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GATE - 2021

Questions with Detailed Solutions

MECHANICAL ENGINEERING

(Forenoon Session)

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GATE - 2021 MECHANICAL ENGINEERING
Questions with Detailed Solutions

Forenoon Session

SUBJECT-WISE WEIGHTAGE

S. No.	NAME OF THE SUBJECT	No. of QUESTIONS
01	Engineering Mechanics	2
02	Strength of Material	4
03	Theory of Machines & Vibrations	6
04	Machine Design	4
05	Fluid Mechanics & Turbo Machinery	4
06	Heat Transfer	4
07	Thermodynamics	8
08	IM & OR	4
09	Production	10
10	Engineering Materials	1
11	Engineering Mathematics	8
12	Verbal Ability	3
13	Numerical Ability	7
Total No. of Questions		**65**

Section : General Aptitude

01. "The increased consumption of leafy vegetables in the recent months is a clear indication that the people in the state have begun to lead a healthy lifestyle"

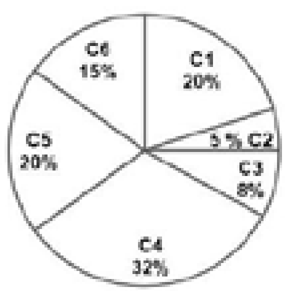
Which of the following can be logically inferred from the information presented in the above statement?

(a) Consumption of leafy vegetables may not be the only indicator of healthy lifestyle
(b) The people in the state have increased awareness of health hazards causing by consumption of junk foods
(c) The people in the state did not consume leafy vegetables earlier
(d) Leading a healthy lifestyle is related to a diet with leafy vegetables

Ans: (d)

Sol: One can clearly infer that eating leafy vegetables undoubtely lead a healthy life style.

02.



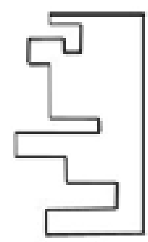
Company	Ratio
C1	3:2
C2	1:4
C3	5:3
C4	2:3
C5	9:1
C6	3:4

The distribution of employees at the rank of executives, across different companies C1, C2, ... C6 is presented in the chart given above. The ratio of executives with a management degree to those without a management degree in each of these companies is provided in the table above. The total number of executives across all companies is 10,000. The total number of management degree holders among the executives in companies C2 and C5 together is ________.

(a) 225 (b) 600
(c) 2500 (d) 1900

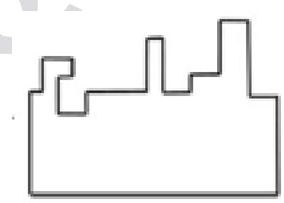
Ans: (d)

03.

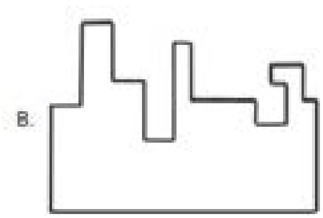


A jigsaw puzzle has 2 pieces. One of the pieces is shown above. Which one of the given options for the missing piece when assembled will form a rectangle? The piece can be moved, rotated or flipped to assemble with the above piece.

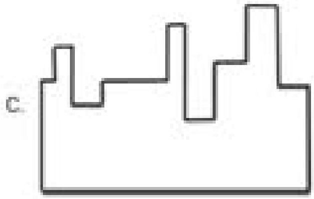
(a)



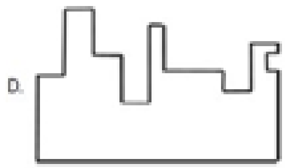
(b)



(c)



(d)



Ans: (b)

04. Oxpeckers and rhinos manifest a symbiotic relationship in the wild. The oxpeckers warn the rhinos about approaching poachers, thus possibly saving the lives of the rhinos. Oxpeckers also feed on the parasitic ticks found on rhinos.
In the symbiotic relationship described above, the primary benefits for oxpeckers and rhinos respectively are,
(a) Oxpeckers save the lives of poachers, rhinos save their own lives.
(b) Oxpeckers save their habitat from poachers while the rhinos have no benefit.
(c) Oxpeckers get a food source, rhinos have no benefit.
(d) Oxpeckers get a food source, rhinos may be saved from the poachers.

Ans: (d)

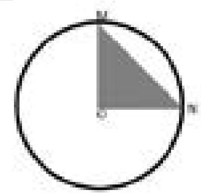
Sol: Oxpeckers feed on the parasitic ticks found on rhinos. They warn rhinos about approaching poachers.

05.
$$\text{If}\begin{cases} "\oplus" \text{ means } "-", \\ "\otimes" \text{ means } "\div", \\ "\Delta" \text{ means } "+", \\ "\nabla" \text{ means } "\times", \end{cases}$$
then, the value of the expression $\Delta 2 \oplus 3 \Delta ((4 \otimes 2) \nabla 4)$ =

(a) 7 (b) 6
(c) –1 (d) –0.5

Ans: (a)

06.



In the above figure, O is the center of the circle and, M and N lie on the circle.
The area of the right triangle MON is 50 cm^2.
What is the area of the circle in cm^2?
(a) 100 π (b) 2 π
(c) 50 π (d) 75 π

Ans: (a)

07. Consider the following sentences:
(i) After his surgery, Raja hardly could walk.
(ii) After his surgery, Raja could barely walk.
(iii) After his surgery, Raja barely could walk.
(iv) After his surgery, Raja could hardly walk.
Which of the above sentences are grammatically CORRECT?
(a) (i) and (iii) (b) (ii) and (iv)
(c) (iii) and (iv) (d) (i) and (ii)

Ans: (b)

Sol: When you say you could hardly do something, you are emphasing that it is very difficult for you to do it. Could + Adverb + Verb1.

08. Five persons P, Q, R, S and T are sitting in a row not necesarily in the same order. Q and R are separated by one person, and S should both be seated adjacent to Q.

The number of distinct seating arrangements possible is:

(a) 8 (b) 4

(c) 10 (d) 16

Ans: (a)

09. Ms. X came out of a building through its front door to find her shadow due to the morning sun falling to her right side with the building to her back. From this, it can be inferred that building is facing _____

(a) South (b) West

(c) North (d) East

Ans: (a)

10. The number of hens, ducks and goats in farm P are 65, 91 and 169, respectively. The total number of hens, ducks and goats in a nearby farm Q is 416. The ratio of hens: ducks: goats in farm Q is 5:14:13. All the hens, ducks and goats are sent from farm Q to farm P.

The new ratio of hens:ducks:goats in farm P is ______

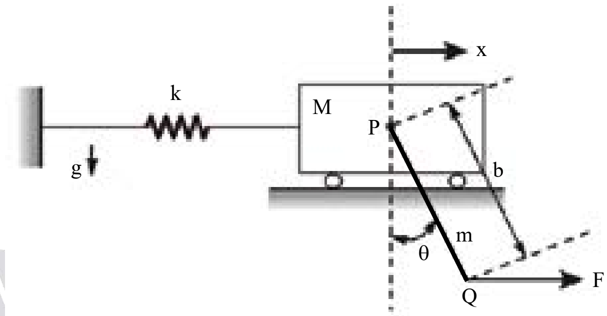
(a) 5:14:13 (b) 10:21:26

(c) 5:7:13 (d) 21:10:26

Ans: (b)

Section : MECHANICAL ENGINEERING

01. Consider a two degree of freedom system as shown in the figure, where PQ is a rigid uniform rod of length, b and mass, m.



Assume that the spring deflects only horizontally and force F is applied horizontally at Q. For this system, the Lagrangian, L is

(a) $\frac{1}{2}M\dot{x}^2+\frac{1}{2}mb\dot{\theta}\dot{x}\cos\theta+\frac{1}{6}mb^2\dot{\theta}^2-\frac{1}{2}kx^2$

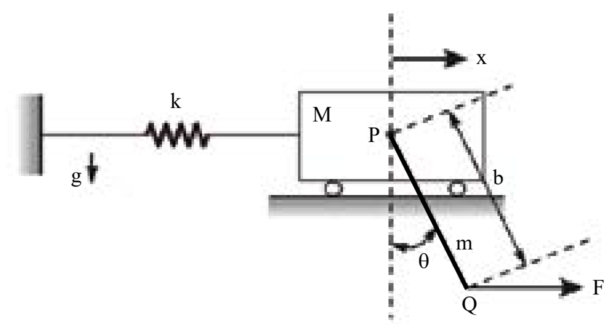
(b) $\frac{1}{2}M\dot{x}^2+\frac{1}{2}mb\dot{\theta}\dot{x}\cos\theta+\frac{1}{6}mb^2\dot{\theta}^2-\frac{1}{2}kx^2+mg\frac{b}{2}\cos\theta+Fb\sin\theta$

(c) $\frac{1}{2}(M+m)\dot{x}^2+\frac{1}{2}mb\dot{\theta}\dot{x}\cos\theta+\frac{1}{6}mb^2\dot{\theta}^2-\frac{1}{2}kx^2+mg\frac{b}{2}\cos\theta$

(d) $\frac{1}{2}(M+m)\dot{x}^2+\frac{1}{6}mb^2\dot{\theta}^2-\frac{1}{2}kx^2+mg\frac{b}{2}\cos\theta$

01. Ans: (c)

Sol:



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1) PE of spring $= \frac{1}{2}k.x^2$

2) KE of block $= \frac{1}{2}\times M\times \dot{x}^2$

3) KE of rod:

Mass of element, $dm = m\times\frac{dy}{b}$

$$KE = \frac{1}{2}dm\times v^2 = \frac{1}{2}\times dm\times\left\{v_x^2+v_y^2\right\}$$

$$v_x = \dot{x}_1 = \frac{d}{dt}\{x_1\} = \frac{d}{dt}\{x+y\sin\theta\}$$

$$\therefore \quad v_x = \dot{x}+y\times\cos\theta\times\dot{\theta}$$

$$v_y = \frac{d}{dt}(y_1) = \frac{d}{dt}(y\cos\theta) = -y\sin\theta\times\dot{\theta}$$

$$\therefore \quad \text{KE of rod} = \int\frac{1}{2}.dm\times v^2$$

$$= \int\frac{1}{2}\times m\times\frac{dy}{b}\times\left\{\left(\dot{x}+y\cos\theta\times\dot{\theta}\right)^2+\left(-y\sin\theta\times\dot{\theta}\right)^2\right\}$$

$$\therefore = \frac{m}{2b}\int_0^b\left\{\dot{x}^2+y^2\times\dot{\theta}^2+2\times\dot{x}\times y\times\dot{\theta}\times\cos\theta\right\}dy$$

$$\therefore \; = \frac{m}{2b}\times\left\{\dot{x}^2\times b+\dot{\theta}^2\times\frac{b^3}{3}+\dot{x}\times\dot{\theta}\times\cos\theta\times b^2\right\}$$

$$\therefore = \frac{1}{2}m\dot{x}^2+\frac{1}{6}m\times\dot{\theta}^2\times b^2+\frac{1}{2}\times m\times\dot{x}\times\dot{\theta}\times\cos\theta\times b$$

$$\text{PE of rod} = \int -g\times y_1\times dm$$

$$= \int_0^b -g\times y\times\cos\theta\times m\times\frac{dy}{b}$$

$$= -\frac{1}{2}\times m\times b\times\cos\theta\times g$$

$\therefore$ PE = PE of spring + PE of rod

$$PE = \frac{1}{2}k.x^2+\left\{-\frac{1}{2}\times m\times g\times b\times\cos\theta\right\}$$

KE = KE of block + KE of rod

$$\therefore \quad KE = \frac{1}{2}\times M\times\dot{x}^2+\frac{1}{2}m\dot{x}^2+\frac{1}{6}m\times\dot{\theta}^2\times b^2+\frac{1}{2}\times m\times\dot{x}\times\dot{\theta}\times\cos\theta\times b$$

$\therefore$ Lagrange $L = KE - PE$

$$= \frac{1}{2}\{m+M\}\times\dot{x}^2+\frac{1}{6}m\times\dot{\theta}^2\times b^2+\frac{1}{2}\times m\times\dot{x}\times\dot{\theta}\times\cos\theta\times b-\frac{1}{2}k.x^2+\frac{1}{2}\times m\times b\times\cos\theta\times g$$

02. Consider a binomial random variable X. If $X_1, X_2, \ldots, X_n$ are independent and identically distributed samples from the distribution of X with sum $Y = \Sigma_{i=1}^{n} X_i$, then the distribution of Y as $n\to\infty$ can be approximated as

(a) Exponential (b) Binomial
(c) Bernoulli (d) Normal

02. Ans: (d)

03. A single jet Pelton wheel operates at 300 rpm. The mean diameter of the wheel is 2 m. Operating head and dimensions of jet are such that water comes out of the jet with a velocity of 40 m/s and flow rate of 5 m³/s. The jet is deflected by the bucket at an angle of 165°. Neglecting all losses, the power developed by the Pelton wheel is _______ MW (round off to two decimal places)

03. Ans: (2.65)

Sol: Given data:

Pelton wheel

$N = 300$ rpm, $D = 2$ m, $V = 40$ m/s

$Q = 5\ m^3/s$, $\theta = 180 - 165 = 15°$

The bucket speed (u) is given by

$$u = \frac{\pi DN}{60} = \frac{\pi\times 2\times 300}{60} = 31.4\ m/s$$

The power developed by the rotor (R.P) is given by

$$R.P = \rho Q(V-u)(1+K\cos\theta)\times u$$

$= 1000 \times 5\ (40 - 31.4) \times (1+\cos15)$

$= 2.65$ MW

04. A pressure measurement device fitted on the surface of a submarine, located at a depth H below the surface of an ocean, reads an absolute pressure of 4.2 MPa. The density of sea water is 1050 kg/m^3, the atmospheric pressure is 101 kPa, and the acceleration due to gravity is 9.8 m/s^2. The depth H is _____ m (round off to the nearest integer).

04. Ans: (398)

Sol: By hydrostatic law,

$P = P_{atm} + \rho gh$

$4.2 \times 10^6 = 101 \times 10^3 + 1050 \times 9.8 \times h$

$\Rightarrow h = 398$ m

05. The relative humidity of ambient air at 300 K is 50% with a partial pressure of water vapour equal to p_v. The saturation pressure of water at 300 K is p_{sat}. The correct relation for the air-water mixture is

(a) $p_v = 2p_{sat}$ (b) $p_v = 0.622p_{sat}$

(c) $p_v = p_{sat}$ (d) $p_v = 0.5p_{sat}$

05. Ans: (d)

Sol: We know

$\phi = 0.5$ (given)

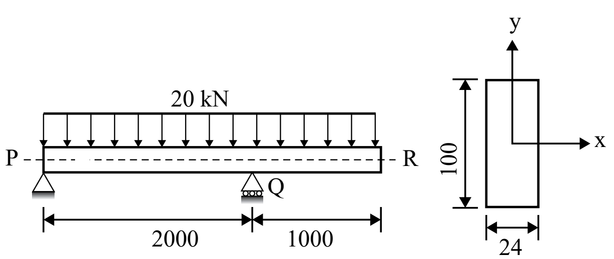
$\phi = \dfrac{p_v}{p_{v_s}}$ (where p_{vs} is p_{sat} at 300 K)

$0.5 = \dfrac{p_v}{p_{sat}}$

$p_v = 0.5\ p_{sat}$

06 An overhanging beam PQR is subjected to uniformly distributed load 20 kN/m as shown in the figure.

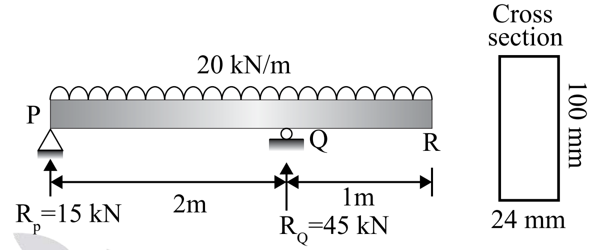
Beam Cross-section

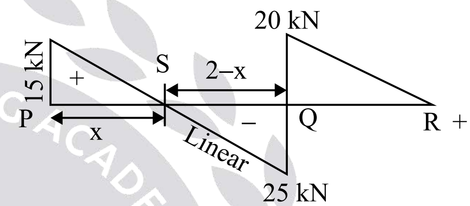


The maximum bending stress developed in the beam is _____ MPa (round off to one decimal place).

06. Ans: (250)

Sol:





SFD

$R_P + R_Q = 60$ kN

$\Sigma M_P = 0$

$(20 \times 3)(1.5) - R_Q \times 2 = 0$

$R_Q = 45$ kN

$R_P = 15$ kN

Location of 'S' :

From similar triangles

$\dfrac{15}{x} = \dfrac{25}{2-x}$

$6 - 3x = 5x$

$x = \dfrac{3}{4}\text{m} = 0.75$ m

Bending moment calculation,

$(B.M)_P = (B.M)_R = 0$

$(B.M)_S = M_S - M_P = \dfrac{1}{2} \times 0.75 \times 15 = 5.625$ kN − m

$(B.M)_Q = (-20 \times 1) \times 0.5 = -10$ kN-m (Maximum)

Maximum Bending moment = $(B.M)_Q = -10$ kN-m

$(\sigma_{bending})_{max} = \dfrac{(B.M)_{max}}{Z_{N.A}}$

$= \dfrac{6M}{bd^2} = \dfrac{6 \times 10 \times 10^6}{24 \times 100^2} = 250$ MPa

$\therefore (\sigma_{bending})_{max} = 250$ MPa

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Regular	Daily 6 to 8 Hours	**2nd & 17th April 2021**	9 to 10 Months	Kukatpally (EC, EE) Abids (CE, ME)
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Spark	Daily 6 to 8 Hours	**17th May 2021**	9 to 10 Months	Kukatpally (EC, EE) Abids (CE, ME)
		1st & 17th June 2021		

07. Consider a steam power plant operating on an ideal reheat Rankine cycle. The work input to the pump is 20 kJ/kg. The work output from the high pressure turbine is 750 kJ/kg. The work output from the low pressure turbine is 1500 kJ/kg. The thermal efficiency of the cycle is 50%. The enthalpy of saturated liquid and saturated vapour at condenser pressure are 200 kJ/kg and 2600 kJ/kg, respectively. The quality of steam at the exit of the low pressure turbine is ______ % (round off to the nearest integer).

07. Ans: (93)

Sol: Given:

$W_p = 20$ kJ/kg

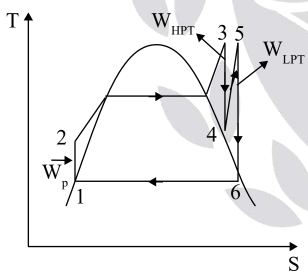
$W_{HPT} = 750$ kJ/kg

$W_{LPT} = 1500$ kJ/kg

$\eta = 50\%$

At condenser pressure

$h_f = 200$ kJ/kg, $h_g = 2600$ kJ/kg



$W_{net} = (W_{HPT} + W_{LPT}) - W_P$

$= (1500+750) - 20$

$= 2230$ kJ/kg

$\eta = 0.5 = \frac{W_{net}}{q_{in}} = \frac{2230}{q_{in}}$

$q_{in} = 4460$ kJ/kg

$W_{net} = q_{in} - q_R$

$q_R = 2230$ kJ/kg

$q_R = 2230 = h_6 - h_1$

$h_1 = h_f$ @ condenser pressure

$h_1 = 200$ kJ/kg

$2230 = h_6 - 200$

$h_6 = 2430$ kJ/kg

$h_6 = h_f + x_6 (h_g - h_f)$ @ condenser pressure

$2430 = 200 + x_6 (2600 - 200)$

$\Rightarrow x_6 = 0.929$

$\Rightarrow x_6 = 0.93 \approx 93\%$

08. Robot Ltd. wishes to maintain enough safety stock during the lead time period between starting a new production run and its completion such that the probability of satisfying the customer demand during the lead time period is 95%. The lead time period is 5 days and daily customer demand can be assumed to follow the Gaussian (normal) distribution with mean 50 units and a standard deviation of 10 units. Using $\phi^{-1}(0.95) = 1.64$, where ϕ represents the cummulative distribution function of the standard normal random variable, the amount of safety stock that must be maintained by Robot Ltd. to achieve this demand fulfillment probability for the lead time period is ____ units (round off to two decimal places).

08. Ans: (36.67)

Sol: For 95% service level, Z = 1.64

Lead time (LT) = 5 days

Average demand = 50 units

Demand standard deviation, $\sigma_D = 10$ units

Safety stock = $Z\,\sigma_L$

σ_L = standard deviation of demand during lead time

$= \sigma_D \sqrt{LT}$

$= 10\sqrt{5} = 22.36$

Safety stock = $1.64 \times 22.36 = 36.67$ units

AST

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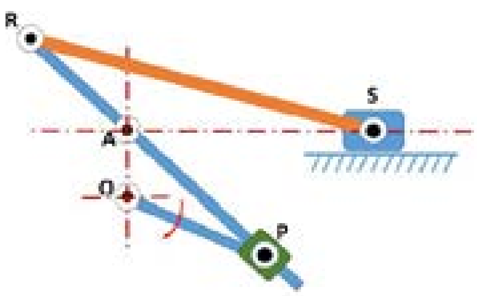
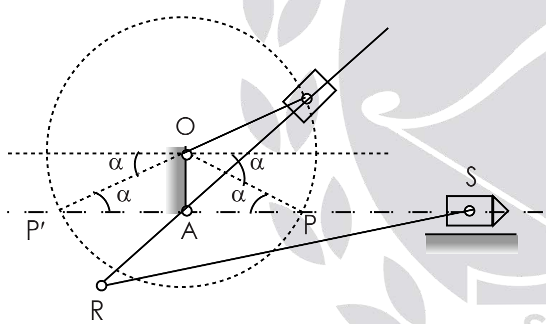
09. The Whitworth quick return mechanism is shown in the figure with link lengths as follows: OP = 300 mm, OA = 150 mm, AR = 160 mm, RS = 450 mm.



The quick return ratio for the mechanism is ____ (round off to one decimal place).

09. Ans: (2)

Sol:



Whitworth Quick return mechanism

$$\sin\alpha = \frac{\text{fixed link length}}{\text{crank radius}}$$

$$= \frac{OA}{OP} = \frac{150}{300} = \frac{1}{2}$$

$$\alpha = 30^\circ$$

$$QRR = \frac{180+2\alpha}{180-2\alpha} = \frac{180+2\times30^\circ}{180-2\times30^\circ} = 2$$

10. The Dirac-delta function ($\delta(t-t_0)$ for t, $t_0 \in R$, has the following property

$$\int_a^b \varphi(t)\delta(t-t_0)dt = \begin{cases} \varphi(t_0) & a \quad t_0 \quad b \\ 0 & \text{otherwise} \end{cases}$$

The Laplace transform of the Dirac-delta function $\delta(t-a)$ for $a > 0$; $L(\delta(t-a)) = F(s)$ is

(a) e^{sa} (b) e^{-sa}

(c) ∞ (d) 0

10. Ans: (b)

Sol: Dirac delta function $\delta(t-a)$ is given by

$$\delta(t-a) = \lim_{\in\to0}\begin{cases} \frac{1}{\in}, a \le t \le a+\in \\ 0, \text{otherwise} \end{cases}$$

$$\because L\{f(t)\} = \int_0^\alpha e^{-st}.f(t)dt$$

$$\Rightarrow L\{\delta(t-a)\} = \lim_{\in\to0}\left(\int_0^\alpha e^{-st}.\delta(t-a)dt\right)$$

$$\Rightarrow \begin{aligned} &L\{\delta(t-a)\} \\ &= \lim_{\in\to0}\left(\int_0^a e^{-st}(0)dt + \int_a^{a+\in} e^{-st}\frac{1}{\in}dt + \int_{a+\in}^{\alpha} e^{-st}.(0)dt\right)\end{aligned}$$

$$\Rightarrow L\{\delta(t-a)\} = \lim_{\in\to0}\left(\int_a^{a+\in} e^{-st}.\frac{1}{\in}dt\right)$$

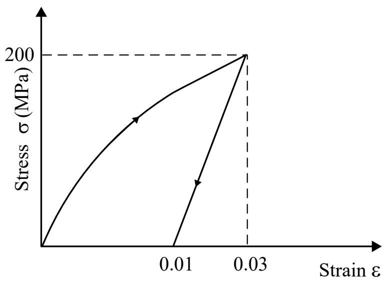
$$= \lim_{\in\to0}\left(\frac{e^{-st}}{-s\in}\right)_a^{a+\in}$$

$$= \lim_{\in\to0}\left(\frac{e^{-as}-e^{-s(a+\in)}}{s\in}\right)\left(\frac{0}{0}\text{ form}\right)$$

$$= \frac{e^{-as}}{s}\lim_{\in\to0}\left(\frac{0-(-s)e^{-s\in}}{1}\right)$$

$\therefore$ L $\{\delta(t-a)\} = e^{-as}$

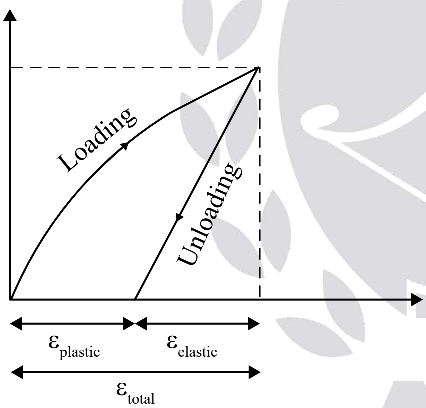
11. The loading and unloading response of a metal is shownin the figure. The elastic and plastic strains corresponding to 200 MPa stress, respectively, are



(a) 0.01 and 0.02 (b) 0.01 and 0.01
(c) 0.02 and 0.01 (d) 0.02 and 0.02

11. Ans: (c)

Sol: The loading-unloading stress strain curve is,



On comparing above curve with given curve,

Plastic strain, $\varepsilon_{plastic} = 0.01$

Elastic strain, $\varepsilon_{elastic} = 0.03 - 0.01 = 0.02$

12. Consider a single machine workstation to which jobs arrive according to a Poisson distribution with a mean arrival rate of 12 jobs/hour. The process time of the workstation is exponentially distributed with ta mean of 4 minutes. The expected number of jobs at the workstation at any given point of time is _______ (round off to the nearest integer).

12. Ans: (4)

Sol: $\lambda = 12$ /hr,

$\mu = \frac{60}{4} = 15$/hr

Length of the system = $= \frac{\lambda}{\mu - \lambda} = \frac{12}{15-12} = 4$

13. Superheated steam at 1500 kPa, has a specific volume of 2.75 m^3/kmol and compressibility factor (Z) of 0.95. The temperature of steam is ____°C (round off to the nearest integer).

(a) 249 (b) 471
(c) 522 (d) 198

13. Ans: (a)

Sol: P = 1500 kPa

v = 2.75 m^3/kmol

z = 0.95

We know, $pv = z\bar{R}T$

$1500 \times 2.75 = 0.95 \times 8.314 \times T$

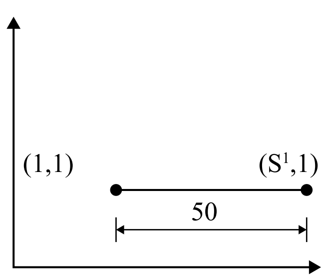
T = 522.26 K

T = 249°C

14. The XY table of a NC machine tool is to move from P(1,1) to Q(51,1); all coordinates are in mm. The pitch of the NC drive leadscrew is 1 mm. If the backlash between the leadscrew and the nut is 1.8°, then the total backlash of the table on moving from P to Q is _______ mm (round off to two decimal places).

14. Ans: (0.25)

Sol:



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Batch Type	Timings	Batch Date	Duration	Venue
Morning, Evening Batches	**6am to 8am** & **6pm to 8:30pm**	20th March 2021	8 to 10 Months	Abids, Dilsukhnagar, Kukatpally.

GATE + PSUs – 2022 & ESE + GATE + PSUs – 2022 @ DELHI

Batch Type	Timings	Batch Date	Duration	Venue
Regular Batches	Daily 5 to 6 Hours	5th March 2021	6 to 7 Months	ACE campus Saket
		7th April 2021		
		15th May 2021		
		5th June 2021		

GATE + PSUs – 2022 & ESE + GATE + PSUs – 2022 @ PUNE

Batch Type	Timings	Batch Date	Duration	Venue
Regular / Weekend Batches	Daily 5 to 6 Hours	20th March 2021	6 to 7 Months	Pune Classroom

GATE + PSUs – 2022 & 2023 @ VIZAG

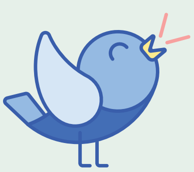
Batch Type	Timings	Batch Date	Duration	Venue
Weekend Batch	Saturday **2 pm to 8 pm** Sunday **9am to 6pm**	3rd April 2021	6 to 7 Months	Vizag Classroom

GATE + PSUs – 2022 & 2023 @ VIJAYAWADA

Batch Type	Timings	Batch Date	Duration	Venue
Weekend Batch	Saturday **2 pm to 8 pm** Sunday **9am to 6pm**	3rd April 2021	6 to 7 Months	Vijayawada Classroom

GATE + PSUs – 2022 @ TIRUPATI

Batch Type	Timings	Batch Date	Duration	Venue
Weekend Batch	Saturday **2 pm to 8 pm** Sunday **9am to 6pm**	20th March 2021	6 to 7 Months	Tirupati Classroom



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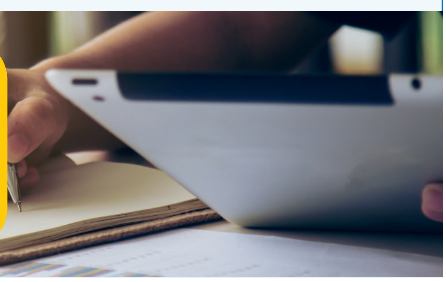


Total distance travelled = 50 mm

pitch (P) = 1 mm

Rotation (Lead screw)	**NC-table movement**
1	1 mm = P
Rotations = ?	50 mm

Rotations required = 50

Total backlash in degree = 50 × 1.8° = 90°

Rotation	**Distance**
360°	1 mm = P
90°	Rotations = ?

Backlash distance $= \frac{90^\circ}{360^\circ} = 0.25$ mm

Total Backlash distance = 0.25 mm

15. Consider fully developed, steady state incompressible laminar flow of a viscous fluid between two large parallel horizontal plates. The bottom plate is fixed and the top plate moves with a constant velocity of U = 4 m/s. Separation between the plates is 5 mm. There is no pressure gradient in the direction of flow. The density of fluid is 800 kg/m^3, and the kinematic viscosity is 1.25×10^{-4} m^2/s. The average shear stress in the fluid is _____ Pa (round off to the nearest integer).

15. Ans: (80)

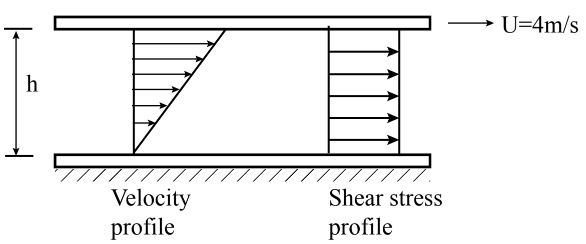
Sol: Given data:

For Couette flow with zero pressure gradient, velocity profile is linear and it is given by

$$u = \frac{U}{h}.y$$

Therefore, shear stress is constant everywhere and is equal to

$$\tau = \mu\frac{U}{h} = \frac{\rho\nu U}{h} = \frac{800\times1.25\times10^{-4}\times4}{5\times10^{-3}} = 80 \text{ Pa}$$



16. An orthogonal cutting operation is performed using a single point cutting tool with a rake angle of 12° on a lathe. During turning, the cutting force and the friction force are 1000 N and 600 N, respectively. If the chip thickness and the uncut chip thickness during turning are 1.5 mm and 0.75 mm, respectively, then the shear force is _______ N (round off to two decimal places).

16. Ans: (692.20)

Sol: Given, $\alpha_o = 12°$

$F_c = 1000$ N

$F = 600$ N

$t_c = 1.5$ mm

$t_o = 0.75$ mm

Shear force, F_s = ?

chip thickness ratio,

$$r = \frac{t_o}{t_c} = \frac{0.75}{1.5} = 0.5$$

$$\tan\phi = \frac{r\cos\alpha_o}{1 - r\sin\alpha_o}$$

$$\tan\phi = \frac{0.5\times\cos12^\circ}{1-0.5\times\sin12^\circ} \Rightarrow \phi = 28.178^\circ$$

$F_c = N\cos\alpha_o + Fin\sin\alpha_o$

$1000 = N\cos(12°) + 600\sin(12°)$

$N = 894.806$ N

$$\tan\beta = \frac{F}{N} = \frac{600}{894.806}$$

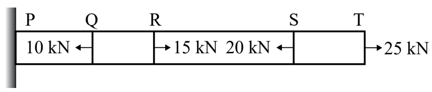
$\beta = 33.843°$

$$F_s = F_c\frac{\cos(\phi+\beta-\alpha_o)}{\cos(\beta-\alpha_o)}$$

$$F_s = 1000\times\frac{\cos(28.178^\circ+33.843^\circ-12^\circ)}{\cos(33.843^\circ-12^\circ)}$$

$F_s = 692.20$ N

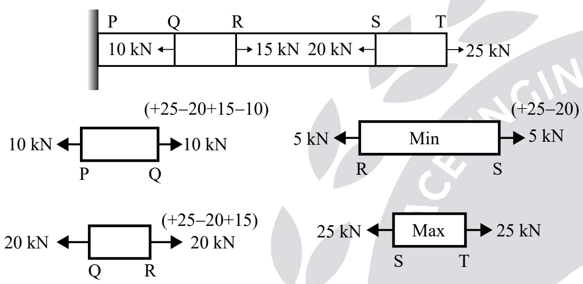
17. A prismatic bar PQRST is subjected to axial loads as shown in the figure. The segments having maximum and minimum axial stresses, respectively, are



(a) QR and RS (b) ST and PQ
(c) ST and RS (d) QR and PQ

17. Ans: (c)

Sol:



$P_{max} = P_{ST} = 25$ kN
$P_{min} = P_{RS} = 5$ kN

since given bar is prismatic,
Area = A = constant
$\therefore \sigma \propto P$
Maximum and minimum axial stresses are in ST and RS portions.

18. Let C represent the unit circle centered at origin in the complex plane, and complex variable, $z = x + iy$. The value of the contour integral $\oint_C \frac{\cosh 3z}{2z} dz$ (where integration is taken counter clockwise) is

(a) 0 (b) 2
(c) $2\pi i$ (d) πi

18. Ans: (d)

Sol: Let $I = \oint_C \frac{\cosh(3z)}{2z} dz$, where C: |z| = 1

Then $I = \oint_C \frac{\left(\frac{\cosh(3z)}{2}\right)}{[z-0]} dz$

$\Rightarrow I = 2\pi i \left(\frac{\cosh(3z)}{2}\right)_{z=0}$

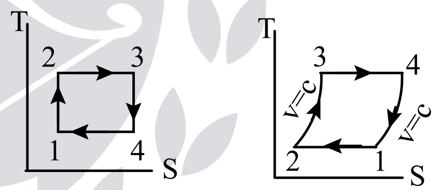
$\Rightarrow I = \pi i[\cosh(0)] \qquad \left(\because \cosh(0) = \frac{e^0 + e^0}{2} = 1\right)$

$\therefore I = \pi i$

19. In which of the following pairs of cycles, both cycles have at least one isothermal process?
(a) Brayton cycle and Rankine cycle
(b) Carnot cycle and Stirling cycle
(c) Bell-Coleman cycle and Vapour compression refrigeration cycle
(d) Diesel cycle and Otto cycle

19. Ans: (b)

Sol: Carnot cycle and Stirling cycle



Carnot Cycle Stirling Cycle

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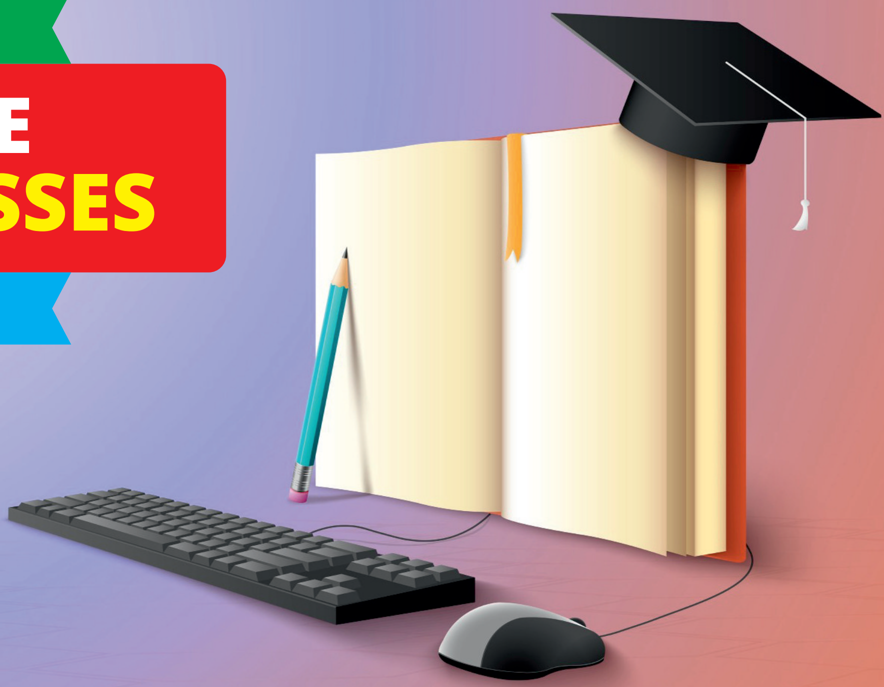

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20. The correct sequence of matching operations to be performed to finish a large diameter through hole is
(a) drilling, boring, reaming
(b) drilling, reaming, boring
(c) boring, reaming, drilling
(d) boring, drilling, reaming

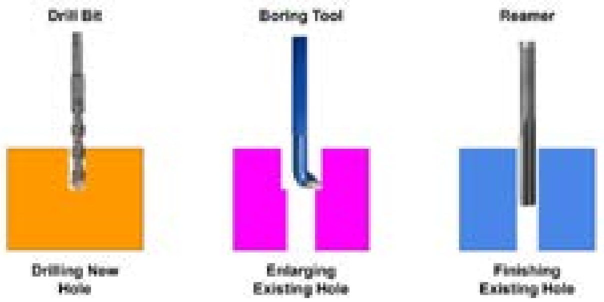
20. Ans: (a)

Sol: Drilling: to produce a hole (Fig), which then may be followed by boring it to improve its dimensional accuracy and surface finish.

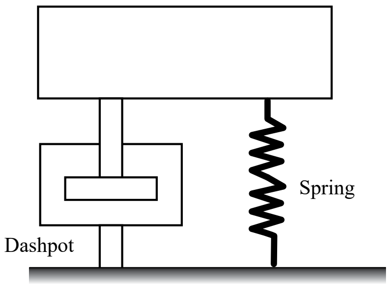
Boring: to enlarge a hole or cylindrical cavity made by a previous process or to produce circular internal grooves (Fig)

Reaming is an operation used to (a) make an existing hole dimensionally more accurate than can be achieved by drilling alone and (b) improve its surface finish. The most accurate holes in workpieces generally are produced by the following sequence of operations:

Centering $\rightarrow$ Drilling $\rightarrow$ Boring $\rightarrow$ Reaming



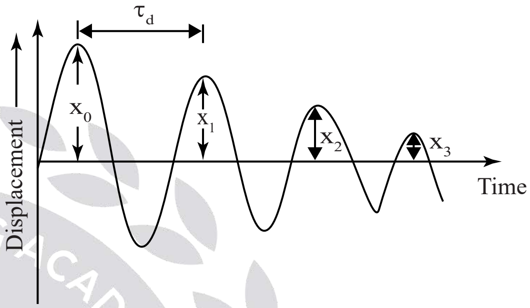
21. Consider a single degree of freedom system comprising a mass M, supported on a spring and a dashpot as shown in the figure.



If the amplitude of the free vibration response reduces from 8 mm to 1.5 mm in 3 cycles, the damping ratio of the system is ______ (round off to three decimal places).

21. Ans: (0.088)

Sol:



$x_o = 8.0$ mm

$x_3 = 1.5$ mm

$$\frac{x_o}{x_3} = \frac{x_o}{x_1} \times \frac{x_1}{x_2} \times \frac{x_2}{x_3}$$

$$= e^{\delta} . e^{\delta} . e^{\delta}$$

$$\Rightarrow \frac{x_o}{x_3} = e^{3\delta}$$

$$\Rightarrow \ln\left(\frac{x_o}{x_3}\right) = 3\delta$$

$$\delta = \frac{1}{3}\ln\left(\frac{8}{1.5}\right)$$

$$\frac{2\pi\xi}{\sqrt{1-\xi^2}} = \frac{1}{3}\ln\left(\frac{8}{1.5}\right)$$

$$\Rightarrow \xi = 0.0884$$

22. The value of $\lim\limits_{x\to 0}\left(\frac{1-\cos x}{x^2}\right)$ is

(a) 1 (b) $\frac{1}{3}$

(c) $\frac{1}{4}$ (d) $\frac{1}{2}$

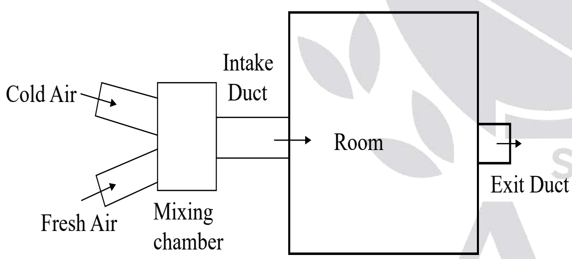
22. Ans: (d)

Sol: Let, $\ell = \lim\limits_{x\to 0}\dfrac{1-\cos(x)}{x^2}$

Then, $\ell = \lim\limits_{x\to 0}\dfrac{0+\sin(x)}{2x}$

$$\therefore \ell = \frac{1}{2}(1) = \frac{1}{2} \qquad \left(\because \lim_{x\to 0}\frac{\sin x}{x} = 1\right)$$

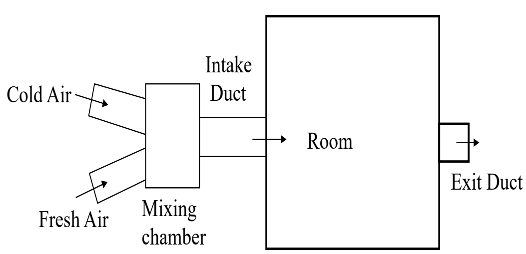
23. An air-conditioning system provides a continuous flow of air to a room using an intake duct and an exit duct, as shown in the figure. To maintain the quality of the indoor air, the intake duct supplies a mixture of fresh air with a cold air stream. The two streams are mixed in an insulated mixing chamber located upstream of the intake duct. Cold air enters the mixing chamber at 5°C, 105 kPa with a volume flow rate of 1.25 m^3/s during steady state operation. Fresh air enters the mixing chamber at 34°C and 105 kPa. The mass flow rate of the fresh air is 1.6 times of the cold air stream. Air leaves the room through the exit duct at 24°C.



Assuming the air behaves as an ideal gas wtih c_p = 1.005 kJ/kg.K and R = 0.287 kJ/kg.K, the rate of heat gain by the air from the room is ______ kW (round off to two decimal places).

23. Ans: (4.96)

Sol:



Apply ideal gas equivalent at (1) {for cold air}

$$p_1\dot{V}_1 = \dot{m}_1 RT_1$$

$$105 \times 1.25 = \dot{m}_1 \times 0.287 \times 278$$

$$\left.\begin{aligned}\dot{m}_1 &= 1.645 \text{ kg/s}\\ \dot{m}_2 &= 1.6\dot{m}_1 = 2.632\text{kg/s}\end{aligned}\right|\begin{aligned}\dot{m}_3 &= \dot{m}_1 + \dot{m}_2 = 4.277 \text{ kg/s}\\ \dot{m}_4 &= \dot{m}_3 = 4.277 \text{ kg/s}\end{aligned}$$

Energy balance in mixing chamber

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$$

$$\Rightarrow \dot{m}_1 c_p T_1 + \dot{m}_2 c_p T_2 = \dot{m}_3 c_p T_3$$

$$1.645\,(278) + 2.632\,(307) = 4.277\,\{T_3\}$$

$$\Rightarrow T_3 = 295.85 \text{ K}$$

Energy balance in Room:

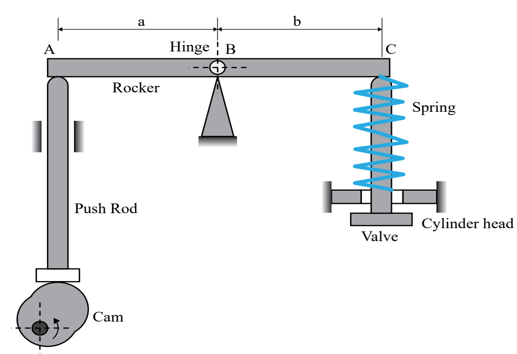
Heat gain by the air from the room $= \dot{m}_3\{h_4 - h_3\}$

$$= \dot{m}_3 c_p\{T_4 - T_3\}$$

$$= 4.277 \times 1.005\ \{297 - 295.85\}$$

$$\dot{Q} = 4.943 \text{ kW}$$

24. A tappet valve mechanism in an IC engine comprises a rocker arm ABC that is hinged at B as shown in the figure. The rocker is assumed rigid and it oscillates about the hinge B. The mass moment of inertia of the rocker about B is 10^{-4} kg-m^2. The rocker arm dimensions are a = 3.5 cm and b = 2.5 cm. A pushrod pushes the rocker at location A, when moved vertically by a cam that rotates at N rpm. The pushrod is assumed massless and has a stiffness of 15 N/mm. At the other end C, the rocker pushes a valve against a spring of stiffness 10 N/mm. The valve is assumed massless and rigid.

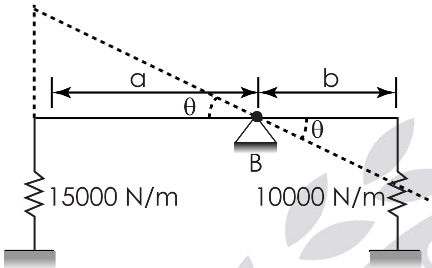


Resonance in the rocker system occurs when the cam shaft runs at a speed of _____ rpm (round off to the nearest integer).

(a) 790 (b) 4739
(c) 2369 (d) 496

24. Ans: (b)

Sol:



Given,

$k_1 = 15$ N/mm $= 15 \times 10^3$ N/m

$k_2 = 10$ N/mm $= 10 \times 10^3$ N/m

Mass moment of inertia of rocker, $I_B = 10^{-4}$ kg-m^2

$a = 3.5$ cm $= 0.035$ m ,

$b = 2.5$ cm $= 0.025$ m

Applying moment about point B

$$I_B\ddot{\theta} + k_1 a^2\theta + k_2 b^2\theta = 0$$

The resonance occurs at natural frequency,

$$\omega_n = \sqrt{\frac{k_1 a^2 + k_2 b^2}{I_B}}$$

$$\omega_n = \sqrt{\frac{15\times10^3\times0.035^2 + 10\times10^3\times0.025^2}{10^{-4}}}$$

$$= \sqrt{246250} = 496.235 \text{ rad/s}$$

$$N = \frac{60\times\omega_n}{2\pi} = 4738.7 \text{ rpm}$$

25. In modern CNC machine tools, the backlash has been eliminated by

(a) slider crank mechanism
(b) ratchet and pinion
(c) preloaded ballscrews
(d) rack and pinion

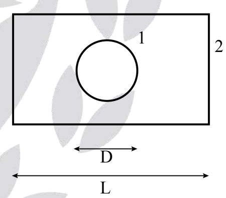
25. Ans: (c)

Sol: The stiffness of the machine tool and the backlash in gear drives and lead- screws are important factors in achieving dimensional accuracy. Backlash in modern machines is eliminated *by using preloaded ball screws*. Also, a rapid response to command signals requires that friction in machine slide ways and inertia be minimized. The latter can be achieved by reducing the mass of moving components of the machine, such as, for example, by using lightweight materials, including ceramics.

26. A solid sphere of radius 10 mm is placed at the centroid of a hollow cubical enclosure of side length 30 mm. The outer surface of the sphere is denoted by 1 and the inner surface of the cube is denoted by 2. The view factor F_{22} for radiation heat transfer is _______ (rounded off to two decimal places).

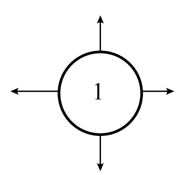
26. Ans: (0.76)

Sol:



$D = 20$ mm $= 0.02$ m

$L = 30$ mm $= 0.03$ m



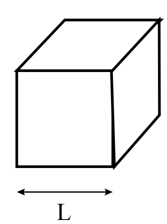
$F_{11} = 0$

$F_{11} + F_{12} = 1$

$F_{12} = 1$

$A_1 = \pi D_1^2$

$A_1 = \pi(0.02)^2$



$F_{22} \neq 0$

$A_2 = 6L^2 = 6(0.03)^2$

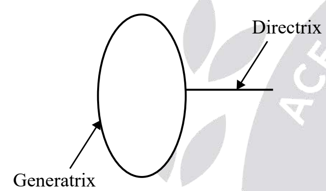
$A_1F_{12} = A_2F_{21}$

$$F_{21} = \frac{A_1}{A_2} F_{12}$$

$$F_{21} = \frac{\pi(0.02)^2}{6(0.03)^2} \times 1$$

$$F_{21} = 0.2327$$
$$F_{21} + F_{22} = 1$$
$$F_{22} = 1 - F_{21} = 1 - 0.2327$$
$$F_{22} = 0.767$$

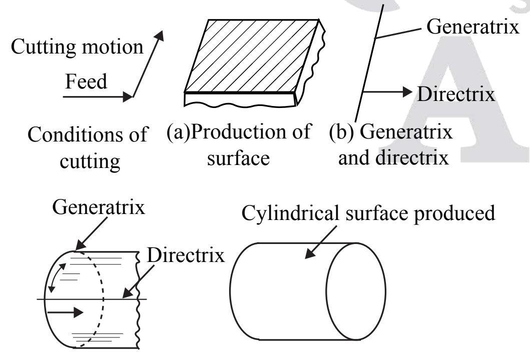
27. In a machining operation, if a cutting tool traces the workpiece such that the directrix is perpendicular to the plane of the generatrix as shown in figure, the surface generated is



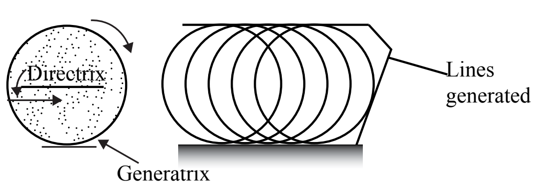
(a) spherical (b) plane
(c) a surface of revolution (d) cylindrical

27. Ans: (d)

Sol: Two straight lines which are generatrix and directrix respectively form a plane.



(c) Directrix perpendicular to plane of generatrix



(d) Principle in the plane of generatrix

Generation of various surfaces			
Generatrics	**Directrix**	**Process**	**Surface obtained**
Straight line	Straight line	Tracing	Plane
Circular	Straight line	Tracing	cylindrical
Plane curve	Circular	Tracing	Surface of revolution
Circular	Straight line	Generation	Straight line (plain surface in practice)

28. An infinitely long pin fin, attached to an isothermal hot surface, transfers heat at a steady rate of $\dot{Q}_1$ to the ambient air. If the thermal conductivity of the fin material is doubled, while keeping everything else constant, the rate of steady-state heat transfer from the fin becomes $\dot{Q}_2$. The ratio $\frac{\dot{Q}_2}{\dot{Q}_1}$ is

(a) $\sqrt{2}$ (b) $\frac{1}{\sqrt{2}}$

(c) 2 (d) $\frac{1}{2}$

28. Ans: (a)

Sol: For long fin

$$Q_1 = \sqrt{hPkA_C}\,\theta_0$$

$$Q_1 \propto \sqrt{k}$$

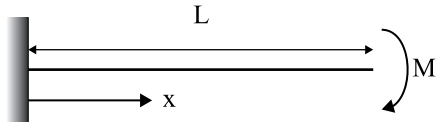
$$\frac{Q_2}{Q_1} = \sqrt{\frac{k_2}{k_1}}$$

if $k_2 = 2k_1$

$$\frac{Q_2}{Q_1} = \sqrt{\frac{2k_1}{k_1}}$$

$$\frac{Q_2}{Q_1} = \sqrt{2}$$

29. A cantilever beam of length, L, and flexural rigidity, EI, is subjected to an end moment, M, as shown in the figure. The deflection of the beam at $x = \frac{L}{2}$ is

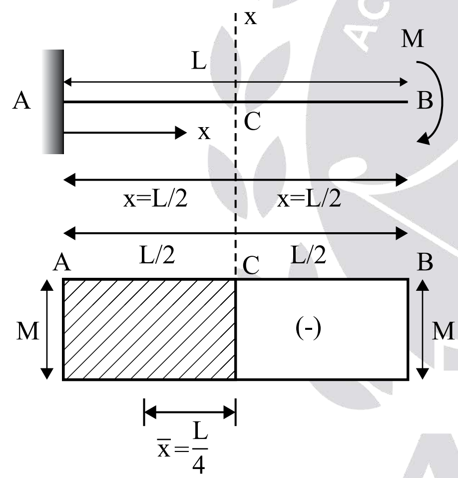


(a) $\frac{ML^2}{8EI}$ (b) $\frac{ML^2}{4EI}$

(c) $\frac{ML^2}{16EI}$ (d) $\frac{ML^2}{2EI}$

29. Ans: (a)

Sol:



Moment area method :

$$y_C - y_A = \left[\frac{[A_{BMD}]_C^A}{EI}\right]\bar{x}_c$$

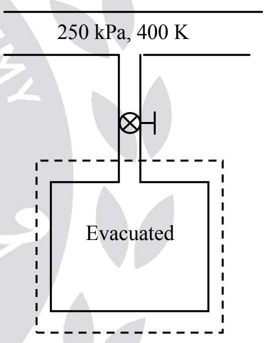
$$y_c - 0 = \frac{1}{EI}\left(-M \times \frac{L}{2}\right) \times \frac{L}{4}$$

$$y_c = \frac{ML^2}{8EI}\ (\downarrow)$$

30. A rigid insulated tank is initially evacuated. It is connected through a valve to a supply line that carries air at a constant pressure and temperature of 250 kPa and 400 K respectively. Now the valve is opened and air is allowed to flow into the tank until the pressure inside the tank reaches to 250 kPa at which point the valve is closed. Assume that the air behaves as a perfect gas with constant properties (c_p = 1.005 kJ/kg.K, c_v = 0.718 kJ/kg.K, R = 0.287 kJ/kg.K). Final temperature of the air inside the tank is ________ K (round off to one decimal place).

30. Ans: (560)

Sol:



Given:

$T_i = 400$ K

$T_2 = ?$

We know

$T_2 = \gamma T_i$

$T_2 = (1.4 \times 400)$

$= 560$ K

31. A true centrifugal casting operation needs to be performed horizontally to make copper tube sections with outer diameter of 250 mm and inner diameter of 230 mm. The value of acceleration due to gravity, $g = 10\ m/s^2$. If a G-factor (ratio of centrifugal force to weight) of 60 is used for casting the tube, the rotational speed required is _____ rpm (round off to the nearest integer)

31. Ans: (675.23)

Sol: Given, True centrifugal casting,

Outer diameter, $D_0 = 250$ mm

Inner diameter, $D_i = 230$ mm

$$D_{avg} = \frac{250+230}{2} = 240\ \text{mm} = 0.24\text{m}$$

$R_{avg} = 0.12$ m

Acceleration due to gravity (g) = 10 m/s^2

G factor (G) = 60

N = ?

$$G = \frac{mR_m\omega^2}{mg}$$

$$60 = \frac{0.12\omega^2}{10}$$

$\omega = 70.71$ rad/s

Required Rotational Speed (N)

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

$$= \frac{60\times 70.71}{2\pi} = 675.23\ \text{rpm}$$

32. Consider a reciprocating engine with crank radius R and connecting rod of length L. The secondary unbalance force for this case is equivalent to primary unbalance force due to a virtual crank of

(a) radius $\frac{L^2}{4R}$ rotating at half the engine speed

(b) radius $\frac{R^2}{4L}$ rotating at twice the engine speed

(c) radius $\frac{L}{2}$ rotating at twice the engine speed

(d) radius $\frac{R}{4}$ rotating at half the engine speed

32. Ans: (b)

Sol: Unbalanced secondary force,

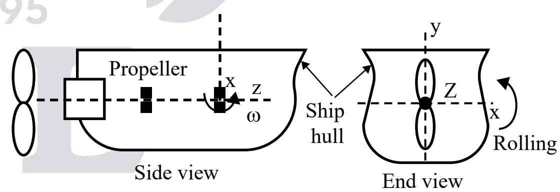
$$F_s = mr\omega^2\frac{\cos 2\theta}{n}$$

$$= m\times\left(\frac{r}{4n}\right)\times(2\omega)^2\times\cos 2\theta$$

$$\text{Balancing radius} = \frac{r}{4n} = \frac{r}{4\times\frac{\ell}{r}} = \frac{r^2}{4\ell}$$

Balancing crank speed = 2ω

33. The figure shows an arrangement of a heavy propeller shaft in a ship. The combined polar mass moment of inertia of the propeller and the shaft is 100 kg.m^2. The propeller rotates at $\omega = 12$ rad/s. The waves acting on the ship hull induces a rolling motion as shown in the figure with an angular velocity of 5 rad/s. The gyroscopic moment generated on the shaft due to the motion described is _____ N.m (round off to the nearest integer).



33. Ans: (0)

Sol: As the axes of the rolling of the ship and the axes of the rotor are parallel, there is no precession of the axis of spin.

Gyroscopic couple = $= I.(\vec{\omega}_s\times\vec{\omega}_p) = 0$

34. A 200 mm wide plate having a thickness of 20 mm is fed through a rolling mill with two rolls. The radius of each roll is 300 mm. The plate thickness is to be reduced to 18 mm in one pass using a roll speed of 50 rpm. The strength coefficient (K) of the work material flow curve is 300 MPa and the strain hardening exponent, n = 0.2. The coefficient of friction between the rolls and the plate is 0.1. If the friction is sufficient to permit the rolling operation then the roll force will be ______ kN (round off to the nearest integer).

34. Ans: (874.70)

Sol: b = W = 200 mm (width of plate)

$H_o = 20$ mm

R = 300 mm

$H_1 = 18$ mm

N = 50 rpm

Strength coefficient (k) = 300 MPa

n = 0.2

$\mu = 0.1$

$$L = \sqrt{R\ \Delta H} = \sqrt{300\times(20-18)} = 24.494 \text{ mm}$$

F_{avg} = Roll force = $\bar{Y}_{avg}.b.L$

$$\varepsilon = \ln\left(\frac{H_o}{H_1}\right) = \ln\left(\frac{20}{18}\right) = 0.105$$

$$\bar{Y}_{avg} = \frac{k\,\varepsilon^n}{n+1}$$

$$= \frac{300\times 0.105^{0.2}}{0.105+1} = 172.98 \text{ MPa}$$

$$F_{avg} = \bar{Y}_{avg}\left[1+\frac{\mu L}{4H}\right]\times b\times L$$

$$= 172.98\left[1+\frac{0.1\times 24.494}{4\times 19}\right]\times 200\times 24.494$$

$$= 874.705 \text{ kN}$$

35. The resistance spot welding of two 1.55 mm thick metal sheets is performed usign welding current of 10000 A for 0.25 s. The contact resistance at the interface of the metal sheets is 0.0001 Ω. The volume of weld nugget formed after welding is 70 mm^3, the thermal efficiency of the welding process is ______ % (round off to one decimal place).

35. Ans: (33.6)

Sol: Given data,

Resistance spot welding

Sheet thickness (t) = 1.55 mm

Current (I) = 10000 A

Time (τ) = 0.25 s

Contact Resistance (R) = 0.001 Ω

Volume of Nugget (N) = 70 mm^3

Heat required to melt unit volume (u)

$$= \frac{H_u}{V} = 12 \text{ J/mm}^3$$

$$\text{Thermal efficiency}(\eta_{th}) = \frac{\text{heat uitlised }(H_u)}{\text{Heat energy supplied }(H_s)}$$

Heat utilized (H_u) = u × v = 12 × 70 = 840 J

Heat energy supplied (H_s) = $I^2R\tau$

$= (10000)^2\times 0.0001\times 0.25$

$= 2500$ J

$$\eta_{th} = \frac{H_u}{H_s} = \frac{840}{2500} = 33.6\%$$

36. A set of jobs A, B, C, D, E, F, G, H arrive at time t = 0 for processing on turning and grinding machines. Each job needs to be processed in sequence - first on the turning machine and second on the grinding machine, and the grinding must occur immediately after turning. The processing times of the jobs are given below.

Job	A	B	C	D	E	F	G	H
Turning (minutes)	2	4	8	9	7	6	5	10
Grinding (minutes)	6	1	3	7	9	5	2	4

If the makespan is to be minimized, then the optimal sequence in which these jobs must be processed on the turning and grinding machines is

(a) A-E-D-F-H-C-G-B

(b) B-G-C-H-F-D-E-A

(c) G-E-D-F-H-C-A-B

(d) A-D-E-F-H-C-G-B

36. Ans: (a)

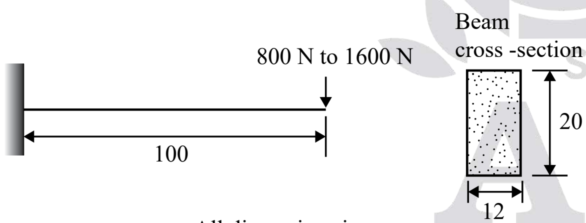
Sol:

Job	A	B	C	D	E	F	G	H
Turning (minutes)	2	4	8	9	7	6	5	10
Grinding (minutes)	6	1	3	7	9	5	2	4

According to Johnson's rule, the sequence is

A - E - D - F - H - C - G - B

37. A machine part in the form of cantilever beam is subjected to fluctuating load as shown in the figure. The load varies from 800 N to 1600 N. The modified endurance, yield and ultimate strengths of the material ae 200 MPa, 500 MPa and 600 MPa, respectively.



All dimensions in mm

The factor of safety of the beam using modified Goodman criterion is _______ (round off to one decimal place).

37. Ans: (2)

Sol:

(i) $P_m = \dfrac{P_{max} + P_{min}}{2} = \dfrac{1600 + 800}{2} = 1200 \text{ N}$

$Pa = \dfrac{P_{max} - P_{min}}{2} = \dfrac{1600 - 800}{2} = 400 \text{ N}$

(ii) Bending stress,

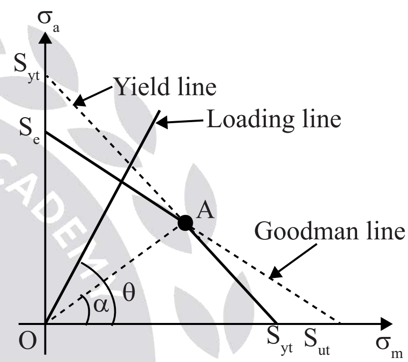
$$\sigma = \frac{M\,y}{I} = \frac{P \times L \times \frac{t}{2}}{\frac{bt^3}{12}} = \frac{6P \times L}{bt^2}$$

$$\sigma_m = \frac{6 \times P_m \times L}{b \times t^2} = \frac{6 \times 1200 \times 100}{12 \times 20^2} = 150 \text{ MPa}$$

$$\sigma_a = \frac{6 \times P_a \times L}{b \times t^2} = 50 \text{ MPa}$$

(iii) Loading line, $\tan\theta = \dfrac{\sigma_a}{\sigma_m} = \dfrac{50}{150} = \dfrac{1}{3}$ ---- (i)

(iv) Modified Goodman diagram,



Yield line $\Rightarrow \sigma_m + \sigma_a = S_{yt}$

$\Rightarrow \sigma_m + \sigma_a = 500$ ---- (ii)

Goodman line

$$\frac{\sigma_m}{S_{ut}} + \frac{\sigma_a}{S_e} = 1$$

$$\frac{\sigma_m}{600} + \frac{\sigma_a}{200} = 1$$

$\Rightarrow \sigma_m + 3\sigma_a = 600$ ---- (iii)

On solving eq.(ii) and (iii)

$\Rightarrow \sigma_a = 50$ MPa

$\Rightarrow \sigma_m = 450$ MPa

$\tan\alpha = \dfrac{\sigma_a}{\sigma_m} = \dfrac{50}{450} = \dfrac{1}{9}$ ---- (iv)

From (i) and (iv)

$\tan\theta > \tan\alpha$

$\therefore \theta > \alpha$

Design line is Goodman line,

$$\frac{\sigma_m}{S_{ut}} + \frac{\sigma_a}{S_e} = \frac{1}{FOS}$$

$$\frac{150}{600} + \frac{50}{200} = \frac{1}{FOS}$$

$\therefore$ FOS = 2

38. Customers arrive at a shop according to the Poisson distribution with a mean of 10 customers/hour. The manager notes that no customer arrives for the first 3 minutes after the shop opens. The probability that a customer arrives within the next 3 minutes is

(a) 0.86 (b) 0.61

(c) 0.50 (d) 0.39

38. Ans: (b)

Sol:

(i) Probability of zero customers in 3 min ($\lambda T = 0.5$)

$$P_1 = P(0,3) = = \frac{e^{-0.5}\times(0.5)^0}{0!} = 0.606$$

(ii) Probability of 1 customer in 6 min ($\lambda T = 1$)

$$P_3 = P(1,6) = = \frac{e^{-1}\times(1)^1}{1!} = 0.3678$$

$\Rightarrow P_1 \times P_2 = P_3$

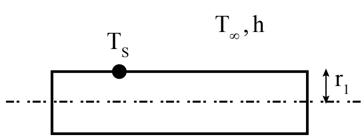
$\Rightarrow 0.606 \times P_2 = 0.3678$

$\Rightarrow P_2 = 0.6069 \approx 0.61$

39. An uninsulated cylindrical wire of radius 1.0 mm produces electric heating at the rate of 5.0 W/m. The temperature of the surface of the wire is 75°C when placed in air at 25°C. When the wire is coated with PVC of thickness 1.0 mm, the temeprature of the surface of the wire reduces to 55°C. Assume that the heat generation rate from the wire and the convective heat transfer coefficient are same for both uninsulated wire and the coated wire. The thermal conductivity of PVC is ______ W/m.K (round off to two decimal places).

39. Ans: (0.11)

Sol: Without insulation:



Given data:

$r_1 = 1$ mm, $\frac{Q}{L} = 5$ W/m

$T_S = 75°C$, $T_\infty = 25°C$

$$Q = \frac{T_S - T_\infty}{\frac{1}{hA_S}}$$

$Q = hA_S(T_S - T_\infty)$

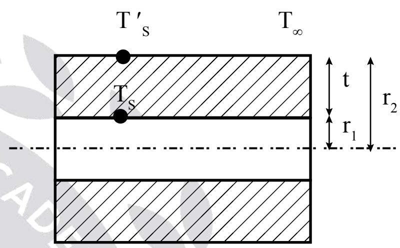
$Q = h2\pi r_1 L(T_S - T_\infty)$

$\frac{Q}{L} = 2\pi h r_1 \left(T_S - T_\infty\right)$

$5 = 2\pi \times h \times 1 \times 10^{-3} \times (75–25)$

$h = 15.91$ W/m²K

With insulation



Given data:

$r_1 = 1$ mm, $t = 1$ mm

$r_2 = r_1 + t = 2$ mm $= 2 \times 10^{-3}$ m

$T_S = 55°C$, $T_\infty = 25°C$

$$Q = \frac{T'_S - T_\infty}{\frac{1}{hA_S}} = hA_S\left(T'_S - T_\infty\right)$$

$Q = h2\pi r_2 L\left(T'_S - T_\infty\right)$

$\frac{Q}{L} = 2\pi r_2 h\left(T'_S - T_\infty\right)$

$5 = 2\pi \times 2 \times 10^{-3} \times 15.91 \times \left(T'_S - T_\infty\right)$

$T'_S - T_\infty = 25$

$T'_S = 25 + T_\infty = 25 + 25 = 50°C$

$T'_S = 50°C$

$$Q = \frac{T_S - T'_S}{\frac{\ell n\left(\frac{r_2}{r_1}\right)}{2\pi k L}}$$

$$\frac{Q}{L} = \frac{T_S - T'_S}{\frac{\ell n\left(\frac{r_2}{r_1}\right)}{2\pi k}}, \; 5 = \frac{55-50}{\frac{\ell n\left(\frac{2}{1}\right)}{2\pi \times k}}$$

$\Rightarrow k = 0.11$ W/mK

40. The fundamental thermodynamic relation for a rubber band is given by $dU = Tds + \tau dL$, where T is the absolute temperature, S is the entropy, τ is the tension in the rubber band, and L is the length of the rubber band. Which one of the following relations is CORRECT:

(a) $\left(\frac{\partial T}{\partial L}\right)_S = \left(\frac{\partial \tau}{\partial S}\right)_L$ (b) $T = \left(\frac{\partial U}{\partial S}\right)_\tau$

(c) $\left(\frac{\partial T}{\partial S}\right)_L = \left(\frac{\partial \tau}{\partial L}\right)_S$ (d) $\tau = \left(\frac{\partial U}{\partial S}\right)_L$

40. Ans: (a)

Sol: $dU = Tds + \tau dL$

$dz = Mdx + Ndy$

$z = U,\ M = T,\ x = s,\quad N = \tau;\ y = L$

$$\left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y$$

$$\left(\frac{\partial T}{\partial L}\right)_S = \left(\frac{\partial \tau}{\partial S}\right)_L$$

41. Let $f(x) = x^2 - 2x + 2$ be a continuous function defined on $x \in [1,3]$. The point x at which the tangent of f(x) becomes parallel to the straight line joining f(1) and f(3) is

(a) 3 (b) 1

(c) 0 (d) 2

41. Ans: (d)

Sol: Let, $f(x) = x^2 - 2x + 2$ and $[a,b] = [1,3]$

Then, $f'(x) = 2x - 2$

By a mean value theorem

$$\exists\ c \in (1,3) \Rightarrow f'(c) = \frac{f(3)-f(1)}{3-1}$$

$$\Rightarrow 2c - 2 = \frac{5-1}{2}$$

$\Rightarrow c - 1 = 1$

$\therefore\ c = 2$ (or) $x = 2$

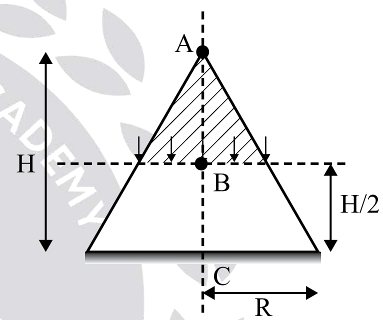
42. A right solid circular cone standing on its base on a horizontal surface is of height H and base radius R. The cone is made of a material with specific weight w and elastic modulus E. The vertical deflection at the mid-height of the cone due to self-weight is given by

(a) $\frac{wRH}{8E}$ (b) $\frac{wH^2}{8E}$

(c) $\frac{wH^2}{6E}$ (d) $\frac{wRH}{6E}$

42. Ans: (b)

Sol:



$w = \gamma = \rho g$

$\delta_{A/C} = \delta_{A/B} + \delta_{B/C}$

$\delta_{B/C} = \delta_{A/C} - \delta_{A/B}$

$$= \frac{wH^2}{6E} - \frac{w\left(\frac{H}{2}\right)^2}{6E}$$

$$= \frac{wH^2}{6E} - \frac{wH^2}{24E} = \frac{3wH^2}{24E} = \frac{wH^2}{8E}$$

43. If y(x) satisfies the differential equation

$$(\sin x)\frac{dy}{dx} + y\cos x = 1.$$

subject to the conditions $y(\pi/2) = \pi/2$, then $y(\pi/6)$ is

(a) $\frac{\pi}{3}$ (b) 0

(c) $\frac{\pi}{6}$ (d) $\frac{\pi}{2}$

43. Ans: (a)

Sol: Given $(\sin x)\frac{dy}{dx} + y\cos x = 1$

$$\Rightarrow \quad (y\cos x - 1)dx + (\sin x)dy = 0 \text{ ...... (1)}$$

$$(\because Mdx + Ndy = 0)$$

Here, $\frac{\partial M}{\partial y} = \cos x = \frac{\partial N}{\partial x} = \cos x$

$\therefore$ (1) is an exact D.E

The general solution of (1) is given by

$$\int (y\cos x - 1)dx + \int (0)dy = c$$

$\Rightarrow$ ysinx – x = c .... (2)

gives $y\left(\frac{\pi}{2}\right) = \frac{\pi}{2}$ .... (3)

using (2) , (3) becomes

$$\frac{\pi}{2}\sin\left(\frac{\pi}{2}\right) - \frac{\pi}{2} = c$$

$\Rightarrow c = 0$

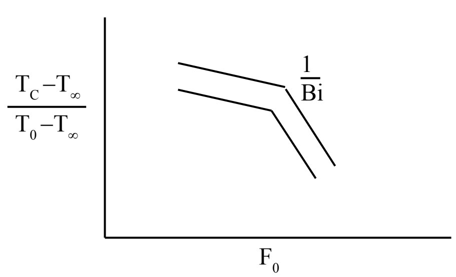
$\therefore$ The solution of (1) is $y = \frac{x}{\sin x}$

$$\text{Hence, } y\left(\frac{\pi}{6}\right) = \frac{\frac{\pi}{6}}{\sin\frac{\pi}{6}} = \frac{\pi}{6}\left(\frac{1}{\frac{1}{2}}\right) = \frac{\pi}{3}$$

44. A hot steel spherical ball is suddenly dipped into a low temperature oil bath.
Which of the following dimensionless parameters are required to determine instantaneous center temperature of the ball using a Heisler chart?
(a) Nusselt number and Grashoff number
(b) Reynolds number and Prandtl number
(c) Biot number and Fourier number
(d) Biot number and Froude number

44. Ans: (c)

Sol: Heisler chart



T_C = Centerline Temp

$$\frac{T_C - T_\infty}{T_0 - T_\infty} = f\left[\frac{1}{Bi}, F_0\right]$$

45. Consider a vector p in 2-dimensional space. Let its direction (counter-clokwise angle with the positive x-axis) be θ. Let p be an eigenvector of a 2 × 2 matrix A with corresponding eigenvalue λ, λ > 0. If we denote the magnitude of a vector v by ||v||, identify the VALID statement regarding p′ = Ap.
(a) Direction of p′ = θ, ||p′|| = λ||p||
(b) Direction of p′ = λ θ, ||p′|| = λ||p||
(c) Direction of p′ = λ θ, ||p′|| = ||p||
(d) Direction of p′ = θ, ||p′|| = ||p|| λ

45. Ans: (a)

Sol: If x is an eigen vector of a 2 × 2 matrix A corresponding to an eigen value 'λ'

then Ax = λx

Repalce x by ρ

i.e. Aρ = λρ

$\rho' = \lambda\rho \qquad (\because \rho' = A\rho)$

i.e eigen vector ρ′ is λ times of eigen vector ρ.

$\therefore \; ||\rho'|| = \lambda||\rho||$

46. Activities A, B, C and D form the critical path for a project with a PERT network. The means and variances of the activity duration for each activity are given below. All activity durations follow the Gaussian (normal) distribution, and are independent of each other.

Activity	A	B	C	D
Mean (days)	6	11	8	15
Variance (days^2)	4	9	4	9

The probability that the project will be completed within 40 days is ________ (round off to two decimal places).
(Note: Probability is a number between 0 and 1).

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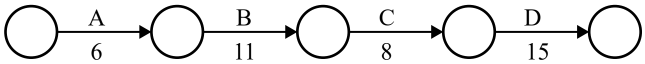
46. Ans: (0.5)

Sol:



Critical path = A - B - C - D

Critical time (T_E) = 6+11+8+15 = 40 days

Duration (D) = 40 days

$$Z = \frac{D - T_E}{\sigma_{cp}}$$

At Z = 0 ⇒ Probability = 0.5

47. The ordinary differential equations $\frac{dy}{dt} = -\pi y$ subject to an initial condition y(0) = 1 solved numerically using the following scheme:

$$\frac{y(t_{n+1}) - y(t_n)}{h} = -\pi y(t_n)$$

where h is the time step, t_n = nh, and n = 0, 1, 2, ...

This numerical scheme is stable for all values of h in the interval __________.

(a) 0 < h < 1 (b) $0 \quad h \quad \frac{\pi}{2}$

(c) $0 \quad h \quad \frac{2}{\pi}$ (d) for all h > 0

47. Ans: (c)

Sol: Given $\frac{dy}{dE} = -\pi y$ .... (1) $\left(\because \frac{dy}{dx} = f(x,y)\right)$

with y (0) = 1 .... (2) ($\because$ $y(x_0) = y_0$)

also given that $\frac{y(t_{n+1}) - y(t_n)}{h} = -\pi y(t_n)$

$\Rightarrow \quad y(t_{n+1}) - y(t_n) = h(-\pi y(t_n))$

$\Rightarrow \quad y(t_{n+1}) = y(t_n) + h\, f(t_n, y_n)$

which is the Euler's method.

Now, $y_{n+1} = y_n + h\,(-\pi\, y_n)$

$\Rightarrow \quad y_{n+1} = (1 - h\pi)y_n$ .... (3)

which is in the form of $y_{n+1} = \in y_n + hK$

But Euler's method is stable if |E| < 1

$\Rightarrow |1 - h\pi| < 1$

$\Rightarrow -1 < 1 - h\pi < 1$

$\Rightarrow -1-1 < -1 + 1 - h\pi < -1 + 1$

$\Rightarrow -2 < -h\pi < 0$

$\Rightarrow \frac{2}{\pi} \quad h \quad \frac{0}{\pi}$

$\therefore 0 \quad h \quad \frac{2}{\pi}$ (or) $h \in \left(0, \frac{2}{\pi}\right)$

48. In a grinding operation of a metal, specific energy consumption is 15 J/mm^3. If a grinding wheel with a diameter of 200 mm is rotating at 3000 rpm to obtain a material removal rate of 6000 mm^3/min, then the tangential force on the wheel is ______N (round off to two decimal places).

48. Ans: (47.75)

Sol: Given, Grinding operation,

Specific energy consumption (U) = 15 J/mm^3

Grinding wheel diameter (D) = 200 mm

Rotational speed (N) = 300 rpm

$MRR = 6000\,mm^3/min = \frac{6000}{60}\frac{mm^3}{sec} = 100\ mm^3/sec$

Tangential force (F) = ?

Power = F × V

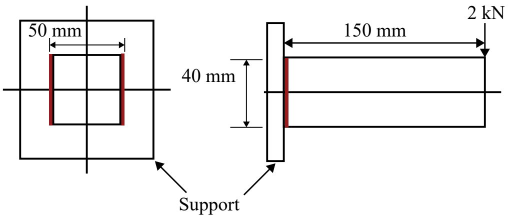
$\Rightarrow F \times \frac{\pi DN}{60 \times 1000} = u \times MRR$

$F \times \frac{\pi \times 200 \times 3000}{60 \times 1000} = 100 \times 15$

F = 47.746 N

F ≅ 47.75 N

49. A cantilever beam of rectangular cross-section is welded to a support by means of two fillet welds as shown in figure. A vertical load of 2 kN acts at free end of the beam.



Considering that the allowable shear stress in weld is 60 N/mm², the minimum size (leg) of the weld required is _____ mm (round off to one decimal place).

49. Ans: (6.7)

Sol:

(i) Direct shear stress,

$$\tau = \frac{P}{A} = \frac{2 \times 10^3}{2 \times t \times 40} = \frac{25}{t}\ \text{N/mm}^2$$

(ii) Bending stress (σ_b)

$$\sigma_b = \frac{M\,y}{I} = \frac{2000 \times 150 \times \frac{40}{2}}{2 \times \frac{t \times 40^3}{12}}$$

$$\sigma_b = \frac{562.5}{t}\ \text{N/mm}^2$$

(iii) Using shear stress theory :

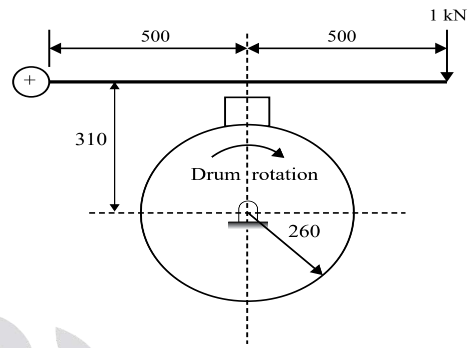
$$\left\{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2\right\}^{0.5} \le \tau_{allow}$$

$$\left\{\left(\frac{562.5}{2 \times t}\right)^2 + \left(\frac{25}{t}\right)^2\right\}^{0.5} = 60$$

$\therefore$ t = 4.7 mm

Weld size, $h = t \times \sqrt{2} = 6.66$ mm = 6.7 mm

50. A short shoe drum (radius 260 mm) brake is shown in the figure. A force of 1 kN is applied to the lever. The coefficient of friction is 0.4.

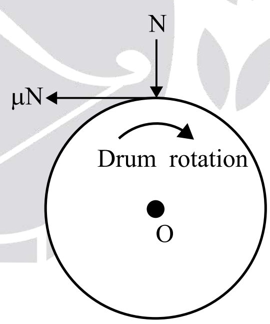


The magnitude of the torque applied by the brake is _____ N.m (round off to one decimal place).

50. Ans: (200)

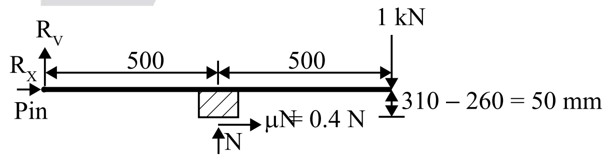
Sol:

(i) FBD of drum :



Braking torque = m NR ---- (i)

(ii) FBD of Lever :



$\Sigma M_{pin} = 0$

$N \times 500 + 0.4\,N \times 50 = 10^3 \times 1000$

$\therefore$ N = 1923 N

From equation (i)

Braking torque = μNR

= 0.4 × 1923 × 260 = 200 Nm

Hearty Congratulations to our

GATE - 2020 TOP RANKERS

EC

KALPIT AGRAWAL	PAVAN KUMAR REDDY A	D SURENDRA KUMAR	K MUKHESH	GHANENDRA SINGH	KV PAVAN KUMAR REDDY	VELURU APARANJINI	JYOTSNA PRIYA RAGU	NISHANT DHULL
AIR – 1	AIR – 1	AIR – 3	AIR – 4	AIR – 6	AIR – 7	AIR – 9	AIR – 10	AIR – 10

EE

ABHASH RAI	RUPAM RAJ	ALIN ANTO	AYUSH RAJ	NEERAJ KUSHWAHA	JATIN TIWARI	HIMANSHU KUMAR	NIKHIL KUMAR	YUVRAJ SINGH RATHORE
AIR – 1	AIR – 2	AIR – 4	AIR – 4	AIR – 6	AIR – 8	AIR – 9	AIR – 9	AIR – 9

CE

AJAY SINGHAL	SUMIT DEWDA	ASHISH CHOUDHARY	ADITYA SHARMA	TARUN GUPTA	SANAT DUTTA	SATISH RAI
AIR – 1	AIR – 1	AIR – 3	AIR – 4	AIR – 8	AIR – 9	AIR – 10

ME

VIKASH KUMAR	SHREYASH AGARWAL	MAYANK GUPTA	AKSHAY KUTE	V. V. ATCHUTA SRAVAN KUMAR	AVINASH VERMA	VIVEK KUMAR KASHYAP	NIKHIL GAIKWAD	APURVA KRISHNA YADAV	SHASHI BHUSHAN	SANKET BHATT
AIR – 1	AIR – 3	AIR – 5	AIR – 6	AIR – 6	AIR – 9	AIR – 9	AIR – 4 (XE)	AIR – 7 (XE)	AIR – 7 (XE)	AIR – 10 (XE)

CS

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IN

KRISHNA SINGH RAJPUT	SHAKTI PATHAK	SIDDHARTHA SINHA ROY	AKASH CHOTIA	SUSHANTHIKA J	RIYA ARON
AIR – 1	AIR – 3	AIR – 5	AIR – 6	AIR – 7	AIR – 10

PI

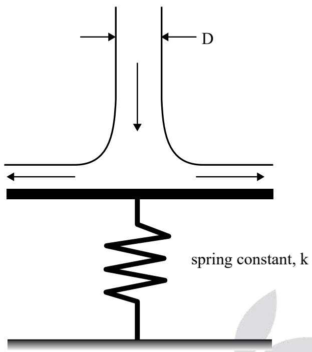
SURYANSH GARG	MOHIT JEENA	PRAVEEN KUMAR	ROHIT AGARWAL	ANKIT YADAV	GOWTHAM GUDIMELLA	SUBHANSHU RANJAN TIWARI	GANESH ADIGAUR	DEEPESH SHARMA
AIR – 1	AIR – 2	AIR – 2	AIR – 4	AIR – 6	AIR – 6	AIR – 8	AIR – 9	AIR – 10

and many more...

Total Selections in Top 10 | 58

EE : 9	EC : 9	ME:7	CE : 7	CS : 7	IN : 6	PI : 9	XE : 4

51. A cylindrical jet of water (density = 1000 kg/m^3) impinges at the center of a flat, circular plate and spreads radially outwards, as shown in the figure. The plate is resting on a linear spring constant k = 1 kN/m. The incoming jet diameter is D = 1 cm.



If the spring shows a steady deflection of 1 cm upon impingement of jet, then the velocity of the incoming jet is ____ m/s (round off to one decimal place).

51. Ans: (11.3)

Sol: Given data:

Spring constant, k = 1 kN/m

Jet diameter, D = 1 cm = 0.01 m

Spring deflection, x = 1 cm = 0.01 m

The spring force must be equal to the impact force exerted by jet

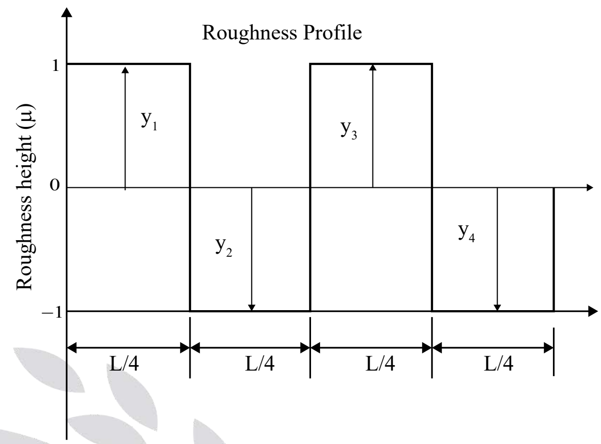
$\therefore\ F_{spring} = F_{jet}$

$kx = \rho a V^2$

$$1000 \times 0.01 = 1000 \times \frac{\pi}{4} \times 0.01^2 \times V^2$$

$$V = \sqrt{\frac{4}{\pi \times 0.01}} = 11.3 \text{ m/s}$$

52. Consider the surface roughness profile as shown in the figure.



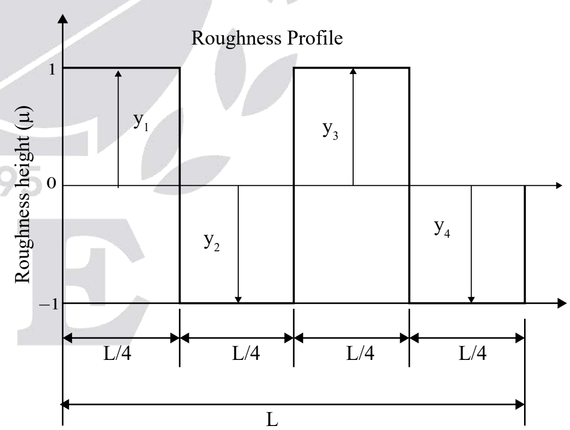
The center line average roughness (R_a, in μm) of the measured length (L) is

(a) 4 (b) 0

(c) 2 (d) 1

52. Ans: (d)

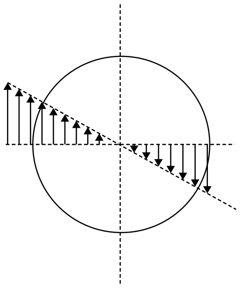
Sol: Given from the figure



$$\text{Centre line average } (R_a) = \frac{\Sigma A}{L}$$

$$R_a = \frac{(4 \times 1)\frac{L}{4}}{L} = 1\text{ mm}$$

53. Shear stress distribution on the cross-section of the coil wire in a helical compression spring is shown in the figure. This shear stress distribution represents



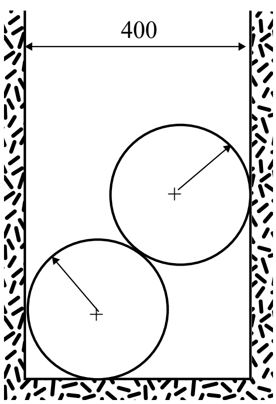
(a) combined direct shear and torsional shear stress in the coil wire cross-section
(b) combined direct shear and torsional shear stress along with the effect of stress concentration at inside edge of the coil wire cross-section
(c) direct shear stress in the coil wire cross-section
(d) torsional shear stress in the coil wire cross-section

53. Ans: (a)

Sol: The figure represents variation of shear stress considering direct shear loading and torsional loading.

As the variation is linear it is observed that the effect of curvature is not considered.

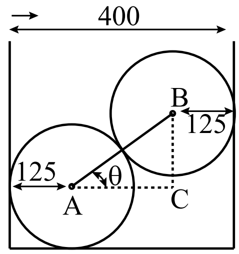
54. Two smooth identical spheres each of radius 125 mm and weight 100 N rest in a horizontal channel having vertical walls. The distance between vertical walls of the channel is 400 mm.



The reaction at the point of contact between two spheres is ____ N (round off to one decimal place)

54. Ans: (125)

Sol:



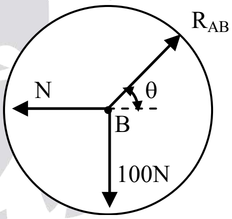
$l(AC) = 400 - 125 - 125 = 150$

$l(AB) = 125 + 125 = 250$

$\therefore \cos\theta = \frac{150}{250} = \frac{3}{5}$

$\therefore \sin\theta = \frac{4}{5}$

FBD for Upper Cylinder:



$\Sigma F_y = 0$

$\therefore R_{AB} \times \sin\theta = 100$

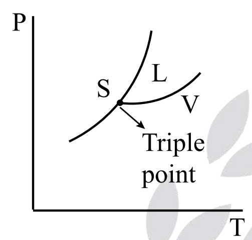
$\therefore R_{AB} \times \frac{4}{5} = 100$

$\therefore R_{AB} = 125\text{ N}$

55. In the vicinity of the triple point, the equation of liquid-vapour boundary in the P-T phase diagram for ammonia is **lnP = 24.38 – 3063/T**, where P is pressure (in Pa) and T is temperature (in K). Similarly, the solid-vapour boundary is given by **ln P = 27.92 – 3754/T**. The temperature at the triple point is ____ K (round off to one decimal place).

55. Ans: (195.2)

Sol:



For ammonia

$\ln P = 24.38 - \dfrac{3063}{T}$ (liquid vapour boundary)

$\ln P = 27.92 - \dfrac{3754}{T}$ (solid vapour boundary)

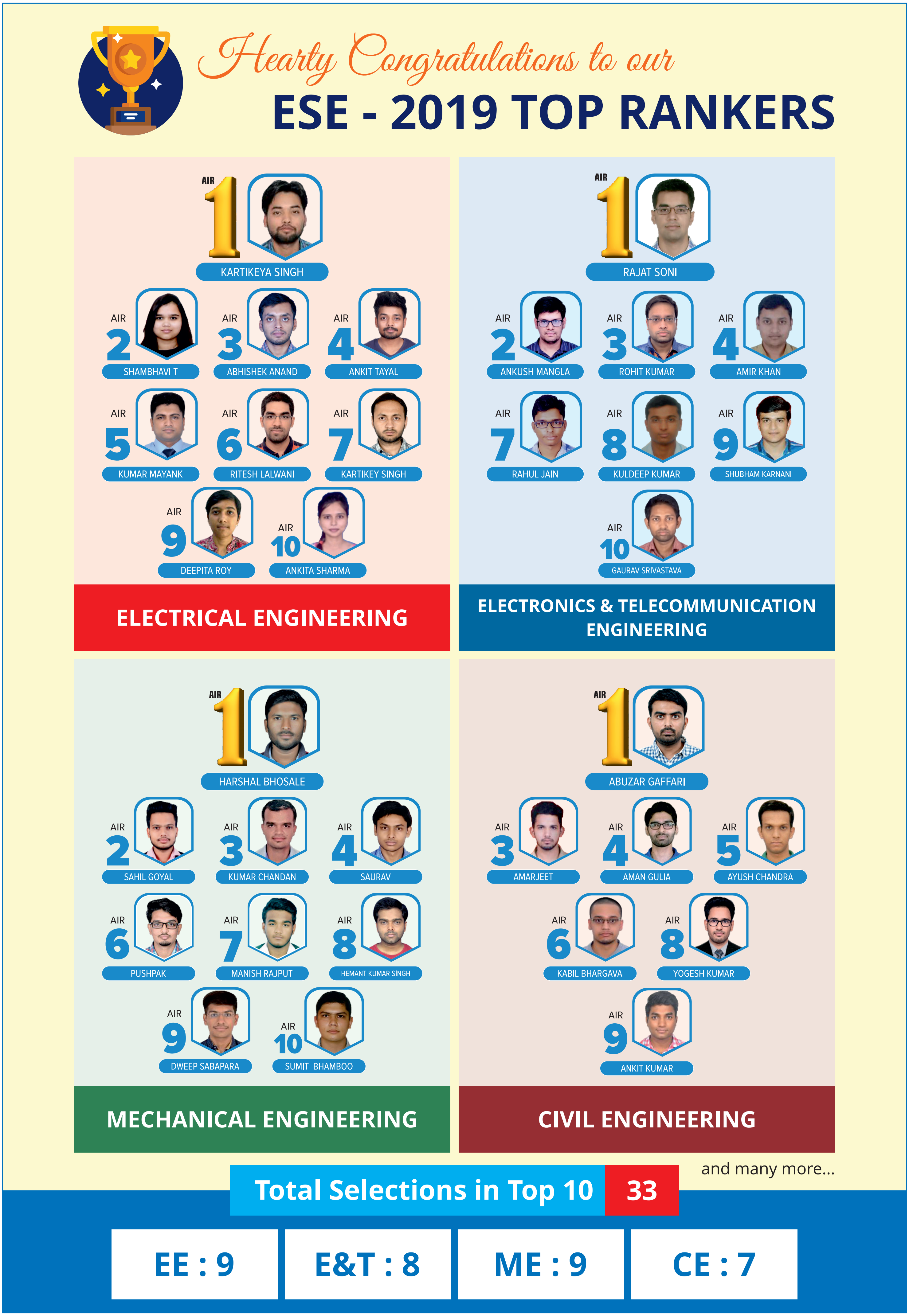
at Triple point pressure from both the equation will be same.

(a) Triple point

$$24.38 - \frac{3063}{T} = 27.92 - \frac{3754}{T}$$

$$\frac{3754}{T} - \frac{3063}{T} = 3.54$$

$$T = 195.2\ \text{K}$$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E&T : 8
ME : 9
CE : 7