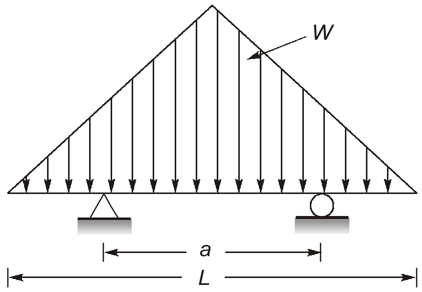
5. (b)

$$\text{By pass factor}\,(x) = \frac{40-35}{45-35} = \frac{5}{10} = 0.2$$

$$\eta_{\text{cooling}} = 1 - x = 1 - 0.2 = 0.8$$

$$\eta_{\text{cooling}} = 0.8$$

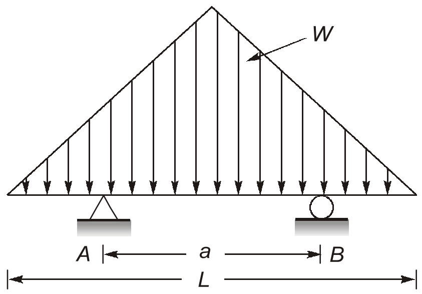
Q.6 The distance '*a*' for which bending moment at the center of beam shown below should be zero is



(a) $\frac{L}{2}$ (b) $\frac{L}{3}$

(c) $\frac{L}{4}$ (d) $\frac{L}{6}$

6. (b)



$$R_A = R_B = \frac{wL}{4}$$

$$M_{center} = \frac{wL}{4} \times \frac{a}{2} - \frac{wL}{4} \times \frac{L}{6} = 0$$

$$a = \frac{L}{3}$$

Q.7 At time $t = 0$, a 2.0 kg particle has the position vector $\vec{r} = (4\text{m})\hat{i} - (2\text{m})\hat{j}$ relative to the origin. Its velocity is given by $\vec{v} = (-6t^2\,\text{m/s})\hat{i}$ for $t \geq 0$ in seconds. About the point (– 2m, – 3 m, 0), the torque acting on the particle for $t > 0$ is obtained in unit vector notation as:

(a) $(24t\ \text{Nm})\hat{k}$ (b) $(-24t\ \text{Nm})\hat{k}$

(c) $(-48t\ \text{Nm})\hat{k}$ (d) $(48t\ \text{Nm})\hat{k}$

7. (a)

$$\vec{a} = \frac{d\vec{v}}{dt} = -12t\,\hat{i}$$

Force, $\vec{\tau}$ = mass × acceleration

$$= 2 \times (-12t)\,\hat{i}$$

$$= -24t\,\hat{i}$$

Position vector with respect to point of interest,

$$\vec{r} = \left(4\hat{i} - 2\hat{j}\right) - \left(-2\hat{i} - 3\hat{j}\right) = 6\hat{i} + \hat{j}$$

Torque,
$$\vec{\tau} = \vec{r} \times \vec{F}$$
$$= \left(6\hat{i} + \hat{j}\right) \times \left(-24t\hat{i}\right) = 24t\hat{k}$$

Q.8 The speed of an engine varies from 320 rad/sec to 300 rad/sec. During a cycle the change in kinetic energy is found to be 600 Nm. The inertia of the flywheel in kgm^2 is

(a) 0.0967
(b) 0.0854
(c) 0.0761
(d) 0.0658

8. (a)

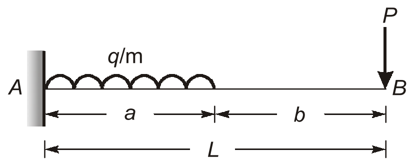
$$\Delta E = I\omega^2 C_s$$

$$\omega = \frac{320 + 300}{2} = 310 \text{ rad/sec}$$

$$C_s = \frac{320 - 300}{310} = 0.06451$$

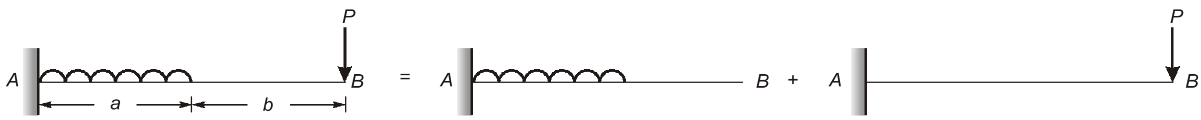
$$I = \frac{600}{(310)^2 \times 0.06451} = 0.0967 \text{ kgm}^2$$

Q.9 A cantilever beam AB supports a uniform load of intensity 'q' acting over part of the span and a concentrated load P acting at the free end as shown in figure. The deflection at 'B' of the beam is



(a) $\dfrac{qa^3}{24EI}(4L - a) + \dfrac{PL^3}{3EI}$
(b) $\dfrac{qa^3}{12EI}(4L - a) + \dfrac{PL^3}{3EI}$
(c) $\dfrac{qa^3}{24EI}(4L - a) + \dfrac{PL^3}{6EI}$
(d) $\dfrac{qa^3}{24EI}(4L - a) + \dfrac{PL^3}{24EI}$

9. (a)



$$\delta_B = \frac{qa^3}{24EI}(4L - a) + \frac{PL^3}{3EI}$$

Q.10 A single plate clutch effective on both sides carries an axial thrust of 1600 N. The effective radius of frictional surface is 100 mm and μ = 0.2. The torque, (in Nm) than can be transmitted, is

(a) 32
(b) 64
(c) 16
(d) 128

10. (b)

$$W = 1600 \text{ N}$$

$$R_{\text{eff.}} = \frac{100}{1000} = 0.1 \text{ m}$$

$$\mu = 0.2$$

Frictional torque, $T_f = n\mu W R_{\text{eff.}}$

$$= 2 \times 0.2 \times 1600 \times 0.1 = 64 \text{ Nm}$$

Q.11 The stress at a point in a body is given by

$$\sigma = \begin{vmatrix} 5 & 3 & 2 \\ 3 & -1 & 0 \\ 2 & 0 & 4 \end{vmatrix}$$

If modulus of elasticity, $E = 2 \times 10^5$ N/mm^2 and Poisson ratio, μ = 0.3, then the normal strain in x-direction is

(a) 2.05×10^{-5}
(b) 4.1×10^{-5}
(c) 6×10^{-5}
(d) 3×10^{-5}

11. (a)

$$\sigma_{xx} = 5 \text{ MPa}, \sigma_{yy} = -1 \text{ MPa}$$

$$\sigma_{zz} = 4 \text{ MPa}$$

Strain in x-direction

$$\epsilon = \frac{1}{E}\left[\sigma_{xx} - \mu\left(\sigma_{yy} + \sigma_{zz}\right)\right]$$

$$\epsilon = \frac{1}{2 \times 10^5}\left[5 - 0.3(-1+4)\right]$$

$$\epsilon = 2.05 \times 10^{-5}$$

Q.12 The least radius of gyration of a ship is 9 m and the metacentric height is 750 mm. The time period of oscillation of the ship is

(a) 42.41 sec
(b) 75.4 sec
(c) 20.85 sec
(d) 85 sec

12. (c)

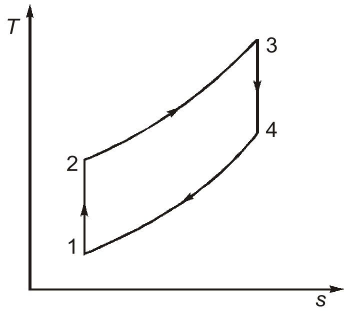
$$T = 2\pi\sqrt{\frac{K_G^2}{g.GM}} = 2\pi\sqrt{\frac{(9)^2}{9.81 \times 0.750}}$$

$$= 20.85 \text{ sec}$$

Q.13 An ideal Brayton cycle has a net work output of 150 kJ/kg and a back work ratio of 0.4. If both the turbine and the compressor had an isentropic efficiency of 85%, the net work output of the cycle would be

(a) 74 kJ/kg
(b) 95 kJ/kg
(c) 109 kJ/kg
(d) 128 kJ/kg

13. (b)



$$W_{net} = W_T - W_C = 150$$

$$\frac{W_C}{W_T} = 0.4$$

$\Rightarrow$ $$W_C = 0.4\ W_T$$

$\therefore$ $$0.6\ W_T = 150$$

$\Rightarrow$ $$W_T = 250\text{ kJ/kg}$$

and $$W_C = 250 - 150 = 100\text{ kJ/kg}$$

Now, $$W_{net\ actual} = \eta_T W_T - \frac{W_C}{\eta_C}$$

$$= 0.85 \times 250 - \frac{100}{0.85} = 94.853\text{ kJ/kg}$$

Multiple Choice Questions : Q. 14 to Q. 15 carry 1 mark each

Q.14 If $x = r\cos\theta$ and $y = r\sin\theta$, then the value of $\frac{\partial^2 r}{\partial x^2} + \frac{\partial^2 r}{\partial y^2}$ is

(a) 2

(b) $\frac{1}{r}\left[\left(\frac{\partial r}{\partial x}\right)^2 + \left(\frac{\partial r}{\partial y}\right)^2\right]$

(c) $r\left[\left(\frac{\partial r}{\partial x}\right)^2 + \left(\frac{\partial r}{\partial y}\right)^2\right]$

(d) $\frac{1}{r}\left[\frac{\partial r}{\partial x} + \frac{\partial r}{\partial y}\right]^2$

14. (b)

$$x = r\cos\theta \text{ and } y = r\sin\theta$$

$$r^2 = x^2 + y^2$$

$$r = \sqrt{x^2 + y^2}$$

$$\frac{\partial r}{\partial x} = \frac{x}{(x^2+y^2)^{1/2}}$$

$$\frac{\partial r}{\partial y} = \frac{y}{(x^2+y^2)^{1/2}}$$

$$\frac{\partial^2 r}{\partial x^2} = \frac{1}{(x^2+y^2)^{1/2}} - \frac{x^2}{(x^2+y^2)^{3/2}} = \frac{y^2}{(x^2+y^2)^{3/2}}$$

$$\frac{\partial^2 r}{\partial y^2} = \frac{1}{(x^2+y^2)^{1/2}} - \frac{y^2}{(x^2+y^2)^{3/2}} = \frac{x^2}{(x^2+y^2)^{3/2}}$$

$$\frac{\partial^2 r}{\partial x^2} + \frac{\partial^2 r}{\partial y^2} = \frac{y^2}{(x^2+y^2)^{3/2}} + \frac{x^2}{(x^2+y^2)^{3/2}} = \frac{1}{(x^2+y^2)^{1/2}} = \frac{1}{r}$$

$$\left(\frac{\partial r}{\partial x}\right)^2 + \left(\frac{\partial r}{\partial y}\right)^2 = \frac{x^2}{(x^2+y^2)} + \frac{y^2}{x^2+y^2} = 1$$

$$\frac{\partial^2 r}{\partial x^2} + \frac{\partial^2 r}{\partial y^2} = \frac{1}{r}\left[\left(\frac{\partial r}{\partial x}\right)^2 + \left(\frac{\partial r}{\partial y}\right)^2\right]$$

Q.15 A 3 × 3 matrix follows the characteristic equation given by,

$$A^3 - 6A^2 + 9A - 4I = 0$$

The sum and product of Eigen values of the matrix A^{-1} is

(a) $\frac{1}{6}, \frac{1}{4}$
(b) $\frac{9}{4}, \frac{1}{4}$
(c) $\frac{6}{4}, \frac{4}{6}$
(d) Data insufficient

15. (b)

Let the Eigen values of A are $\lambda_1, \lambda_2, \lambda_3$.

$$\lambda_1 + \lambda_2 + \lambda_3 = 6$$

$$\lambda_1\lambda_2 + \lambda_2\lambda_3 + \lambda_3\lambda_1 = 9$$

$$\lambda_1\lambda_2\lambda_3 = 4$$

Eigen values of A^{-1} are $\frac{1}{\lambda_1}, \frac{1}{\lambda_2}, \frac{1}{\lambda_3}$

$$\text{Sum of Eigen values of } A^{-1} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2} + \frac{1}{\lambda_3} = \frac{\lambda_2\lambda_3 + \lambda_3\lambda_1 + \lambda_1\lambda_2}{\lambda_1\lambda_2\lambda_3} = \frac{9}{4}$$

$$\text{Product of Eigen values of } A^{-1} = \frac{1}{\lambda_1}\cdot\frac{1}{\lambda_2}\cdot\frac{1}{\lambda_3} = \frac{1}{4}$$

Numerical Answer Type Questions : Q.16 to Q.23 carry 1 mark each

Q.16 Hot gases enters to a heat exchanger at 300°C and leave at 180°C. The cold air enters at 25°C leaves 165°C. The capacity ratio of heat exchanger is __________.

16. (0.857)(0.85 to 0.86)

For hot fluid,

$$T_{h1} = 300°C,\ T_{h2} = 180°C$$

For cold fluid,

$$T_{c1} = 25°C,\ T_{c2} = 165°C$$

Applying energy balance equation,

$$\text{Heat lost by hot fluid} = \text{Heat gained by cold fluid}$$

$$m_h c_{ph}(T_{h1} - T_{h2}) = m_c c_{pc}(T_{c2} - T_{c1})$$

$$C_h(T_{h1} - T_{h2}) = C_c(T_{c2} - T_{c1})$$

$$C_h(300 - 180) = C_c(165 - 25)$$

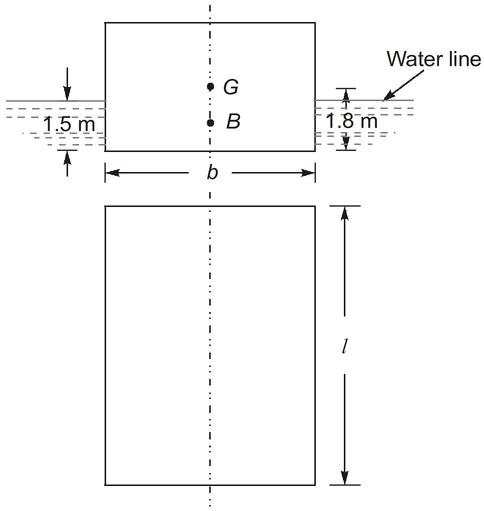
$$120C_h = 140C_c$$

or

$$\frac{C_c}{C_h} = \frac{120}{140} = 0.857$$

Q.17 A rectangular floating body is 20 m long and 5 m wide. The water line is 1.5 m above the bottom. If the centre of gravity is 1.8 m from the bottom, the metacentric height is __________ m.

17. **(0.33)(0.325 to 0.340)**



$$l = 20 \text{ m}$$
$$b = 5 \text{ m}$$

Distance between centre of buoyancy (B) and centre of gravity (G),

$$BG = 1.8 - \frac{1.5}{2} = 1.05 \text{ m}$$

$$I = \frac{lb^3}{12} = \frac{20 \times (5)^3}{12} = 208.33 \text{ m}^4$$

$$\forall = b \times 1.5 \times l$$
$$= 5 \times 1.5 \times 20 = 150 \text{ m}^3$$

Distance between centre buoyancy (B) and metacentre (M),

$$BM = \frac{I}{\forall} = \frac{208.33}{150} = 1.38 \text{ m}$$

Metacentric height, $GM = BM - BG$

$$= 1.38 - 1.05 = 0.33 \text{ m}$$

Q.18 The annual demand for a component is 7000 units, the carrying cost is ₹ 600/unit/year, the ordering cost is ₹ 1500 per order, and the shortage cost is ₹ 1600/unit/year. The optimal value of economic order quantity is ____________ units.

18. **(219.37)(219 to 220)**

Given:

$$D = 7000 \text{ unit/year}$$
$$C_o = ₹\ 1500\text{/order}$$
$$C_h = ₹\ 600\text{/unit/order}$$
$$C_b = ₹\ 1600\text{/unit/year}$$

$$EOQ,\ Q^* = \sqrt{\frac{2DC_o}{C_h}\left(\frac{C_b + C_h}{C_b}\right)}$$

$$= \sqrt{\frac{2 \times 7000 \times 1500}{600}\left(\frac{1600 + 600}{1600}\right)}$$

$$= 219.37 \text{ unit} \simeq 220 \text{ units}$$

Q.19 The estimated duration of times for an activity in a PERT network under the worst and best environment is 18 and 12 days. The variance of this activity is ________ day.

19. **(1)**

$$\text{Variance, } V = \left(\frac{b-a}{6}\right)^2 = \left(\frac{18-12}{6}\right)^2 = 1 \text{ day}$$

Q.20 Autogenous gas tungsten arc welding of a steel plate is carried out with welding current of 400 Amp., voltage of 20 V and weld speed of 15 mm/min. Consider the heat transfer efficiency from the arc to the weld pool as 85%. The heat input per unit length is __________ kJ/mm.

20. **(27.2)(27 to 27.5)**

Given:

$$\text{efficiency, } \eta = 0.85$$

$$\text{Current, } I = 400 \text{ Amp}$$

$$\text{Voltage, } V = 20 \text{ Volts}$$

$$\text{Speed, } C = 15 \text{ mm/min} = \frac{1}{4} \text{ mm/sec}$$

$$\text{Heat input, } Q = \frac{VI.\eta}{C} = \frac{400 \times 20 \times 0.85}{1/4}$$

$$= 27200 \text{ J/mm} = 27.2 \text{ kJ/mm}$$

Q.21 A cutting tool has a nose radius of 2 mm, the feed rate for a theoretical surface roughness of 4 microns is ____________ mm/rev.

21. **(0.25)(0.23 to 0.27)**

Given:

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

$$f = ?$$

$$R_t = \frac{f^2}{8R}$$

$$f^2 = R_t \times 8 \times R = 0.004 \times 8 \times 2$$

$$f = \sqrt{0.004 \times 8 \times 2} = 0.252 \text{ mm/rev.}$$

Q.22 A contour having a perimeter of 180 mm is pierced out from a 4 mm thick sheet having ultimate shear strength of 300 MPa. The penetration is 20%. Then the amount of shear, if the punch force is to be reduced to 50%, will be _____ mm.

22. **(0.8) (0.7 to 0.9)**

Given:

$$L = 180 \text{ mm}$$

$$t = 4 \text{ mm}$$

$$\tau_u = 300 \text{ MPa}$$

$$P = 0.2$$

$$\text{Shear, } s = ?$$

$$F = 0.5\, F_{max}$$

$$\because \quad F = \frac{F_{max} Pt}{Pt + s}$$

$$F(Pt + s) = F_{max}\, Pt$$

$$s = \frac{F_{max} Pt}{F} - Pt = \frac{Pt}{0.5} - Pt = Pt\left[\frac{1}{0.5} - 1\right] = 0.2 \times 4[1] = \mathbf{0.8 \text{ mm}}$$

Q.23 A close-coiled helical spring is to carry a load of 120 N. The mean coil diameter has to be 10 times that of wire diameter. If the maximum shear stress is not to exceed 100 MPa, then the diameter will be ________ mm .

23. (56.64)(56 to 57)

$$W = 120 \text{ N}$$
$$D = 10\text{d}$$
$$R = 5\text{d}$$
$$\tau_s = 100 \text{ N/mm}^2$$
$$\tau_s = \frac{16WR}{\pi d^3}\left(1+\frac{d}{4R}\right) = \frac{16W(5d)}{\pi d^3}\left(1+\frac{d}{4(5d)}\right)$$
$$100 = \frac{80W}{\pi d^2}(1.05)$$
$$d^2 = \frac{1.05\times 80\times 120}{\pi(100)}$$
$$d = 5.664 \text{ mm}$$
$$D = 5.664 \times 10 = 56.64 \text{ mm}$$

Numerical Answer Type Questions : Q.24 to Q.25 carry 1 mark each

Q.24 If the probability of a bad reaction from a certain injection is 0.001, then chances that out of 2000 individuals more than 2 will get a bad reaction is ________.

24. 0.32 (0.30 to 0.35)

It follows Poisson's distribution as probability of occurrence is very small.

Mean $m = np = 2000 \times 0.001 = 2$

Probability that more than 2 get a bad reaction is

$$= 1 - (\text{no bad reaction} + \text{one bad reaction} + 2 \text{ bad reactions})$$
$$= 1-\left[e^{-2}+\frac{2e^{-2}}{1!}+\frac{2^2e^{-2}}{2!}\right]$$
$$= 1-\left[\frac{5}{e^2}\right] = 0.323$$

Q.25 A function is defined as $f(z)=\dfrac{e^{-3z}}{(z-\log 3)^3}$. The residue of the function at its pole is ________.

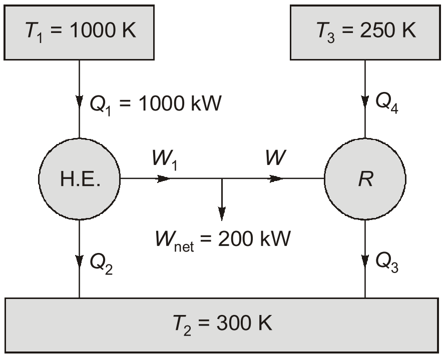
25. 0.167 (0.14 to 0.18)

Residue at $z = \log 3$ is,

$$= \frac{1}{2!}\frac{d^2}{dz^2}e^{-3z}\bigg|_{z=\log 3} = \frac{1}{2!}\times 3\times 3e^{-3z}\bigg|_{z=\log 3}$$
$$= \frac{1}{2!}\times 3\times 3e^{-3\log 3} = \frac{1}{6} = 0.167$$

Multiple Choice Questions : Q. No. 26 to Q. No. 39 carry 2 marks each

Q.26 A reversible heat engine operates as shown in figure. The engine drives a reversible refrigerator. The net work output of the engine refrigerator plant is 200 kW. What is the refrigeration effect?



(a) 3000 kW
(b) 2500 kW
(c) 2000 kW
(d) 1500 kW

26. (b)

For reversible heat engine,

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

$$= 1 - \frac{300}{1000} = 0.70$$

also $$\eta = \frac{W_1}{Q_1}$$

∴ $$0.70 = \frac{W_1}{1000}$$

or $$W_1 = 700 \text{ kW}$$

For reversible refrigerator,

$$W = W_1 - W_{net}$$

$$= 700 - 200 = 500 \text{ kW}$$

$$(COP)_R = \frac{T_3}{T_2 - T_3} = \frac{250}{300 - 250} = 5$$

also $$(COP)_R = \frac{\text{Refrigeration effect} : Q_4}{\text{Work input} : W}$$

∴ $$5 = \frac{Q_4}{500}$$

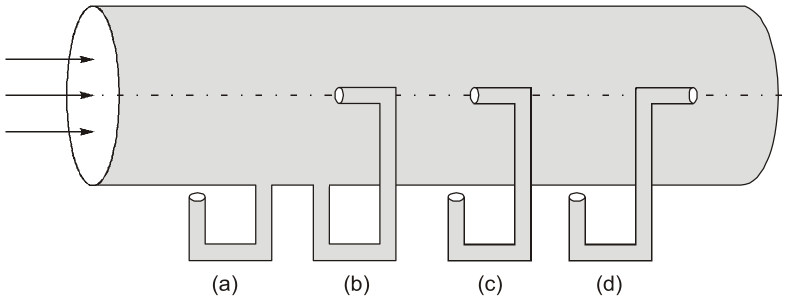
or $$Q_4 = 5 \times 500 = 2500 \text{ kW}$$

Q.27 During peritectic solidification, one liquid

(a) Combines with one solid to form a second new solid
(b) Solidifies into two different solids
(c) Forms one solid
(d) Forms one solid and another liquid

27. (a)

Q.28 Which configuration measures the total pressure?



28. (c)

Q.29 The connecting rod bolts are tightened up with initial tension greater than external load, so that
(a) failure of the bolt will be static
(b) the resultant load on bolt will not be affected by external cyclic load
(c) the bolt will not fail by fatigue although the external load may be fluctuating
(d) all the above

29. (d)
All the above are true, as the net load on the bolt always remains tensile.

Q.30 If two pieces of material *A* and *B* have the same bulk modulus, but the value of *E* for *B* is 1% greater than that of *A*. The value of *G* for material *B* in terms of *E* and *G* for the material *A* is

(a) $\dfrac{101E_AG_A}{101E_A - 3G_A}$ (b) $\dfrac{101E_AG_A}{101E_A + 3G_A}$

(c) $\dfrac{101E_AG_A}{101E_A + 4G_A}$ (d) $\dfrac{101E_AG_A}{101E_A - 4G_A}$

30. (a)

Material *A*
$K_a = K$
E_A
G_A

Material *B*
$k_B = K$
$E_B = 1.01E_A$
$G_B = ?$

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

$$\Rightarrow \quad K = \frac{GE}{9G-3E}$$

$$\frac{G_AE_A}{9G_A - 3E_A} = \frac{G_BE_B}{9G_B - 3E_B}$$

$$\frac{G_AE_A}{9G_A - 3E_A} = \frac{G_B 1.01E_A}{9G_B - 3.03E_A}$$

$$\frac{9G_B - 3.03E_A}{1.01G_B} = \frac{9G_A - 3E_A}{G_A}$$

$$\frac{9}{1.01} - \frac{303}{101}\frac{E_A}{G_B} = 9 - \frac{3E_A}{G_A}$$

$$\frac{3E_A}{G_A} - \frac{303}{101}\frac{E_A}{G_B} = 9 - \frac{9}{1.01} = \frac{0.9}{101}$$

$$\frac{3E_A}{G_A} - \frac{9}{101} = \frac{303}{101} \times \frac{E_A}{G_B}$$

$$\frac{303E_A - G_A}{101G_A} = \frac{303E_A}{101G_B}$$

$$\frac{G_A}{303E_A - 9G_A} = \frac{G_B}{303E_A}$$

$$G_B = \frac{303G_AE_A}{303E_A - 9G_A}$$

$$G_B = \frac{101G_AE_A}{303E_A - 3G_A}$$

Q.31 A steel rod 20 mm in diameter and 6 meter long is connected to two grips one at each end at a temperature of 120°C. What is the pull exerted when the temperature falls to 40°C if the ends yield by 1.10 mm?

Take $E = 2 \times 10^5$ N/mm^2 and $\alpha = 1.2 \times 10^{-5}$/°C

(a) 48.80 kN
(b) 24.39 kN
(c) 97.56 kN
(d) 12.19 kN

31. (a)

Fall of temperature $= T = 120 - 40 = 80$°C

$$\text{Temperature strain} = \frac{\text{Contraction prevented}}{\text{Original length}}$$

$$= \frac{\alpha TL - \delta}{L} = \frac{1.2 \times 10^{-5} \times 80 \times 6000 - 1.1}{6000} = \frac{4.66}{6000}$$

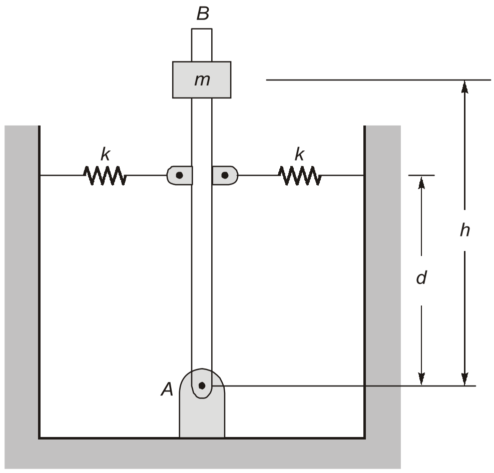
Temperature stress = Strain × Young's modulus

$$= \frac{4.66}{600} \times 2 \times 10^5 = 155.33 \text{ N/mm}^2$$

Pull in the rod = Stress × Area

$$= 155.33 \times \frac{\pi}{4} \times 20^2 \text{ N} \simeq 48.80 \text{ kN}$$

Q.32 For the configuration shown in the figure. If m = 150 kg, h = 800 mm, and the constant of each spring is k = 3.8 kN/m, the value of distance d (in mm) for which the equilibrium of the rigid rod AB is stable in the position shown will be (Each spring can act in either tension or compression. Use g = 9.81 m/sec^2)



(a) 343.6
(b) 392.4
(c) 426.3
(d) 248.8

32. (b)

Let θ be the small rotation of AB

$$x = d\theta$$
$$F = kx = kd\theta$$
$$\Sigma M_A = 0$$
$$\Rightarrow \quad 2F \times d = mgh\theta$$
$$\Rightarrow \quad 2kd^2\theta - mgh\theta = 0$$
$$d_{cr} = \sqrt{\frac{mgh}{2k}} = \sqrt{\frac{150 \times 9.81 \times 0.8}{2 \times 3.8 \times 10^3}}$$
$$d_{cr} = \sqrt{0.154\,\text{m}}$$
$$d_{cr} = 0.3924 \text{ m} = 392.4 \text{ mm}$$

Q.33 A flywheel having moment of inertia of 0.2 kgm^2 is suspended from a wire of stiffness of 1.176 Nm rad. The flywheel is subjected to a periodic torque having a maximum value of 0.8 Nm at a frequency of 4 rad/sec. A viscous dashpot applies damping couple of 0.4 Nm at an angular velocity of 1 rad/sec. Then the maximum angular displacement from rest position is (rad)

(a) 0.17
(b) 0.25
(c) 0.31
(d) 0.42

33. (c)

The torsional amplitude of vibration

$$\theta = \frac{T_o}{\sqrt{(k_t - I_p\omega^2)^2 + (c_t\omega)^2}}$$

$$\theta = \frac{0.8}{\sqrt{(1.176 - 0.2 \times 4^2)^2 + (0.4 \times 4)^2}} = 0.31$$

Q.34 If pitch of rivets is '4' times diameter of rivet hole, then the tearing efficiency of the rivet joint will be

(a) 60% (b) 75%
(c) 65% (d) 80%

34. (b)

Given; pitch, $p = 4 \times \text{diameter} = 4\text{ d}$

$$\eta_{\text{tearing}} = 1 - \frac{d}{p} = 1 - \frac{d}{4d} = 0.75 = 75\%$$

Q.35 A gun of mass 2000 kg, fires horizontally a shell of mass 40 kg with a velocity of 100 m/s. The velocity of the gun immediately after firing is

(a) 2 m/s (b) 1 m/s
(c) 3 m/s (d) 4 m/s

35. (a)

Applying conservation of momentum equation,

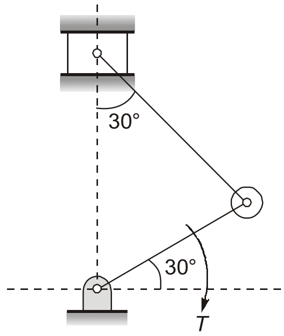
$$m_g u_g + m_s u_s = m_g v_g + m_s v_s$$

$$O = m_g v_g + m_s v_s$$

$$v_g = \frac{-m_s v_s}{m_g} = \frac{-40 \times 100}{2000} = -2 \text{ m/s}$$

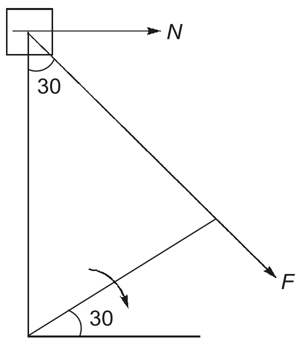
(– ve sign denotes opposite direction)

Q.36 The figure below shows the schematic diagram of an IC engine producing a torque T = 40 Nm at the given instant. The coulomb friction coefficient between the cylinder and the piston is 0.08. If the mass of piston is 0.5 kg and the crank radius is 0.1 m, the coulomb friction force occurring at the piston cylinder interface is



(a) 16 N (b) 0.4 N
(c) 4 N (d) 16.4 N

36. (a)



$$F = \frac{T}{r} = \frac{40}{0.1} = 400 \text{ N}$$

$\therefore$ Normal force on piston

$\Rightarrow$ $F\sin 30° = 400\sin 30° = 200$ N

Now frictional force $= \mu N$

$= 0.08 \times 200 = 16$ N

Q.37 If a beam of rectangular cross section is subjected to a vertical shear force V, the shear force carried by the upper one-third of the cross-section is

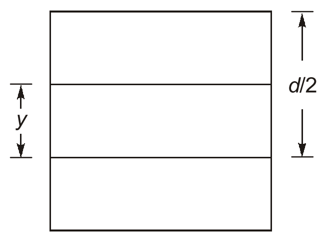
(a) zero

(b) $\frac{7V}{27}$

(c) $\frac{8V}{27}$

(d) $\frac{V}{3}$

37. (b)



$$\tau = \frac{SA\bar{y}}{Ib} = \frac{V \times \left(\frac{d}{2} - y\right) \times b \times \left[\frac{\left(\frac{d}{2} + y\right)}{2}\right]}{Ib}$$

$$\tau = \frac{V \times \left(\frac{d^2}{4} - y^2\right)}{2I}$$

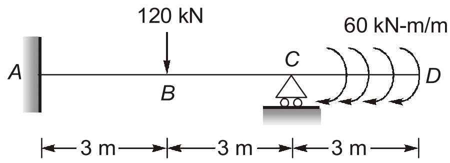
$$dF = \tau \times bdy$$

$$= \frac{V \times \left(\frac{d^2}{4} - y^2\right)}{2I} \times bdy$$

$$F = \frac{Vb}{2I}\int_{d/6}^{d/2}\left(\frac{d^2}{4} - y^2\right)dy$$

$$= \frac{Vb}{2I}\left[\frac{d^2}{4}y - \frac{y^3}{3}\right]_{d/6}^{d/2} = \frac{7V}{27}$$

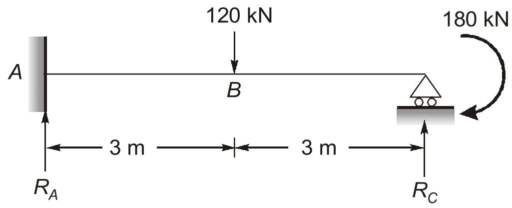
Q.38 A beam carries a concentrated load at point *B* and a uniformly distributed moment in the span CD as shown in the figure below



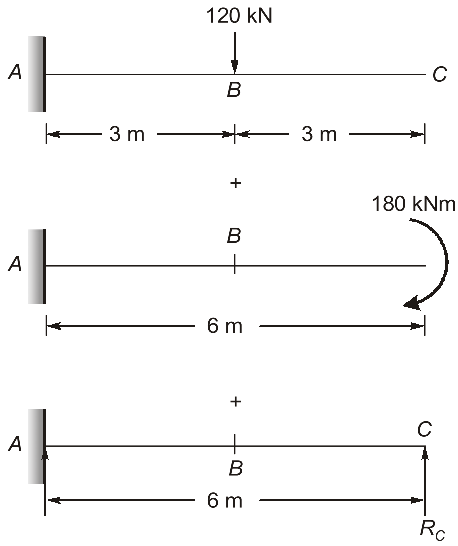
The vertical reaction at *A* and *C* are respectively

(a) 37.5 kN, 82.5 kN
(b) 112.5 kN, 7.5 kN
(c) 7.5 kN, 112.5 kN
(d) 82.5 kN, 37.5 kN

38. (a)



Deflection at point *C* can be computed by the principal of super imposition



$$\delta_{C/A} = \left[\frac{120\times 3^3}{3EI} + \frac{120\times 3^2}{2EI}\times 3\right] + \left[\frac{180\times 6^2}{2EI}\right] - \left[\frac{R_C\times 6^3}{3EI}\right] = 0$$

$$R_C = 82.5 \text{ kN}$$

$$\Sigma F_y = 0$$

$$R_A + R_C = 120$$

$$R_A = 37.5 \text{ kN}$$

Q.39 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I	List-II
A. Irreversibility	**1.** Mechanical equivalent
B. Joule-Thomson experiment	**2.** Thermodynamic temperature scale
C. Joule's experiment	**3.** Throttling process
D. Reversible engines	**4.** Loss of availability

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	1	2	3	4
(c)	4	3	2	1
(d)	1	2	4	3

39. (a)

Multiple Choice Questions : Q. No. 40 to Q. No. 41 carry 2 marks each

Q.40 The rate at which ice melts is proportional to amount of ice at the instant. If half the quantity melts in 30 minutes, then the ratio of amount left to original amount present after 2 hours is

(a) 1 : 8
(b) 1 : 6
(c) 1 : 16
(d) 1 : 4

40. (c)

$$\frac{dm}{dt} = km$$

$$m = m_o e^{kt}$$

At $t = \frac{1}{2}$ hour,

$$m = \frac{m_o}{2}$$

$$\frac{m_o}{2} = m_o e^{k \times \frac{1}{2}}$$

$$\frac{1}{2}k = ln\left(\frac{1}{2}\right) \Rightarrow k = 2ln\left(\frac{1}{2}\right) / \text{hour}$$

At $t = 2$ hours,

$$m' = m_o e^{kt} = m_o e^{2ln(1/2)\times 2}$$

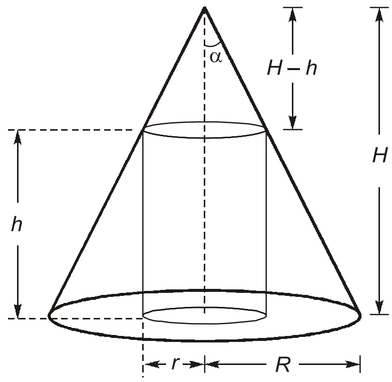
$$m' = m_o e^{ln(1/2)^4}$$

$$\frac{m'}{m_o} = \left(\frac{1}{2}\right)^4 = \frac{1}{16}$$

Q.41 A cylinder is inscribed in a cone of height H and radius R. If the volume of the cylinder is maximum, then height of the cylinder is

(a) $\frac{H}{2}\tan^{-1}\left(\frac{R}{H}\right)$
(b) $\frac{H}{6}\tan^{-1}\left(\frac{R}{H}\right)$
(c) $\frac{H}{3}\tan^{-1}\left(\frac{R}{H}\right)$
(d) $\frac{H}{3}$

41. (d)



$$\alpha = \tan^{-1}\left(\frac{R}{H}\right)$$

$$\text{Volume of the cylinder} = \pi\, r^2\, h$$

$$\frac{r}{(H-h)} = \tan\alpha$$

$$r = (H-h)\tan\alpha$$

$$\text{Volume of cylinder } V = \pi r^2 h = \pi(H-h)^2 \tan^2\alpha \times h$$

$$\text{For maximum volume } \frac{dV}{dh} = 0$$

$$\frac{d}{dh}\{\pi\tan^2\alpha\,(H^2 + h^2 - 2Hh)h\} = 0$$

$$\pi\tan^2\alpha\,[H^2 + 3h^2 - 4Hh] = 0$$

$$3h^2 - 4Hh + H^2 = 0$$

$$3h(h-H) - H(h-H) = 0$$

$$(h-H)(3h-H) = 0$$

$h \neq H$ $\quad\because$ at $h = H$, r will be zero and cylinder becomes line.

So, $h = \dfrac{H}{3}$

Numerical Answer Type Questions : Q.42 to Q.53 carry 2 marks each

Q.42 A brick work of a furnace consists of three layers made of fire clay (k_1 = 0.94 W/mK), crushed diatomite brick (k_2 = 0.13 W/mK) and red brick (k_3 = 0.7 W/mK) respectively. The respective thickness of these layers are 11 cm, 6 cm and 25 cm. If the furnace consists of only two layers of fire clay and red brick so that the heat flow through the brick work remains constant, the thickness of red brick at is __________ cm.

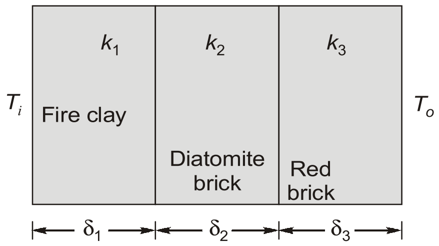
42. (57.36)(56 to 59)

Case -I :

$$\delta_1 = 11 \text{ cm} = 0.11 \text{ m}$$

$$\delta_2 = 6 \text{ cm} = 0.06 \text{ m}$$

$$\delta_3 = 25 \text{ cm} = 0.25 \text{ m}$$

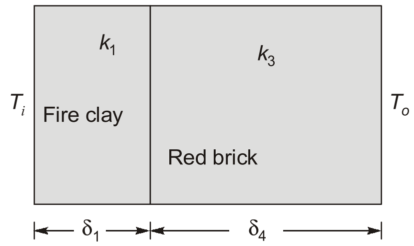


$$\frac{Q}{A} = \frac{T_i - T_o}{\dfrac{\delta_1}{k_1} + \dfrac{\delta_2}{k_2} + \dfrac{\delta_3}{k_3}}$$

$$= \frac{T_i - T_o}{\dfrac{0.11}{0.94} + \dfrac{0.06}{0.13} + \dfrac{0.25}{0.7}}$$

$$= \frac{T_i - T_0}{0.9356} = 1.068\ (T_i - T_0)$$

Case II :



$$\frac{Q}{A} = \frac{T_i - T_o}{\frac{\delta_1}{k_1} + \frac{\delta_4}{k_3}}$$

$$1.068(T_i - T_o) = \frac{T_i - T_o}{\frac{0.11}{0.94} + \frac{\delta_4}{0.7}}$$

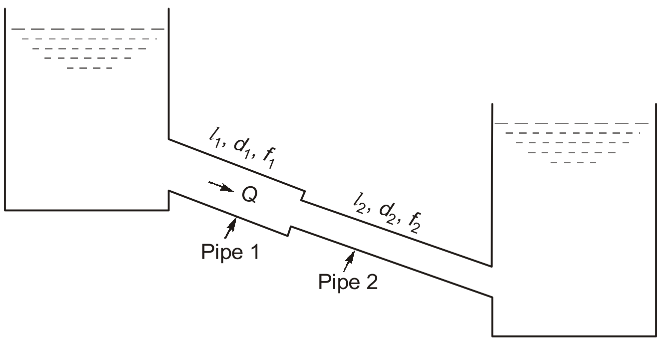
or $\delta_4 = 0.5736 \text{ m} = 57.36 \text{ cm}$

Q.43 Two reservoirs are connected by two pipe 1 and 2 of same length and friction factor, in series. If the diameter of pipe 1 is 25% larger than that of pipe 2, the ratio of head loss in pipe 1 to that of pipe 2 is ________.

43. (0.32768)(0.31 to 0.33)

Head loss due friction: $h_f = \dfrac{flv^2}{2gd}$

where $v = \dfrac{4Q}{\pi d^2}$



$\therefore$ $h_f = \dfrac{fl}{2gd} \times \dfrac{16Q^2}{\pi^2 d^4}$

For pipe 1, $h_{f1} = \dfrac{8f_1 l_1 Q^2}{g\pi^2 d_1^5}$

For pipe 2, $h_{f2} = \dfrac{8f_2 l_2 Q^2}{g\pi^2 d_2^5}$

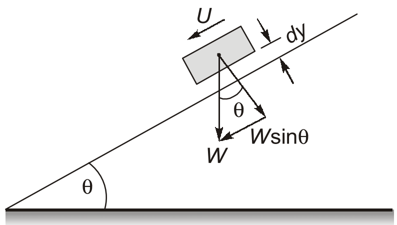
$$\frac{h_{f1}}{h_{f2}} = \frac{8f_1 l_1 Q^2}{g\pi^2 d_1^5} \times \frac{g\pi^2 d_2^5}{8f_2 l_2 Q^2} = \left(\frac{d_2}{d_1}\right)^5 \quad \because f_2 = f_2,\ l_1 = l_2$$

$$= \left(\frac{d_2}{1.25d_2}\right)^5 = 0.32768$$

Q.44 A rectangular block weighing 120 N slides down at 30° inclined plane which is lubricated by a 2.5 mm thick film of oil (relative density 0.85) and viscosity 9 poise. If the contact surface is 0.25 m^2, the terminal velocity of the block is ___________ m/s.

44. (0.67)(0.66 to 0.68)

$$W = 120 \text{ N}$$
$$\theta = 30°$$
$$dy = 2.5 \text{ mm} = 0.0025 \text{ m}$$
$$S = 0.85$$



$\therefore$
$$\rho = 0.85 \times 1000 = 850 \text{ kg/m}^3$$
$$\mu = 9 \text{ poise} = 0.9 \text{ Ns/m}^2$$
$$A = 0.25 \text{ m}^2$$

The component of weight (W), along the block,
$$W\sin\theta = 120 \times \sin 30° = 60 \text{ N}$$

The shear force (F) on the bottom of block,
$$F = W\sin\theta = 60 \text{ N}$$

$$\text{Shear tress: } \tau = \frac{F}{A} = \frac{60}{0.25} = 240 \text{ N/m}^2$$

Using Newton's law of viscosity,

$$\text{Shear tress: } \tau = \mu\frac{du}{dy} = \frac{\mu U}{dy}$$

$\therefore$
$$240 = 0.9 \times \frac{U}{0.0025}$$

or
$$U = 0.666 \text{ m/s}$$
$$\simeq 0.67 \text{ m/s}$$

Q.45 If the one dimensional temperature distribution across a 1 m thick wall is given as

$$T = 50 + 10x + 5x^2 + 2x^3$$

where T is the temperature and x is the distance from one face to other face of wall. If the wall material have thermal diffusivity of 0.002 m^2/hr, the rate of change of temperature at the other face of the wall is________ °C/h.

45. (0.044)(0.04 to 0.05)

$$T = 50 + 10x + 5x^2 + 2x^3$$

$$\frac{\partial T}{\partial x} = 10 + 10x + 6x^2$$

$$\frac{\partial^2 T}{\partial x^2} = 10 + 12x$$

$$\left.\frac{\partial^2 T}{\partial x^2}\right|_{x=1\text{m}} = 10 + 12 \times 1 = 22$$

One dimensional heat transfer across a slab,

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha}\frac{\partial T}{\partial t} \quad \text{without heat generation}$$

$$\therefore \quad 22 = \frac{1}{0.002} \times \frac{\partial T}{\partial t}$$

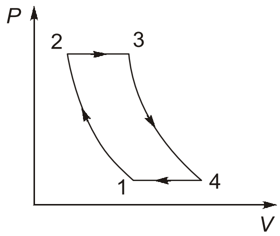
or $$\frac{\partial T}{\partial t} = 0.044\ °\text{C/h}$$

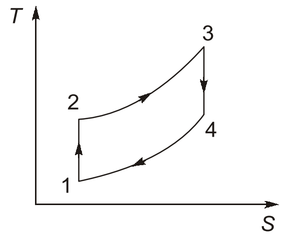
Q.46 An ideal Brayton cycle is operating between the pressure limits of 1 bar and 6 bar. The temperature at the end of the compression and expansion processes are 500 K and 900 K respectively. The ratio of specific heats of the working fluids is 1.4. The ratio of maximum and minimum temperatures of the cycles is _________.

46. (5)(4.9 to 5.1)

Given,

P_1 = 1 bar
P_2 = 6 bar
T_2 = 500 K
T_4 = 900 K
r = 1.4
T_3 = ?
T_1 = ?





For isentropic process 1 – 2

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

$$\Rightarrow \quad \frac{500}{T_1} = (6)^{\frac{0.4}{1.4}}$$

$$\Rightarrow \quad T_1 = 299.66\ \text{K} \approx 300\ \text{K}$$

For isentropic process 3 – 4

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\Rightarrow \quad T_3 = 900 \times (6)^{\frac{0.4}{1.4}} = 1501.66\ \text{K}$$

$$T_3 = 1500\ \text{K}$$

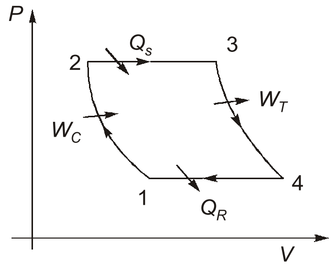
$$\text{Ratio} = \frac{T_{max}}{T_{min}} = \frac{T_3}{T_1} = \frac{1500}{300} = 5$$

Q.47 Atmospheric air at 101.325 kPa and 27°C enters the compressor of a gas turbine operating on Brayton cycle which is having a pressure ratio of 6 $(\gamma_{air} = 1.4)$. If the turbine work is 2.5 times the work of compressor then the maximum temperature in the cycle will be ________K.

47. (1250)(1248 to 1252)

Given,

$$P_1 = 101.325 \text{ kPa}$$
$$T_1 = 300 \text{ K}$$
$$r_p = 6$$
$$\gamma = 1.4$$
$$W_T = 2.5\,W_c$$
$$P_2 = 6 \times 101.325 = 607.95 \text{ kPa}$$



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

$$\Rightarrow \quad T_2 = 300 \times (6)^{\frac{0.4}{1.4}} = 500.55 \text{ K}$$

$$W_T = 2.5\,W_c$$
$$(T_3 - T_4) = 2.5(T_2 - T_1)$$
$$\Rightarrow \quad (T_3 - T_4) = 2.5 \times [500.55 - 300] = 501.375$$

$$\frac{T_3}{T_4} = \left(\frac{P_2}{P_1}\right)^{\frac{0.4}{1.4}}$$

$$\therefore \quad T_4 = \frac{T_3}{1.67}$$

$$\Rightarrow \quad T_3\left[1 - \frac{1}{1.67}\right] = 501.375$$

$$\Rightarrow \quad T_3 = 1250 \text{ K}$$

Q.48 The tool life equation for HSS tool is $VT^{0.12}f^{0.8}d^{0.5}$ = constant. The tool life (T) of 25 min is obtained using the following cutting conditions:

V = 40 m/min; f = 0.30 mm, d = 1.8 mm

If speed (V), feed (f) and depth of cut (d) are increased individually by 20%, the tool life is ______min.

48. (0.756)(0.6 to 0.9)

$$VT^{0.12}f^{0.8}d^{0.5} = C$$
$$(40)(25)^{0.12}(0.3)^{0.8}(1.8)^{0.5} = C$$
$$30.14 = C$$

After increasing by 20%,

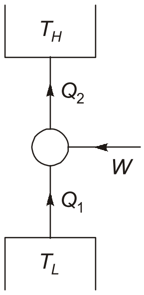
$$(40 \times 1.2)(T)^{0.12}\,(0.3 \times 1.2)^{0.8}(1.8 \times 1.2)^{0.5} = C = 30.14$$
$$48 \times T^{0.12}(0.4416)(1.469) = 30.14$$
$$T^{0.12} = 0.967$$

Tool life, $T = (0.967)^{(1/0.12)} = 0.756$ min

Q.49 The heat rejection ratio of a refrigeration system is 1.2. Then the COP of the heat pump will be ________.

49. (6)

$$\text{HRR} = \frac{Q_2}{Q_1}$$



$$(\text{COP})_R = \frac{Q_1}{W}$$

$$\text{HRR} = 1 + \frac{1}{(COP)_R}$$

$$(\text{COP})_R = 5$$

$$(\text{COP})_{HP} = 1 + (\text{COP})_R$$

$$(\text{COP})_{HP} = 1 + 5 = 6$$

Q.50 A machine is used for turning operation and it takes 30 minutes to machine the component. Efficiency of the machine is 80% and scrap is 25%. The desired output is 1200 pieces per week. Considering 40 hours per week and 50 week in a year. The number of machines required in a year is ________.

50. (25)

$\eta_{machine}$ = 80%

Scrap = 25%

Desired output = 1200 pieces per week

In a week = 40 hours available

In a year = 50 weeks available

Let, number of machines required in a year = N

Useful component coming out of machine = 75%

Number of component required per year

= $1200 \times 50 = 60000$/years

Time available = $40 \times 50 = 2000$ hrs/years

1 hr $\rightarrow$ 2 components

Actual component per machine/hr = $2 \times 0.8 \times 0.75 = 1.2$

$\therefore \quad 2000 \times 1.2 \times N = 60000$

N = 25 machine

Q.51 Four technicians are required to do four different jobs. Estimates of time to complete every job provided by the technician are as below

Technician	Hours to complete Job			
	Job 1	Job 2	Job 3	Job 4
A	20	36	31	27
B	24	34	45	12
C	22	45	38	18
D	37	40	35	28

The minimum time to complete all the jobs is _______ hours.

51. (107)

	1	2	3	4
A	20	36	31	27
B	24	34	45	22
C	22	45	38	18
D	37	40	35	28

Sub-step 1:
Subtract the minimum of the each row from all the elements of the row, i.e.,

0	16	11	7
2	12	23	0
4	27	20	0
9	12	7	0

Sub-step 2:
Since columns 2 and 3 contain no zero entry, we have to subtract minimum element of each column from all the elements of the column, i.e.,

	1	2	3	4
A	0	4	4	7
B	2	0	16	0
C	4	15	13	0
D	9	0	0	0

This is initial basic feasible solution. Checking if optimal assignment can be made. Examine rows successively until a row with exactly one unmarked zero is found. Mark (□) this zero, indicating that an assignment will be made there. Mark (X) all other zeroes in the same column showing that they cannot be used for making other assignments, i.e.,

[0]	4	4	7
2	0	16	0
4	15	13	0
9	0	0	0

Next examine column for single unmarked zeroes, making them (□) and also marking (X) any other zeroes in this rows. Keep repeating the same procedure for rows and columns i.e.

[0]	4	4	7
2	0	16	0
4	15	13	0
9	~~0~~	[0]	~~0~~

[0]	4	4	7
2	[0]	16	~~0~~
4	15	13	[0]
9	~~0~~	[0]	~~0~~

Since there is one assignment in each row and in each column, the optimal assignment can be made in the current solution.

Optimum assignment is

$$A \rightarrow 1,\ B \rightarrow 2,\ C \rightarrow 4,\ D \rightarrow 3$$

$$\text{Total work time} = 20 + 34 + 18 + 35 = 107 \text{ hours}$$

Q.52 The true stress curve is given by $\sigma = 1200\varepsilon^{0.3}$, where the stress σ is in MPa. The true stress under maximum load is ___________ MPa.

52. (836.2)(835 to 837)

$$\sigma_f = k\varepsilon^n$$

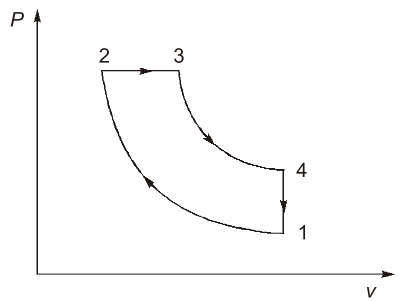
$$k = 1200$$

$$\text{For maximum load, } n = k = 0.3$$

$$\sigma_f = 1200(0.3)^{0.3} = 836.2 \text{ MPa}$$

Q.53 An air standard diesel cycle has a compression ratio 14. The pressure at the beginning of the compression stroke is 1 bar and the temperature is 27°C. The maximum temperature is 2500°C. The thermal efficiency of the cycle will be ______________%.

53. (53.6)(53 to 54)



from figure

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$= 300 \times 14^{0.4} = 300 \times 2.88 = 864\,\text{K}$$

$$P_2 = P_1\left(\frac{T_2}{T_1}\right)^{\frac{\gamma}{\gamma-1}} = 1 \times \left(\frac{864}{300}\right)^{3.5} = 1 \times 40.5 = 40.5 \text{ bar}$$

Now

$$\frac{V_3}{V_2} = \frac{T_3}{T_2} = \frac{2773}{864} = 3.21$$

and

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = \left(\frac{V_4}{V_2} \times \frac{V_2}{V_3}\right)^{\gamma-1}$$

$$\frac{T_3}{T_4} = \left(\frac{14}{3.21}\right)^{0.4} = 4.36^{0.4} = 1.8$$

$$T_4 = \frac{T_3}{1.8} = \frac{2773}{1.8} = 1540°\text{K}$$

$$\eta = \frac{c_p(T_3 - T_2) - c_v(T_4 - T_1)}{c_p(T_3 - T_2)}$$

$$\Rightarrow \quad 1 - \frac{(T_4 - T_1)}{\gamma(T_3 - T_2)} = 1 - \frac{(1540 - 300)}{1.4(2773 - 864)}$$

$$\Rightarrow \quad 1 - 0.464 = 0.536 \text{ or } 53.6\%$$

Numerical Answer Type Questions : Q.54 to Q.55 carry 2 marks each

Q.54 Differential equation given by $\frac{dy}{dx} = 3x + y^2$ is solved using Runge's formula of order 2 with $y = 1.2$ when $x = 1$. The value of y when $x = 1.1$ is __________.

54. (1.722) (1.68 to 1.75)

$x_0 = 1,\ y_0 = 1.2,\ h = 1.1 - 1 = 0.1$

$$f(x, y) = 3x + y^2$$

$$f(x_0, y_0) = 3 \times 1 + (1.2)^2 = 4.44$$

$$k_1 = hf(x_0, y_0) = 0.1 \times 4.44 = 0.444$$

$$k_2 = hf(x_0 + h, y_0 + k_1) = 0.1f(1.1, 1.644)$$

$$= 0.1\,[3 \times 1.1 + (1.644)^2] = 0.600$$

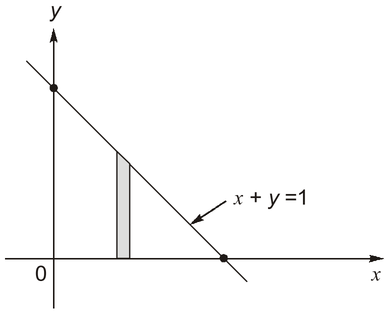
$$y_{n+1} = y_n + \frac{1}{2}(k_1 + k_2) = 1.2 + \frac{1}{2}[0.444 + 0.600] = 1.722$$

Q.55 The integral $I = \oint_C \left[(3x - 8y^2)dy + (4y - 6xy)dx\right]$ is calculated over the closed curve C. If C is the boundary of the region bounded by $x = 0$, $y = 0$ and $x + y = 1$, then the value integral I is ________ .

55. **(0.5)**

By Green's theorem

$$I = \iint_R \left[\frac{\partial(3x - 8y^2)}{\partial x} - \frac{\partial(4y - 6xy)}{\partial y}\right] dx\, dy$$



$$= \int_0^1 \int_0^{1-y} (3 - 4 + 6x) dx\, dy = \int_0^1 \int_0^{1-y} (6x - 1)\, dx\, dy$$

$$= \int_0^1 \left.\frac{6x^2}{2} - x\right|_0^{1-y} dy = \int_0^1 \left[3(1-y)^2 - (1-y)\right] dy$$

$$= \left. -3\frac{(1-y)^3}{3} + \frac{(1-y)^2}{2}\right|_0^1$$

$$= -3 \times \frac{(1-1)}{3} + \frac{(1-1)}{2} + 3\frac{(1-0)}{3} - \frac{(1-0)}{2} = \frac{1}{2} = 0.5$$

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