All India Mock GATE Test Series
Test series 4
Mechanical Engineering

Answer Keys and Explanations

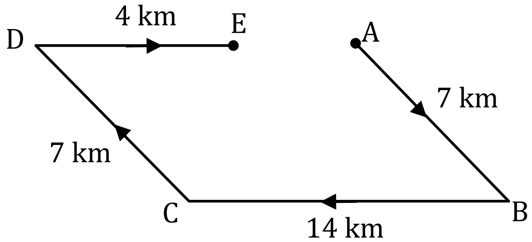
General Aptitude:

1. **[Ans. A]**
Meaning: slow to move or act
Part of Speech: Adjective

2. **[Ans. *] Range: 9 to 9**
Clearly $5 \times 2 = 10, 10 \times 2 = 20, 20 \times 2 = 40, \ldots$
So, the series is a G.P. in which $a_1 = 5$ and $r = 2$
To find the n^{th} term of a Geometric progression, the formula is $a_n = a_1 r^{n-1}$
Let 1280 be the n^{th} term of the series
Then, $5 \times 2^{n-1} = 1280 \Leftrightarrow 2^{n-1} = 256 = 2^8 \Leftrightarrow n - 1 = 8 \Leftrightarrow n = 9$

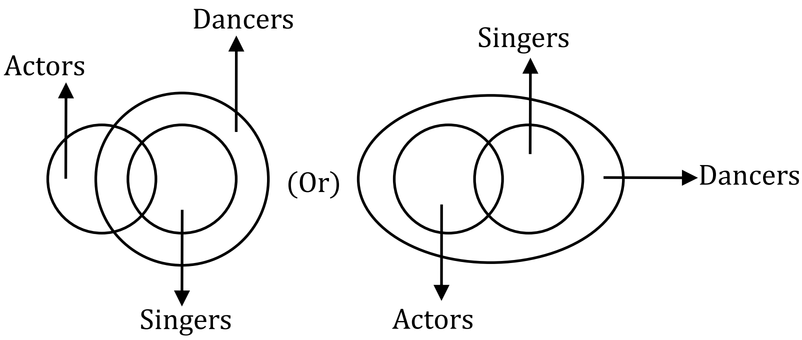
3. **[Ans. A]**
For this type of question take the LCM of speeds and assume the LCM as the distance
Then the time taken at speed of 60 km/hr $= \frac{300}{60} = 5$ hrs
Again the time taken at speed of 50 km/hr $= \frac{300}{50} = 6$ hrs
Thus we see that in place of 5 hrs trains take 6 hrs. Its means train takes 1 hr extra and this one hour is stopping period in the total time of 6 hrs. Thus in 6 hrs train halts for 1 hr. so in 1 hr train will stop for $^1/_6$ hours or 10 minutes.

4. **[Ans. *] Range: 10 to 10**
Let assume, Radha is at Point 'A'



Required distance = $AE = AD - DE$
Since ABCD is a parallelogram
AD= BC
$\therefore\ AE = BC - DE$
$= 14 - 4 = 10$

5. [Ans. A]



Only (1) Follows

6. [Ans. *] Range: 6 to 6

Given:

$R \rightarrow x + 10$	x		$x + 5$	(5)$^+$
$L \rightarrow x + 6$	x		$x + 5$	(1)$^+$
$B \rightarrow x + 5$	$x +$	25	$x + 5$	(1)$^-$
$H \rightarrow x + 4$	x		$x + 5$	
$A \rightarrow x$	x		$x + 5$	(5)$^-$

Thus total 6 coins have to be transferred.

7. [Ans. B]

The numbers are given in pair of 4 and 9.

The unit digit of each pair is 4, and there are 50 such pairs which are mutually multiplied together.

Unit digit $\underbrace{4 \times 9^2}_{4} \times \underbrace{4^3 \times 9^4}_{4} \times \underbrace{4^5 \times 9^6}_{4} \times \ldots . \underbrace{4^{99} \times 9^{100}}_{4}$

Again $4 \times 4 \times 4 \times 4 \ldots 4$(upto 50 times)

i.e., the unit digit of 4^{50}, which is 6

[Since unit digit of 4^{2n} is 6 for $n = 1, 2, 3, \ldots$etc]

8. [Ans. B]

16.66 18.75

17.5

(Boys) (Girls)

$\Rightarrow$ $\frac{50}{3}\times\frac{4}{4}$ $\frac{75}{4}\times\frac{3}{3}$ …… (Making Denominator equal)

$\frac{35}{2}\times\frac{6}{6}$

B G

200/12 225/12

$\Rightarrow$ 210/12

15/12 10/12

$\Rightarrow$ 3 : 2

$\therefore$ Boys $= 3x$; Girls $= 2x$

Given $3x - 2x = 8$

$\therefore x = 8$

Thus the number of Girls = 16 and number of Boys = 24

9. [Ans. D]

Let there be x voters and k votes goes to loser then

$0.8x - 120 = k + (k + 200)$ …….①

Also, $k + 200 = 0.41x$ …….②

From equation ① and ②

$0.8x - 120 = 0.41x - 200 + 0.41x$

$0.02x = 80$

$x = 4000$

$\therefore k = 0.41 \times 4000 - 200$

$\Rightarrow k = 1440$

And $(k + 200) = 1640$

Number of voters voted $= x - 0.2x$

$0.8x = 0.8 \times 4000 = 3200$

Therefore, percentage of votes for defeated candidates $= \frac{1440}{3200} \times 100 = 45\%$

10. [Ans. *] Range: 40 to 40

Given

$W_2 = 1.5\ W_1\ \ \ldots \ldots.(50\%\ \text{Increase in walk})$

$D_1 = D_2$

$\because \dfrac{M_1 \times D_1}{W_1} = \dfrac{M_2 \times D_2}{W_2}$

$\therefore M_2 = 1.5\ M_1$

$\therefore$ If the efficiency of M_1 and M_2 is same, then 50% more work force is required.

But it is given the productivity of new labour is 25% more (i.e., 5/4 times efficient)

$\therefore$ Actual % increase in work force required $= \dfrac{50\%}{5/4} = 40\%$

Technical:

1. **[Ans. B]**

For a $n \times n$ matrix [A] with $\lambda_1, \lambda_2, \lambda_3 \ldots\ldots \lambda_{(n-1)}, \lambda_n$, as the Eigen Values

$\det(A) = (\lambda_1 \times \lambda_2 \times \ldots\ldots \lambda_{(n-1)} \times \lambda_n)$

Since one of the Eigen values is zero

$\det(A) = 0$

2. **[Ans. D]**

$y' e^{\pi x} = y^2 + 1$

$$\frac{dy}{y^2+1} = \frac{dx}{e^{\pi x}}$$

$$\tan^{-1}(y) = \frac{e^{-\pi/x}}{-\pi} + c$$

$$\Rightarrow y = \tan\left(\frac{-e^{-\pi x}}{\pi} + c\right)$$

3. **[Ans. *] Range: 0.72 to 0.74**

Average number of defective items is given by $10(0.1) = 0.1$

$\Rightarrow \lambda = 1$ (Mean of Poisson distribution)

Required probability is given by

$$p(x \le 1) = p(x=0) + p(x=1) = \frac{e^{-\lambda}\lambda^0}{0!} + \frac{e^{-\lambda}\lambda^1}{1!}$$

$$= e^{-\lambda} + e^{-\lambda}$$

$$= 2e^{-\lambda} \Rightarrow 2e^{-1}$$

$$= 0.7358$$

4. **[Ans. A]**

$$\oint_c \frac{f(z)}{(z-z_0)^{n+1}} dz = 2\pi i \frac{f^n(z_0)}{n!}$$

$$= 2\pi i \frac{81 \cos h(0)}{4!}$$

$$= \frac{27}{4}\pi i$$

5. **[Ans. D]**

All entire functions are analytic everywhere

(A) z^4 is an entire function

(B) $e^{2x}(\cos 2y + i\sin 2y) = e^{2x} \cdot e^{i2y} = e^{2(x+iy)} = e^{2z}$

e^{2z} is an entire function

(C) $e^{-x}(\cos y + i\sin y) = e^{-x} \cdot e^{-iy} = e^{-z}$

e^{-z} is also entire function

(D) Imaginary $(z^2) = 2xy = u + iv$

$$\frac{\partial u}{\partial x} = 2y \ \frac{\partial v}{\partial y} = 0, \frac{\partial u}{\partial x} \neq \frac{\partial v}{\partial y}$$ Hence not analytic

6. **[Ans: B]**
Conservation of linear momentum,
$[12 \times 2] + [2 \times (-5)] = [12 + 2] \times V_f$
$V_f = \frac{24 - 10}{14} = 1\text{m/s}$

7. **[Ans.*]Range: 126 to 129**
For brittle materials maximum principle stress theory is valid
$S_{yt} \geq \sigma_1$
$\sigma_1 = \frac{16}{\pi d^3}\left[M + \sqrt{M^2 + T^2}\right]$
$100 \times 10^6 \geq \frac{16}{\pi d^3}\left[M + \sqrt{M^2 + T^2}\right]$
$M = 20 \times 10^6 \times 10^{-3}\text{Nm}$
$T = 4.77 \times 10^6 \times 10^{-3}\text{Nm}$
$100 \times 10^6 \geq \frac{16 \times 10^3}{\pi(d^3)}\left[20 + \sqrt{20^2 + 4.77^2}\right]$
$d^3 \geq \frac{16 \times 10^3}{\pi \times 100 \times 10^6}[\,20 + \sqrt{20^2 + 4.77^2}$
$d \geq 127.3\text{ mm}$

8. **[Ans. A]**
Longitudinal riveted joint takes circumferencial stress
Hence
$\sigma_c = \left(\frac{PD}{2t\eta}\right)$
$\Rightarrow P = \left(\sigma_c \frac{2t\eta}{D}\right)$
$P = \frac{100 \times 2 \times 0.020 \times 0.75}{2}$
$P = 1.5\text{ MPa}$

9. **[Ans. *]Range: 257.88 to 257.88**
From the bet equation,
For raising, 'm' $\frac{4000}{mg} = e^{\mu\theta}$ ________(i)
For lowering 'm' $\frac{mg}{1600} = e^{\mu\theta}$ ________(ii)
From equation (i) & (ii)
$(mg)^2 = 4000 \times 1600$
$m = \frac{\sqrt{4000 \times 1600}}{9.81}$
$m = 257.88\text{ kg}$

10. **[Ans. D]**

For forced damping vibrations $m\ddot{x} + c\dot{x} + kx = Fo\sin(\omega t)$

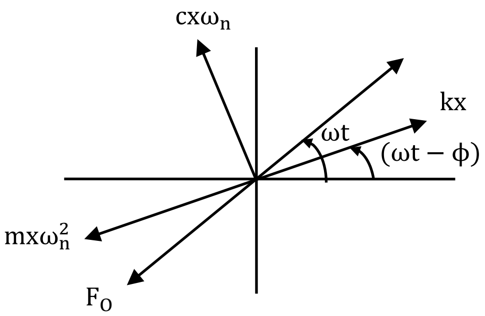
Solution is $x = x\sin(\omega t - \phi)$

$\dot{x} = x\omega_n \cos(\omega t - \phi)$

$\dot{x} = x\omega_n \sin\left(\frac{\pi}{2} + (\omega t - \phi)\right)$

$\ddot{x} = -x\omega_n^2 \sin(\omega t - \phi)$

$$mx\omega_n^2 \sin\big(\pi + (\omega t - \phi)\big) + C \times \omega_n \sin\left(\frac{\pi}{2} + (\omega t - \phi)\right) + kx\sin(\omega t - \phi)$$
$$+ F_O \sin(\pi + \omega t) = 0$$



Phase Diagram

11. **[Ans.*]Range: 118 to 120**

Area of cross section $= 2.356 \times 10^4\ \text{mm}^2$

$$\sigma_t = \frac{P}{A} = \frac{100 \times 10^3}{2.356 \times 10^4} = 4.24\ \text{MPa}$$

Sectional modulus of shaft $= \frac{\pi}{32}\left[\frac{D_o^4 - Di^4}{D_o}\right]$

$= 73.63 \times 10^4\ \text{mm}^4$

Torsional modulus $= \frac{\pi}{16}\left[\frac{D_o^4 - D_i^4}{D_o}\right]$

$= 147.26 \times 10^4\ \text{mm}^4$

$\sigma_b = \left(\frac{M}{z}\right) = 13.58\ \text{MPa}$

Shear stress due to torsion =109.4 MPa

$$\sigma_{max} = \left(\frac{\sigma_t + \sigma_b}{2}\right) + \sqrt{\left(\frac{\sigma_t + \sigma_b}{2}\right)^2 + \tau^2}$$

$= 118.7\ \text{MPa}$

12. **[Ans. C]**

13. **[Ans. C]**

$$u = \frac{\partial \phi}{\partial x} = \frac{\partial}{\partial x}[x(2y-1)] = 2y - 1$$

$$v = \frac{\partial \phi}{\partial y} = \frac{\partial}{\partial y}[x(2y-1)] = 2x$$

$$d\psi = \frac{\partial \psi}{\partial x}\,dx + \frac{\partial \psi}{\partial y}dy$$

$$\Rightarrow d\psi = -vdx + udy$$

$$\Rightarrow d\psi = -2xdx + (2y-1)dy$$

$$\therefore\ \psi = -2 \times \frac{x^2}{2} + \frac{2xy^2}{2} - y + c$$

$$\psi = -x^2 + y^2 - y + c$$

At point P (4, 5)

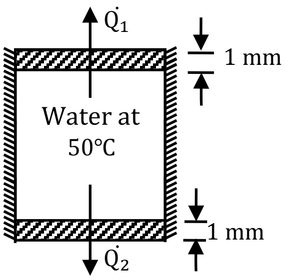
$$\psi = -(4)^2 + (5)^2 - 5$$

$$= 4 \text{ units}$$

14. **[Ans. B]**

15. **[Ans. *]Range: 0.033 to 0.0368**

Method 1



$$\dot{Q} = \dot{Q}_1 + \dot{Q}_2$$

$$= KA\frac{(50-20)}{0.001} + KA\frac{(50-20)}{0.001}$$

$$= 2\ KA \times \frac{30}{0.001} = 2 \times 200 \times A \times \frac{30}{0.001} \cdots\cdots (i)$$

For water

$$\dot{Q} = mc\frac{dT}{dt}$$

$$= \rho\forall C\frac{dT}{dt}$$

$$= 1000 \times (A \times h) \times 4200 \times \frac{dT}{dt}$$

$$= 1000 \times A \times \frac{10}{100} \times 4200\frac{dT}{dt} \cdots\cdots (ii)$$

Equating equation (i) and (ii)

$$1000 \times A \times \frac{10}{100} \times 4200\frac{dT}{dt} = 400 \times A \times \frac{30}{0.001}$$

$$\therefore \frac{dT}{dt} = \frac{400 \times 300}{42000 \times 0.001} = \frac{12}{42 \times 0.001 \times 110} = 28.5714\ °C/S$$

Time taken for the temperature to fall by 28.5714°C is 1 sec so, time taken for the temperature to fall by 1°C is $\frac{1}{28.5714}$ sec = 0.035 sec

Method 2

Rate of heat loss by conduction is equal to – ve rate of change of internal energy.

$$\Rightarrow 2 \times kA\frac{(T - T_\infty)}{L} = -mc\frac{dT}{dt}$$

L→ Thickness of piston

Δ → Area of piston

k → Thermal conductivity of piston material

T_∞ = Temperature of surrounding fluid

m → Mass of water inside the champer

C → Specific heat of water

T → Temperature of water at time instant

$$\Rightarrow \frac{dT}{T - T_\infty} = \frac{-2kA}{\rho Vcl}\ dt$$

$$\Rightarrow \ln\left(\frac{T - T_\infty}{T_0 - T_\infty}\right) = \frac{-2kA}{\rho Vcl}t$$

$\Rightarrow (T - T_\infty) = (T_0 - T_\infty)\, e^{-\frac{2kA}{\rho vcL}t}$

or $t = \dfrac{-\rho vcl}{2kA} \ln\left(\dfrac{T - T_\infty}{T_0 - T_\infty}\right)$

Aim: To find t, if $T = 49°C$ where $T_0 = 50°C$

$\Rightarrow t = \dfrac{-1000 \times 10 \times 10^{-4} \times 0.1 \times 4200 \times 0.001}{2 \times 200 \times 10 \times 10^{-4}} = \times \ln\left(\dfrac{49 - 20}{50 - 20}\right)$

$\Rightarrow t = 0.03559$ sec

16. **[Ans. A]**

Wein's displacement Law

$\lambda_m T = C$

$T \propto \dfrac{1}{\lambda_{max}}$

$\dfrac{T_1}{T_2} = \dfrac{\lambda_{max\,2}}{\lambda_{max\,1}}$

$\Rightarrow \dfrac{T_1}{T_2} = \dfrac{10000}{20000}$

$\Rightarrow \dfrac{T_1}{T_2} = \dfrac{1}{2}$

Also, me know

$E = \sigma\, T^4$

$\Rightarrow \dfrac{E_1}{E_2} = \left(\dfrac{T_1}{T_2}\right)^4$

$\Rightarrow E_2 = E_1 \times \left(\dfrac{T_2}{T_1}\right)^4$

$= 16 \times (2)^4$

$= 256\, J/m^2\, s$

17. **[Ans. C]**

	A	B	C	D
(A)	3	4	2	1
(B)	4	1	3	2
(C)	3	4	1	2
(D)	4	1	2	3

18. **[Ans. *]Range: 45 to 47**

$$(\text{COP})_{\text{max}} = \left(\frac{271}{313-271}\right)$$

$$(\text{COP})_{\text{actual}} = \frac{1}{10}(\text{COP})_{\text{max}} = \frac{\text{RE}}{\text{WD}}$$

$$(\text{COP})_{\text{actual}} = \frac{1}{10}\left(\frac{271}{313-271}\right) = \frac{30}{\text{WD}}$$

$\text{WD} = 46.50$ Watt

19. **[Ans. D]**

Thermal efficiency of gas turbine with ideal regeneration is

$$\eta = \left[1 - \frac{T_{\text{min}}}{T_{\text{max}}} r_p^{\left(\frac{k-1}{k}\right)}\right]$$

20. **[Ans. B]**

$$a \longrightarrow b \longrightarrow c \longrightarrow d \longrightarrow e$$

$\sigma_1^2 = 4\,;\ \sigma_2^2 = 16\,;\ \sigma_3^2 = 4\,;\ \sigma_4^2 = 1$

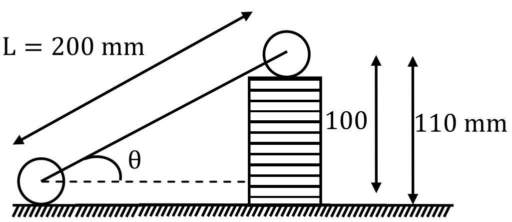
Standard deviation

$$= \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \sigma_4^2}$$

$$= \sqrt{4 + 16 + 4 + 1}$$

$$= 5$$

21. **[Ans. *] Range: 30 to 30**



$$\sin\theta = \frac{100}{200}$$

$$\theta = \sin\frac{1}{2}$$

$$\theta = 30°$$

22. **[Ans. C]**

TIG and PAW uses non consumable electrodes

SMAW uses consumable electrode which is like a stick

SAW uses consumable electrode in wire form

23. **[Ans.*]Range: 0.125 to 0.128**

$$e = \left(\frac{PL}{AE}\right)$$

$$\epsilon_{long} = \left(\frac{P}{AE}\right)$$

$$\mu = -\frac{\epsilon_{lat}}{\epsilon_{long}}$$

$$\Rightarrow -0.3 = \left(\frac{D_f - D_i}{D_i}\right)\left(\frac{L_i}{L_f - L_i}\right)$$

$$-\left(\frac{D_f - D_i}{D_i}\right)\left(\frac{AE}{P}\right) = 0.3$$

$$\Rightarrow D_f = 9.99 \text{ mm}$$

$$\text{Hence true stress } = \frac{4P}{\pi D_{f^2}} = 0.1275 \text{ MPa}$$

24. **[Ans. *] Range: 1.4 to 1.6**

$$N = \frac{1000V}{\pi d} = 238.732 \text{ rpm}$$

Where,

$V \rightarrow$ Cutting speed in m/min

$d \rightarrow$ Diameter in mm

$$f_m = 0.4 \times 238.732 = 95.492 \text{ mm/min}$$

Where f_m is feed in mm/min

$$\text{Machining time} = \frac{\text{length of cut}}{f_m} = 1.57\text{min}$$

25. **[Ans. C]**

In USM tip of the tool (sonotrode) vibrates at frequency of 20 kHz, this variation imports a high velocity to abrasive grains between the tool and work piece and thus material is removed from surface by micro chipping and erosion with fine abrasive grains in a slurry

26. **[Ans. B]**

Taking logarithm of both side of $x^y = y^x$, we obtain

$$y \ln x = x \ln y$$

Differentiating both sides of this equation w.r.t x,

$$y' \ln x + \frac{y}{x} = xy'\frac{1}{y} + \ln y$$

$$y'\left(\ln x - \frac{x}{y}\right) = \ln y - \frac{y}{x}$$

$$y' = \frac{\ln y - \frac{y}{x}}{\ln x - \frac{x}{y}}$$

$$y'|_{(x,y)=(2,4)} = \frac{\ln 4 - 4/2}{\ln 2 - 2/4} = \frac{2\ln 2 - 2}{\ln 2 - \frac{1}{2}}$$

27. **[Ans. B]**

$$\frac{1}{1-e^{-2\pi s/\omega}}\int_0^{\pi/\omega} e^{-st}\sin\omega t\,dt$$

Using $\left(1-e^{-2\pi s/\omega}\right)=\left(1+e^{-\pi s/\omega}\right)\left(1-e^{-\pi s/\omega}\right)$ and integrating by parts or nothing that the integral is the imaginary part of the integral given below,

$$\int_0^{\pi/w} e^{(-s+i\omega)}\,dt=\frac{1}{(-s+iw)}\,e^{(-s+i\omega)t}\Big|_0^{\pi/\omega}$$

$$=\frac{-s-i\omega}{s^2+\omega^2}\left(-e^{-s\pi/\omega}-1\right)$$

$$\text{Imaginary}\left(\frac{-s-i\omega}{s^2+\omega^2}\left(-e^{-s\pi/\omega}-1\right)\right)=\frac{\omega}{s^2+\omega^2}=\left(e^{-s\pi/\omega}+1\right)$$

$$\frac{1}{\left(1+e^{-s\pi/\omega}\right)\left(1-e^{-\pi s/\omega}\right)}\left(1+e^{-s\pi/\omega}\right)\cdot\frac{\omega}{(s^2+\omega^2)}=\frac{1}{1-e^{-\pi s/\omega}}\cdot\frac{\omega}{s^2+\omega^2}$$

28. **[Ans. *] Range: 0.66 to 0.66**

Let U → Unbiased coin; B Biased coin

$P(U)=\frac{2}{3}\ \ P(B)=\frac{1}{3}$

Let A → Appear head both the times

$P(A/U)$ → Getting head on both times when coin is unbiased.

$P(A/U)=\frac{1}{2}\times\frac{1}{2}\qquad\left(P(\text{Head})=\frac{1}{2}\right)$

$P(A/B)$ → Getting head on both times when coin is biased.

$P(A/B)=1\times\frac{1}{2}\qquad(P(\text{Head})=1)$

According Bayes theorem

$$P(A)=P(A\cap U)+P(A\cap B)$$

$$=P(U)P\left(\frac{A}{U}\right)+P(B)P\left(\frac{A}{B}\right)$$

$$=\frac{1}{3}\times\frac{1}{4}+\frac{1}{3}\times 1$$

$$=\frac{1}{3}\left(\frac{1}{2}+1\right)=\frac{1}{3}\times\frac{3}{2}=\frac{1}{2}$$

$P\left(\frac{B}{A}\right)=$ Selected coin is biased coin when two time head already happen

$$P\left(\frac{B}{A}\right)=\frac{P(A\cap B)}{P(A)}=\frac{P(B)P(A/B)}{P(A)}$$

$$=\frac{1/3\times 1}{1/2}=\frac{2}{3}$$

29. **[Ans. B]**

We know that

$$E[g(x)] = \int_{-\infty}^{\infty} g(x)f_x(x)dx$$

$$\Rightarrow E[e^x] = \int_0^1 e^x \cdot 1\, dx = e^1 - e^0$$

$$= e - 1$$

30. **[Ans.*]Range: 2.0 t o2.5**

$T = 80\text{ Nm}, \text{time} = 5\text{ sec.}$

$\text{Initial speed} = 100\text{ rpm}, \text{find speed} = 0$

$$\text{Heat generated} = \left(\frac{I\omega^2}{2}\right)$$

$$\text{Torque} = I\alpha = \frac{I(\omega_f - \omega_i)}{t} = \left(\frac{I_\omega}{t}\right)$$

$$80 = \frac{I \times 2\pi \times 100}{60 \times 5} \Rightarrow I = \frac{120}{\pi}\text{ kJm}^2$$

$$\text{Heat generated} = \frac{1}{2} \times \frac{120}{\pi} \times \left(\frac{2\pi \times 100}{60}\right)^2$$

$$= 2094\text{J}$$

$$= 20.6\text{ kJ}$$

$$\simeq 2.1\text{ kJ}$$

31. **[Ans. *]Range: 75 to 75**

As there is no external moment applied, we can use principle of conversation of angular momentum. i.e,

Initial angular momentum= Final angular momentum

$$(mr^2) \times \omega_0 + (mr^2) \times \omega_0 = m.(2r)^2 \cdot \omega + m(2r^2) \times \omega$$

$$2mr^2 \cdot \omega_0 = 2.m4r^2 \cdot \omega$$

$$\omega = \frac{\omega_0}{4}\text{(where } \omega \text{ is the final angular velocity of system)}$$

$$v_f = (2r) \cdot \omega$$

$$v_i = (r)\omega_0$$

%Loss in kinetic energy

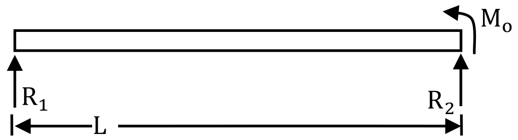
$$= \frac{\text{Initial kE} - \text{Final kE}}{\text{Initial kE}} \times 100$$

$$= \left[\frac{1 - 2 \times \frac{1}{2}m\left[(2r\cdot)\left(\frac{\omega_0}{4}\right)\right]^2}{2 \times \frac{1}{2}m[(r)(\omega_0)]^2}\right] \times 100$$

$$= 75\%$$

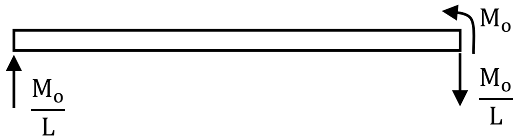
32. **[Ans. B]**
There are two bending moment equation hence we can't use double integration technique.
Area moment method is not applicable here

33. **[Ans. D]**



$R_1 + R_2 = 0$

$M_o + R_2(L) = 0 \Rightarrow R_2 = -\frac{M_o}{L}$ and $R_1 = \frac{M_o}{L}$



Bending moment equation $= \left(\frac{M_o x}{L}\right)$

Now, $\frac{d^2y}{dx^2} = \frac{M_o x}{LEI}$

$\frac{dy}{dx} = \frac{M_o x^2}{2EIL} + c_1$

$y = \frac{M_o x^3}{6\ EIL} + c_1 x + c_2$

At $x = 0$, $y = 0 \Rightarrow c_2 = 0$

At $x = L, y = 0 \Rightarrow c_1 = \frac{M_o L^2}{6EIL} = \frac{-M_o L}{6EI}$

Therefore $y = \frac{M_o x^3}{6EIL} - \frac{M_o Lx}{6EI}$

$\left(\frac{dy}{dx}\right) = \frac{3M_o x^2}{6EIL} - \frac{M_o L}{6EI} = 0 \Rightarrow \frac{M_o x^2}{2EIL} = \frac{M_o L}{6EI}$

$\Rightarrow x = \frac{L}{\sqrt{3}}$

34. **[Ans. *]Range 0.12 to 0.15**

Area of cross section $= \frac{\pi}{4}[d_o^2 - di^2]$

$= \frac{\pi}{4}[300^2 - 50^2]$

$= 68723 \text{ mm}^2$

Load $P = 68723$ N

elongation $= \left(\frac{PL}{AE}\right)$

$= \frac{68723 \times 0.8 \times 4}{\pi \times (0.05)^2 \times 205 \times 10^3 \times 10^6}$

$= 0.137$ mm

35. **[Ans.*] Range: 2.2 to 2.4**

It is equivalent to a simply supported beam with UDL with intensity of load as weight per length.

$\therefore \delta = \left(\frac{W}{L}\right) = \left(\frac{\rho ALg}{L}\right) = (\rho Ag)$

Deflection $= \left(\frac{5qL^4}{384\ EI}\right)$

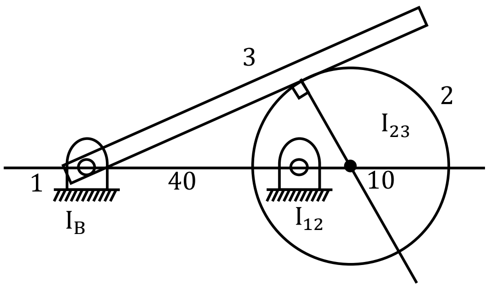
$= \frac{5 \times \rho AgL^4}{384EI}$

$= \frac{5 \times 7600 \times 25 \times 10^{-4} \times 9.81 \times (1)^4}{384 \times 200 \times 10^9 \times I}$

$I = \frac{5 \times 5^3}{12} \times 10^{-12} \text{ mm}^4$

Deflection=2.33 mm

36. **[Ans. *] Range: 0.025 to 0.04**



$\omega_2(I_{12}\ I_{23}) = \omega_3(I_{13}\ I_{23})$

$(2)(10) = \omega_3(50)$

$\omega_3 = \frac{20}{50} = \left(\frac{2}{5}\right)$ rad/s

Sliding velocity of the follower with respect to disc

$= R(\omega_2 - \omega_3)$

$= (0.02)\left(2 - \frac{2}{5}\right)$

$= 0.032$ m/s

37. **[Ans. *] Range: 26 to 27**

$$(\Delta)_{mass} = (\Delta_3) + \frac{mg}{k}$$

Equilibrium Equation

$$(mg)(15) = (k\Delta_1)5 + (k\Delta_2)(10)$$

$$3mg = (k\Delta_1) + 2k\Delta_2$$

$$\left(\frac{\Delta_1}{5} = \frac{\Delta_2}{10}\right), \qquad (\Delta_2 = 2\Delta_1)$$

$$3mg = (k\Delta_1) + 4k\Delta_1$$

$$\Delta_1 = \frac{3mg}{5\,k}$$

$$\frac{\Delta_1}{5} = \frac{\Delta_3}{15}$$

$$\Delta_3 = 3\Delta_1$$

$$\Delta_3 = \frac{9mg}{5\,k}$$

$$\Delta_{mass} = \frac{9\,mg}{5\,k} + \frac{mg}{k}$$

$$\Delta_{mass} = 14\frac{mg}{5k}$$

$$\omega_n = \sqrt{\frac{9}{\Delta}}$$

$$\omega_n = \sqrt{\frac{5k}{14\,m}} = \sqrt{\frac{5 \times 10^3 \times 20}{14 \times 10}}$$

$$\omega_n = 26.72\ \text{rad/s}$$

38. **[Ans. *]Range: 282500 to 283000**

$$\text{Here } J = 2 \times \frac{t \times l^3}{12} = \frac{tl^3}{6}$$

$$\frac{T}{J} = \frac{\tau}{r} \Rightarrow \frac{T \times \frac{l}{2}}{t \times \frac{l^3}{6}} = \left(\frac{3T}{tl^3}\right)$$

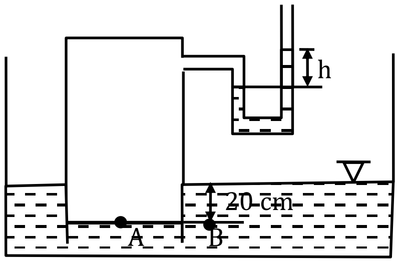
Maximum shear stress occurs at throat

$$\tau_{max} = \frac{3T}{0.707hl^3} = 80\ \text{MPa}$$

$$\Rightarrow T = 282.8 \times 10^3\ \text{Nm}$$

$$= 282800\ \text{Nm}$$

39. **[Ans. *]Range: 9.00 to 9.800**



$P_A = P_B$ (They are on the same horizontal line in the same fluid)

$P_B = P_O + \rho_W gh_W$

$\Rightarrow P_B - P_O + \rho_W g h_W$

$[P_{abs} - P_{atm} = P_{gage}]$

$\Rightarrow P_{gage,\ air} = P_A - P_O = P_B - P_O = 1000 \times 9.81 \times \frac{20}{100}$

$= 1962$ Pa

$P_A - \rho_{manometer} gh = P_O$

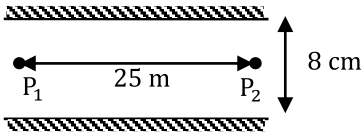
$\Rightarrow P_A - P_O = \rho_{manometer}\, gh$

$\Rightarrow 1962 = [1000 \times 2.1] \times 9.81 \times h$

$\left[S.G = \frac{\rho_{manometr}}{\rho_{water}}\right]$

$\therefore h = \frac{1962}{2100 \times 9.81} = 0.0950 = 9.50$ cm

40. **[Ans. *]Range: 91.000 to 95.000**



For laminar flow between two parallel plates

$P_1 - P_2 = \frac{8\,\mu V_{max} l}{b^2}$

$l = 25m$

$b = 8 \text{ cm} = \frac{8}{100}$ m

$\mu = 2$ Pa.s

$P_1 - P_2 = \frac{12 \times 2 \times 1.5 \times 25}{(0.08)^2} = 93750$ Pa

$\therefore P_1 - P_2 = 93.750$ kPa

41. **[Ans. *]Range: 0.6 to 0.9**

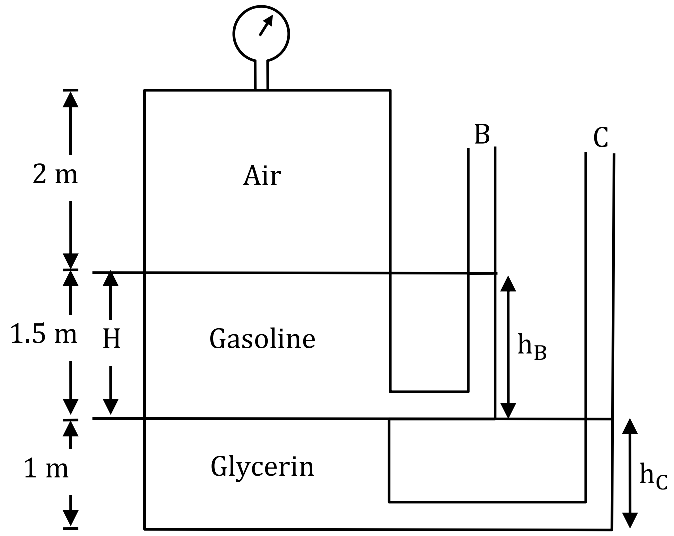
By hydrostatic law (for B)

$P_A + \rho_{air}\, g \times 2 = \rho_B g\, h_B$

$\Rightarrow h_B = \dfrac{P_A + 2g\,\rho_{air}}{g\rho_{gasoline}}$

$= \dfrac{1.5 \times 10^3 + 2 \times 9.81 \times 1.2}{9.81 \times 667}$

$= 0.2328 \text{ m}$



Similarly for C

$P_A + \rho_{air}\, g \times g \times 2 + \rho_{gasoling} \times g \times 1.5 = \rho_c \times g \times h_c$

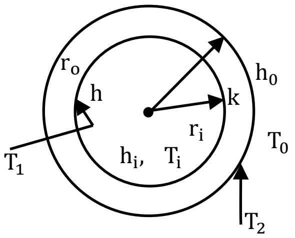
$\Rightarrow h_c = \dfrac{P_A + 1.2 \times 9.81 \times 2 + 667 \times 9.81 \times 1.5}{1236 \times 9.81}$

$= \dfrac{1500 + 23.544 + 9814.9}{1236 \times 9.81} = 0.935$

$H = (1 + 1.5 + h_B) - (1 + h_c)$

$= 0.7978 \text{ m}$

42. **[Ans. *]Range: 298 to 302**



$$\dot{Q} = \frac{T_i - T_o}{\frac{1}{h_i A_i} + \frac{1}{2\pi k L}\ln\frac{r_o}{r_i} + \frac{1}{h_o A_o}}$$

$$U_i = \frac{1}{\frac{1}{h_i} + \frac{r_i}{k}\ln\frac{r_o}{r_i} + \frac{1}{h_o}\times\frac{r_i}{r_o}}$$ (Inner overall heat transfer coefficient)

$$U_o = \frac{1}{\frac{r_o}{r_i}\times\frac{1}{h_i} + \frac{r_o}{k}\ln\frac{r_o}{r_i} + \frac{1}{h_o}}$$ (outer overall heat transfer coefficient)

$$r_i = \frac{D_i}{2} = \frac{25}{2} = 12.5 \text{ mm}$$

$$r_o = \frac{D_o}{2} = \frac{30}{2} = 15 \text{ mm}$$

So, the tube is thin walled i.e., the resistance to conduction can be neglected.

$$U_i = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o}\times\frac{r_i}{r_o}} \qquad U_o = \frac{1}{\frac{r_o}{r_i}\times\frac{1}{h_i} + \frac{1}{h_o}}$$

$$\Rightarrow U_i = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o}\frac{2r_i}{2r_o}} \qquad \Rightarrow U_o = \frac{1}{\frac{2r_o}{2r_i}\frac{1}{h_i} + \frac{1}{h_o}}$$

$$\Rightarrow U_i = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o}\times\frac{D_i}{D_o}} \qquad \Rightarrow U_o = \frac{1}{\frac{D_o}{D_i}\times\frac{1}{h_i} + \frac{1}{h_o}}$$

$$\Rightarrow 360 = \frac{1}{\frac{D_i}{D_o}\left[\frac{1}{h_i}\times\frac{D_o}{D_i} + \frac{1}{h_o}\right]} \qquad \therefore \frac{D_o}{D_i}\times\frac{1}{h_i} + \frac{1}{h_o} = \frac{1}{U_o}$$

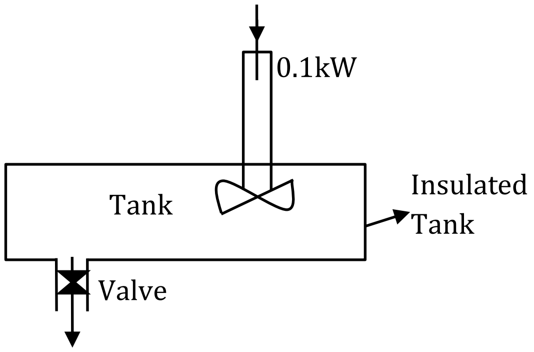
$$\Rightarrow 360 = \frac{1}{\frac{D_i}{D_o}\times\frac{1}{U_o}}$$

$$\Rightarrow \frac{D_i}{D_o}\times\frac{1}{U_o} = \frac{1}{360}$$

$$\therefore U_o = \frac{D_i}{D_o}\times 360$$

$$= \frac{25}{30}\times 360 = 300 \text{ w/m}^2\,°\text{C}$$

43. **[Ans. *]Range: 0.8 to 0.9**



Energy balance equation for the control volume

$$\frac{dE_{cv}}{dT} = \frac{dw}{dt} - h_p \frac{dm}{dt}$$

$h_p \rightarrow$ Exist enthalpy of sir

Since, there is no change in internal energy of air in the tank.

$$h_p \frac{dm}{dt} = \frac{dw}{dt}$$

Where,

$h_p = u + P_v$

$u = 0 \text{ at } t = 0k = -273^\circ C$

$u = u_o + 0.718t$

$0 = u_o + 0.718(-273)$

$u_o = 0.718(273) kJ/kg$

$u = 0.718(273 + t)\ kJ/kg$

$h_p = 0.718(273 + t) + 0.287(t + 273)$

$h_p = 1.005(t + 273)$

At 150°C $\Rightarrow h_p = 425\ kJ/kg$

$$\frac{dm}{dt} = \frac{1}{h_p}\frac{dw}{dt} = \frac{(0.1)\ kJ/s}{425\ kJ/kg}$$

$= 0.236 \times 10^{-3} kg/s$

$m = 0.845\ kg/h$

44. **[Ans. *]Range: 10 to 11**

$P_1 V_1^n = P_2 V^n = P_3 V_3^n$

$$n = \frac{\ln(P_1/P_2)}{\ln(V_2/V_1)} = \frac{\ln(100/37.9)}{\ln(0.2/0.1)} = 1.4$$

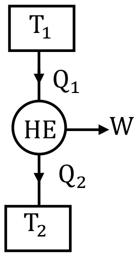
$$n = \frac{\ln(P_2/P_3)}{\ln(V_3/V_2)} = \frac{\ln(37.9/14.4)}{\ln(0.4/0.2)} = 1.4$$

Here expansion process PV^n = Constant and n = 1.4 and for closed system the polytropic work is

$$W_n = \frac{P_1 V_1 - P_2 V_2}{n - 1}$$

$= 10.6$ kJ

45. **[Ans. A]**



Heat to be radiated = Q_2

$Q_2 \propto AT_2^4$

$Q_l = \sigma AT_2^4$

Since the engine is reversible

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2} \Rightarrow Q_1 = \frac{Q_2 T_1}{T_2}$$

$$WD = Q_1 - Q_2 = \frac{Q_2 T_1}{T_2} - Q_2$$

$$WD = Q_2\left(\frac{T_1 - T_2}{T_2}\right)$$

$$Q_2 = \frac{(WD)T_2}{T_1 - T_2}$$

$$\sigma AT_2^4 = \frac{(WD)T_2}{T_1 - T_2} \Rightarrow A = \frac{(WD)T_2}{\sigma T_2^4 (T_1 - T_2)}$$

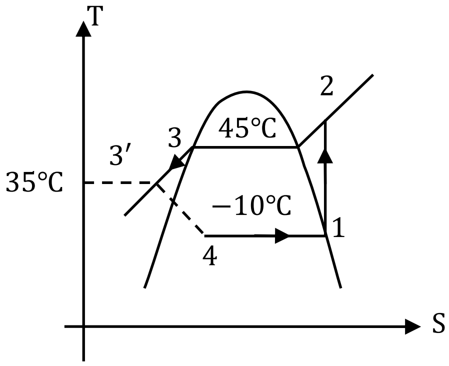
$$A = \frac{WD}{\sigma}\left[\frac{1}{T_1 T_2^3 - T_2^4}\right]$$

For minimum area:

$$\frac{dA}{dT_2} = 0 \quad [\text{For given WD and } T_1]$$

$$\Rightarrow \frac{T_2}{T_1} = \frac{3}{4} \Rightarrow T_2 = \left(\frac{3}{4}\right) T_1$$

46. **[Ans. *] Range: 1.5 to 1.7**



$S_1 = S_2$ [Process 1-2: Reversible adiabatic process]

$\text{at} - 10°C = 1.762\ \text{kJ/kg.K}$

$S_{g1} = S_{g2} + C_{pv} \ln\left(\frac{T_{sup2}}{T_{sat2}}\right)$

$(C_P)_v = 1.061\ \text{kJ/kg/K}$

$h_1 = h_{g1} = 460.7\ \text{kJ/kg}$

$h_2 = h_{g_2} + (C_P)_v(T_{sup2} - T_{sat2}) = 550.4\ \text{kJ/kg}$

$h_3 = h_{f_2} = 133\ \text{kJ/kg}$

$h_3' = h_3 - Cpv\,(45 - 35) = 116.8\ \text{kJ/kg}$

Actual volume flow rate of refrigerant, $V = A \times l_s \times \frac{N}{60} \times \eta_\omega = 0.2316\ m^3/\text{min}$

Mass flow rate $(\dot{m}) = \frac{V}{V_{g_1}} = \frac{0.2316}{0.233} = 0.994\ \text{kg/min}$

Capacity of the plant $= \frac{\dot{m}_R(h_1 - h_3')}{210} = 1.62\ \text{TR}$

47. **[Ans. B]**

48. **[Ans. C]**

When jet interacts with the air around as it flares out. Initially it remains straight up to certain value (Say 5 mm) after then it flares thus reducing depth of penetration.

49. **[Ans. B]**

Statement 2 is wrong:

Eutectic alloys constitute an exception to the general process by which alloys solidify. A eutectic alloy is a particular composition in an alloy system for which solidus and liquids are at the same temperature, Hence solidification occurs at constant temperature.

50. **[Ans. D]**

In point to point operations like drilling cutter diameter compensation does not come into the picture.

Drilling can be done on CNC machine with contouring or continuous control system because such also carry point to point operations.

∴ Cutter diameter compensation not required is correct.

51. **[Ans. *] Range: 34 to 35**

As per Taylor's tool life equation

$VT^n = C$

$V_1T_1^n = C$

$V_2T_2^n = C$

$V_1 = 30\text{ m/min}, T_1 = 60\text{ min}$

$V_2 = 60\text{ m/min}, T_2 = 2\text{min}$

$V_1T_1^n = V_2T_2^n$

Taking log on both sides

$\log V_1 + n\log T_1 = \log V_2 + n\log T_2$

$$\Rightarrow n = \frac{\log\left(\frac{V_2}{V_1}\right)}{\log\left(\frac{T_1}{T_2}\right)} = 0.203$$

$\therefore C = VT^n = (30)(60)^{0.203} = 68.878$

now for

$T = 30\text{ min}, V = ?$

$V(30)^{0.203} = 68.878$

$V = 34.532\text{ m/min}$

52. **[Ans. *]Range: 3.0 to 3.4**

$$MRR = \frac{AI}{\rho ZF}\text{ in CC/s}$$

But in question it is asked in g/s

$$\therefore MRR = \frac{AI}{ZF}\text{ in g/s}$$

$$= \frac{63 \times 5000}{96500 \times 1} = 3.264\text{ g/s}$$

53. **[Ans. C]**

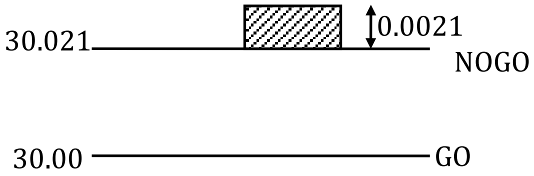
Hole basic size =30 mm

LL of H hole = basic size=30 mm

$D = \sqrt{18 \times 30} = 23.24$ mm

$i = 0.45\sqrt[3]{23.24} + 0.001 \times 23.24 = 1.3074$ microns

Tolerance 1T7=16i=20.918 microns=21 microns=0.021 mm



UL of NOGO plug gauge =30.021+0.0021=30.0231 mm

LL of NOGO plug gauge =30.021 mm

Gauge tolerance =10% of work tolerance =0.0021

54. **[Ans. A]**

Given data

D=15000

$C_o = ₹6.50$

$C_c = 0.25\ p$

The EOQ values are calculated

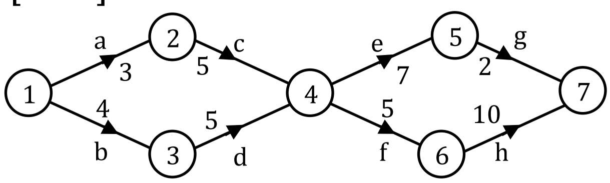
$$EOQ_{(2.50)} = \sqrt{\frac{2DC_o}{C_c}} = \sqrt{\frac{2 \times 15000 \times 6.50}{0.25 \times 2.50}} = 558.57$$

$$EOQ_{(2.30)} = \sqrt{\frac{2DC_o}{C_c}} = \sqrt{\frac{2 \times 15000 \times 6.50}{0.25 \times 2.30}} = 582.35 \text{ (lies in range)}$$

$$EOQ_{(2.00)} = \sqrt{\frac{2DC_o}{C_c}} = \sqrt{\frac{2 \times 15000 \times 6.50}{0.25 \times 2}} = 624.50 \text{ (lies in range)}$$

For 624.50 wires, unit price is less. Hence it is an optional quantity

55. **[Ans. A]**



The paths and duration are given below

$a \to c \to e \to g = 3 + 5 + 7 + 2 = 17$ days

$a \to c \to f \to h = 3 + 5 + 5 + 10 = 23$ days

$b \to d \to e \to g = 4 + 5 + 7 + 2 = 18$ days

$b \to d \to f \to h = 4 + 5 + 5 + 10 = 24$ days

Hence, critical path is $b \to d \to f \to h$