MADE EASY

India's Best Institute for IES, GATE & PSUs

GATE 2017

Mechanical Engineering

(Forenoon Session : 04-02-2017)

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- Students are requested to share their expected marks in GATE 2017.

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SESSION 1

Q.1 A motor driving a solid circular steel shaft transmits 40 kW of power at 500 rpm. If the diameter of the shaft is 40 mm, the maximum shear stress in the shaft is __________ MPa.

Ans. (60.792)

$$T = \frac{P \times 60 \times 10^6}{2\pi N} = \frac{40 \times 60 \times 10^6}{2\pi(500)}$$

$$= 763943.7268 \text{ N-mm}$$

$$\tau_{max} = \frac{16T}{\pi d^3} = \frac{16 \times 763943.7268}{\pi(40)^3}$$

$$= 60.792 \text{ MPa}$$

End of Solution

Q.2 Cylindrical pins of diameter $15^{\pm 0.020}$ mm are being produced on a machine. Statistical quality control tests show a mean of 14.995 mm and standard deviation of 0.004 mm. The process capability index Cp is

(a) 0.833
(b) 1.667
(c) 3.333
(d) 3.750

Ans. (b)

$$Cp = \frac{\text{USL} - \text{LSL}}{6\sigma} = \frac{15.02 - 14.98}{6 \times 0.004} = 1.667$$

End of Solution

Q.3 The damping ratio for a viscously damped spring mass system, governed by the relationship $m\frac{d^2x}{dt^2} + c\frac{dx}{dt} + kx = F(t)$, is given by

(a) $\sqrt{\frac{c}{mk}}$
(b) $\frac{c}{2\sqrt{km}}$
(c) $\frac{c}{\sqrt{km}}$
(d) $\sqrt{\frac{c}{\sqrt{2mk}}}$

Ans. (b)

We know that:

$$2\xi\omega_n = \frac{c}{m}$$

$$\xi = \frac{c}{m \times 2\omega_n} = \frac{c}{2m \cdot \sqrt{\frac{k}{m}}} = \frac{c}{2\sqrt{km}}$$

End of Solution

Q.4 Match the processes with their characteristics.

Process	Characteristics
P : Electrical Discharge Machining	1. No residual stress
Q : Ultrasonic machining	2. Machining of electrically conductive materials
R : Chemical machining	3. Machining of glass
S : Ion Beam Machining	4. Nano-machining

(a) P-2, Q-3, R-1, S-4
(b) P-3, Q-2, R-1, S-4
(c) P-3, Q-2, R-4, S-1
(d) P-2, Q-4, R-3, S-1

Ans. (a)

Process	Characteristics
P : Electrical Discharge Machining	2. Machining of electrically conductive materials
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R : Chemical machining	1. No residual stress
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End of Solution

Q.5 In an arc welding process, welding speed is doubled. Assuming all other process parameters to be constant, the cross sectional area of the weld bead will

(a) increase by 25%
(b) increase by 50%
(c) reduce by 25%
(d) reduce by 50%

Ans. (d)

$$H_s = \frac{VI}{vA_b}$$

If v is doubled $(2v)$ to make H_s constant A_b will be reduced by 50%.

$$H_s = \frac{VI}{2v\dfrac{A_b}{2}} = \frac{VI}{vA_b}$$

End of Solution

Q.6 Consider the two-dimensional velocity field given by $\bar{V} = (5 + a_1 x + +b_1 y)\hat{i} + (4 + a_2 x + b_2 y)\hat{j}$, where a_1, b_1, a_2 and b_2 are constants. Which one of the following conditions needs to be satisfied for the flow to be incompressible?

(a) $a_1 + b_1 = 0$
(b) $a_1 + b_2 = 0$
(c) $a_2 + b_2 = 0$
(d) $a_2 + b_1 = 0$

Ans. (b)

Given that the flow is incompressible.

$$\therefore \quad \text{div}\,\overline{V} = 0$$

$$\frac{\partial}{\partial x}(5 + a_1 x + b_1 y) + \frac{\partial}{\partial y}(8 + a_2 x + b_2 y) = 0$$

$$a_1 + b_2 = 0$$

End of Solution

Q.7 Consider a beam with circular cross-section of diameter d. The ratio of the second moment of area about the neutral axis to the section modulus of the area is

(a) $\frac{d}{2}$ (b) $\frac{\pi d}{2}$

(c) d (d) πd

Ans. (a)

$$\frac{I_{N.A}}{Z_{N.A}} = \frac{I_{N.A.}}{(I_{N.A} / Y_{max})} = Y_{max}$$

For a solid circular cross-section

$$Y_{max} = d/2$$

End of Solution

Q.8 A particle of unit mass is moving on a plane. Its trajectory, in polar coordinates, is given by $r(t) = t^2$, $\theta(t)$, where t is time. The kinetic energy of the particle at time $t = 2$ is

(a) 4 (b) 12

(c) 16 (d) 24

Ans. (c)

$$r = t^2;\ \theta = t$$

$$\text{K.E.} = \frac{1}{2}mv^2 = ? \text{ at } t = 2 \text{ sec}$$

$$\Rightarrow \quad m = 1 \text{ kg}$$

$$\vec{V} = r\omega(\hat{t}) + \frac{dr}{dt}\hat{r} = t^2 \times 1(\hat{t}) + 2t\,\hat{r} \qquad \left[\because \frac{d\theta}{dt} = \omega = 1\right]$$

$$\vec{V} = t^2(\hat{t}) + 2t(\hat{r})$$

at $t = 2s$

$$\vec{V} = 4(\hat{t}) + 4(\hat{r})$$

$$|\vec{V}| = \sqrt{16+16} = \sqrt{32}$$

$$\text{K.E.} = \frac{1}{2}mv^2 = \frac{1}{2} \times 1 \times 32 = 16$$

End of Solution

Q.9 Water (density = 1000 kg/m^3) at ambient temperature flows through a horizontal pipe of uniform cross-section at the rate of 1 kg/s. If the pressure drop across the pipe is 100 kPa, the minimum power required to pump the water across the pipe, in watts, is _________.

Ans. (100)

$$\rho = 1000 \text{ kg/m}^3$$
$$m = 1 \text{ kg/s}$$
$$\Delta p = 100 \text{ kPa} = 100 \times 10^3 \text{ Pa}$$
$$P = \rho Q g h_f$$
$$= Q\Delta p$$
$$= \frac{m}{\rho}\Delta p = \frac{1}{1000} \times 100 \times 10^3 = 100 \text{ W}$$

End of Solution

Q.10 In the engineering stress-strain curve for mild steel, the Ultimate Tensile Strength (UTS) refers to

(a) Yield stress
(b) Proportional limit
(c) Maximum stress
(d) Fracture stress

Ans. (c)

Ultimate tensile strength represents the max. stress that a material can withstand without fracture.

End of Solution

Q.11 Consider the following partial differential equation $u(x, y)$ with the constant $c > 1$:

$$\frac{\partial u}{\partial y} + c\frac{\partial u}{\partial x} = 0$$

Solution of this equation is

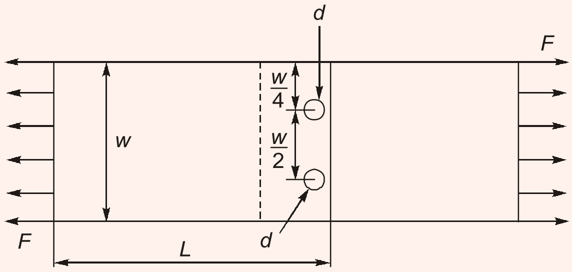
(a) $u(x, y) = f(x + cy)$
(b) $u(x, y) = f(x - cy)$
(c) $u(x, y) = f(cx + y)$
(d) $u(x, y) = f(cx - y)$

Ans. (b)

$$u = f(x - cy)$$
$$\frac{\partial u}{\partial x} = f'(x - cy)(1)$$
$$\frac{\partial u}{\partial y} = f'(x - cy)(-c)$$
$$= -c \cdot f'(x - cy) = -c \cdot \frac{\partial u}{\partial x}$$
$$\therefore \quad \frac{\partial u}{\partial y} + c\frac{\partial u}{\partial x} = 0$$

End of Solution

Q.12 Consider the schematic of a riveted lap joint subjected to tensile load F, as shown below. Let d be the diameter of the rivets, and S_f be the maximum permissible tensile stress in the plates. What should be the minimum value for the thickness of the plates to guard against tensile failure of the plates? Assume the plates to be identical.



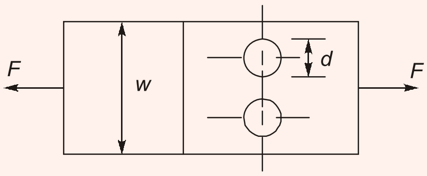
(a) $\dfrac{F}{S_f(w-2d)}$

(b) $\dfrac{F}{S_f w}$

(c) $\dfrac{F}{S_f(w-d)}$

(d) $\dfrac{2F}{S_f w}$

Ans. **(a)**



Safe condition to avoid tearing failure of the joint along the row of rivets,

$$(\sigma_{max})_{tensile} \leq (\sigma_t)_{per}$$

$$\frac{F}{(w-2d)t} = S_f$$

$$t \geq \frac{F}{S_f(w-2d)}$$

End of Solution

Q.13 Metric thread of 0.8 mm pitch is to be cut on a lathe. Pitch of the lead screw is 1.5 mm. If the spindle rotates at 1500 rpm, the speed of rotation of the lead screw (rpm) will be ________.

Ans. **(800)**

Pitch of thread, $P_t = 0.8$ mm

Speed of spindle, $N_t = 1500$ rpm

$P_s = 1.5$ mm

$$N_s \times P_s \times Z_z = N_t \times P_t \times Z_t \qquad [\because Z_s = Z_t = 1]$$

$$N_s \times 1.5 \times 1 = 1500 \times 0.8 \times 1$$

$$N_s = 800 \text{ rpm}$$

End of Solution

Q.14 The differential equation $\frac{d^2y}{dx^2} + 16y = 0$ for $y(x)$ with the two boundary conditions $\left.\frac{dy}{dx}\right|_{x=0} = 1$ and $\left.\frac{dy}{dx}\right|_{x=\frac{\pi}{2}} = -1$ has

(a) no solution
(b) exactly two solutions
(c) exactly one solution
(d) infinitely many solutions

Ans. (a)

$$(D^2 + 16)y = 0$$
$$AE \text{ is } m^2 + 16 = 0$$
$$m = \pm 4i$$

Solution is $y = c_1 \cos 4x + c_2 \sin 4x$

$$y' = -4c_1 \sin 4x + 4c_2 \cos 4x$$
$$y'(0) = 1$$
$$1 = 4c_2$$
$$c_2 = 1/4$$
$$y'(\pi/2) = -1$$
$$-1 = -4c_1 \sin 2\pi + 4c_2 \cos 2\pi$$
$$-1 = 0 + 4c_2$$
$$c_2 = -1/4$$

Therefore the given differential equation has no solution.

End of Solution

Q.15 For steady flow of a viscous incompressible fluid through pipe of constant of diameter, the average velocity in the fully developed region is constant. Which one of the following statements about the average velocity in the developing region is TRUE?

(a) It increases until the flow is fully developed.
(b) It is constant and is equal to the average velocity in the fully developed region.
(c) It decreases until the flow is fully developed.
(d) It is constant but is always lower than the average velocity in the fully developed region.

Ans. (c)

It decreases until the flow is fully developed.

End of Solution

Q.16 A heat pump absorbs 10 kW of heat from outside environment at 250K while absorbing 15 kW of work. It delivers the heat to a room that must be kept warm at 300 K. The Coefficient of Performance (COP) of the heat pump is ________.

Ans. (1.67)

Given that: $\dot{Q}_L = 10 \text{ kW}$

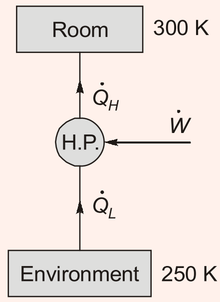
$\dot{W} = 15 \text{ kW}$

Applying first law on heat pump

$$\dot{Q}_L + \dot{W} = \dot{Q}_H$$

$$10 \text{ kW} + 15 \text{ kW} = \dot{Q}_H$$

$$\dot{Q}_H = 25 \text{ kW}$$



$$(\text{COP})_{\text{H.P.}} = \frac{\dot{Q}_H}{\dot{W}} = \frac{25 \text{ kW}}{15 \text{ kW}} = 1.67$$

End of Solution

Q.17 A six-face fair dice is rolled a large number of times. The mean value of the outcomes is _____________.

Ans. (3.5)

Face	1	2	3	4	5	6
Prob.	1/6	1/6	1/6	1/6	1/6	1/6

$$\text{mean} = E(x) = \Sigma x \cdot P(x)$$

$$= 1(1/6) + 2(1/6) + 3(1/6) + 4(1/6) + 5(1/6) + 6(1/6)$$

$$= \frac{1}{6}(1+2+3+4+5+6) = \frac{21}{6} = 3.5$$

End of Solution

Q.18 The product of eigenvalues of the matrix P is

$$P = \begin{bmatrix} 2 & 0 & 1 \\ 4 & -3 & 3 \\ 0 & 2 & -1 \end{bmatrix}$$

(a) – 6
(b) 2
(c) 6
(d) – 2

Ans. (b)

Product of Eigen value = determinant value

$$= 2(3 - 6) + 1\ (8 - 0)$$

$$= 2(-3) + 8$$

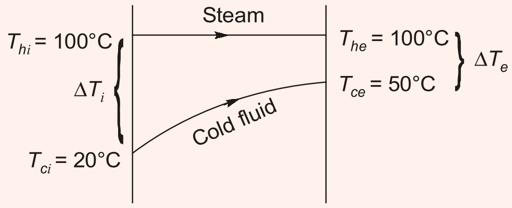
$$= -6 + 8 = 2$$

End of Solution

Q.19 Saturated steam at 100°C condenses on the outside of a tube. Cold enters the tube at 20°C and exits at 50°C. The value of the Log Mean Temperature Difference (LMTD) is __________ °C.

Ans. **(63.82)**

Temperature profiles are



$$\Delta T_i = 100 - 20 = 80°C$$

$$\Delta T_e = 100 - 50 = 50°C$$

(LMTD) (parallel or counter HE)

$$= \frac{\Delta T_i - \Delta T_e}{\ln\frac{\Delta T_i}{\Delta T_e}} = \frac{80-50}{\ln\frac{80}{50}} = 63.82°C$$

End of Solution

Q.20 Which one of the following is NOT a rotating machine?

(a) Centrifugal pump
(b) Gear pump
(c) Jet pump
(d) Vane pump

Ans. **(c)**

End of Solution

Q.21 The molar specific heat at constant volume of an ideal gas is equal to 2.5 times the universal gas constant (8.314 J/mol-K). When the temperature increases by 100 K, the change in molar specific enthalpy is __________ J/mol.

Ans. **(2909.9)**

Given that: $\bar{C}_v = 2.5\bar{R}$ $\quad \bar{C}_v \rightarrow$ Molar specific heat at constant volume

$$\bar{C}_p - \bar{C}_v = \bar{R}$$

$$\Rightarrow \quad \bar{C}_p = \bar{R} + \bar{C}_v = \bar{R} + 2.5\bar{R}$$

$$\bar{C}_p = 3.5\bar{R}$$

Molar specific enthalpy change of ideal gas ($\Delta\bar{H}$)

$$\Delta H = n\bar{C}_p \Delta T$$

$$\overline{\Delta H} = \frac{\Delta H}{n} = \overline{\Delta H} = \bar{C}_p \Delta T = 3.5 \times 8.314 \times 100$$

$$\overline{\Delta H} = 2909.9 \text{ J/mole}$$

End of Solution

Q.22 The Poisson's ratio for a perfectly incompressible linear elastic material is
(a) 1
(b) 0.5
(c) 0
(d) infinity

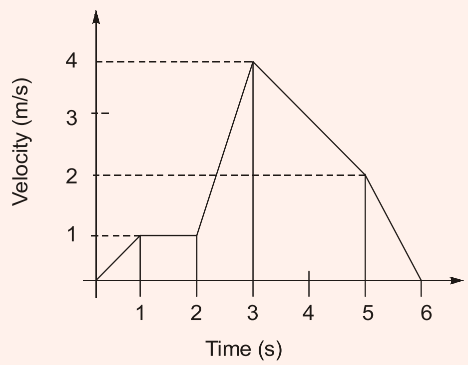
Ans. (b)

For perfectly incompressible material, poisson's ratio = 0.5

(if change in vol. should be zero, μ = 0.5)

End of Solution

Q.23 The following figure shows the velocity time plot for a particle traveling along a straight line. The distance covered by the particle from t = 0 to t = 5s is ________ m.



Ans. (10)

V-t curve

Distance travelled is asked from t = 0 to 5s

$$V = \frac{dS}{dt}$$

$$dS = Vdt$$

$$S = \int_0^5 Vdt$$

Area of V-t graph plotted on time axis from 0 to 5s

$$S = \frac{1}{2}\times 1\times 1 + 1\times 1\times \frac{1}{2}[1+4]\times 1 + \frac{1}{2}[4+2]\times 2$$

$$= 10 \text{ m}$$

End of Solution

Q.24 In a metal forming operation when the material has just started yielding, the principal stresses are σ_1 = +180 MPa, σ_2 = – 100 MPa, σ_3 = 0. Following von Mises criterion, the yield stress is __________ MPa.

Ans. (245.7641)

Safe condition for design as per von-Mises criterion,

$$\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 \le \left(\frac{S_{yt}}{N}\right)^2$$

When yielding occurs, $N = 1$

$$\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 = (S_{yt})^2$$

$$(180)^2 + (-100)^2 - (180)(-100) = (S_{yt})^2$$

$$S_{ty} = 245.7641 \text{ MPa}$$

End of Solution

Q.25 The value of $\lim_{x\to 0} \dfrac{x^2 - \sin(x)}{x}$ is

(a) 0 (b) 3
(c) 1 (d) – 1

Ans. (d)

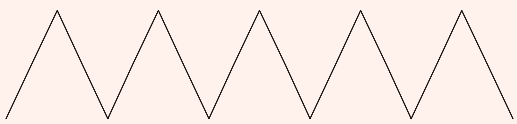
$$\underset{x\to 0}{Lt} \frac{x^3 - \sin x}{x} \quad \left(\frac{0}{0}\text{form}\right)$$

$$\underset{x\to 0}{Lt} \frac{3x^2 - \cos x}{1} = 0 - \cos 0$$

$$= 0 - 1 = -1$$

End of Solution

Q.26 Assume that the surface roughness profile is triangular as shown schematically in the figure. If the peak to valley height is 20 μm, the central line average surface roughness R_o (in μm) is



(a) 5 (b) 6.67
(c) 10 (d) 20

Ans. (a)

$$R_a = \frac{h}{4} = \frac{20}{4} = 5\ \mu\text{m}$$

End of Solution

Q.27 Following data refers to the jobs (P, Q, R, S) which have arrived at a machine for scheduling. The shortest possible average flow time is ___________ days.

Job	Processing Time (days)
P	15
Q	9
R	22
S	12

Ans. (31)

SPT rule given shortest average Job flow time

So, applying SPT

Jobs	Time	Job flow time
Q	9	0 + 9 = 9
S	12	9 + 12 = 21
P	15	21 + 15 = 36
R	22	36 + 22 = 58
		Total = 124

Average job flow time $= \frac{124}{4} = 31\,\text{days}$

End of Solution

Q.28 A parametric curve defined by $x = \cos\left(\frac{\pi u}{2}\right), y = \sin\left(\frac{\pi u}{2}\right)$ in the range $0 \le u \le 1$ is rotated about the X-axis by 360 degrees. Area of the surface generated is

(a) $\frac{\pi}{2}$

(b) π

(c) 2π

(d) 4π

Ans. (c)

$$x = \cos\left(\frac{\pi u}{2}\right); \quad y = \sin\left(\frac{\pi u}{2}\right)$$

$$x^2 + y^2 = 1$$

It represents a circle in x-y plane.

$0 \le u \le 1$ (given range)

$\therefore$ $0 \le x \le 1,\ 0 \le y \le 1$

so, $0 \le \theta \le \frac{\pi}{2}$

Thus, we will get as quarter circle in x-y plane.

$\therefore$ Area of hemisphere $= 2\pi(r)^2 = 2\pi \times (1)^2 = 2\pi$

End of Solution

Q.29 Consider the matrix $P = \begin{bmatrix} \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} \\ 0 & 1 & 0 \\ \frac{-1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} \end{bmatrix}$

Which one of the following statements about P is INCORRECT?

(a) Determinant of P is equal to 1.

(b) P is orthogonal.

(c) Inverse of P is equal to its transpose.

(d) All eigenvalues of P are real numbers.

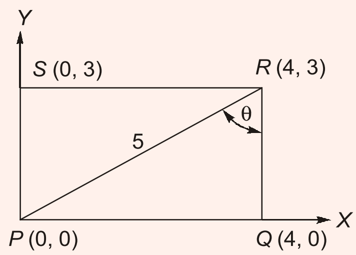
Ans. (d)

Explanations: The Eigen values of an orthogonal matrix are of magnitude 1 and are real (a) complex conjugate pairs.

End of Solution

Q.30 A rectangular region in a solid is in a state of plane strain. The (x, y) coordinates of the corners of the undeformed rectangle are given by $P(0, 0)$, $Q(4, 3)$, $S(0, 3)$. The rectangle is subjected to uniform strain $\varepsilon_{xx} = 0.001$, $\varepsilon_{yy} = 0.002$, $\gamma_{xy} = 0.003$. The deformed length of the elongated diagonal, upto three decimal places, is ______ units.

Ans. (5.0154)



$$\tan\theta = \frac{4}{3}$$
$$\theta = 53.13°$$
$$2\theta = 106.26°$$
$$\cos 2\theta = -0.27999$$
$$\sin 2\theta = 0.96$$

Normal strain on a oblique plane (i.e. RP) inclined at an angle (θ) is given by

$$(\varepsilon_n)_\theta = \frac{1}{2}[\varepsilon_x + \varepsilon_y] + \frac{1}{2}[\varepsilon_x - \varepsilon_y]\cos 2\theta + \left(\frac{\gamma xy}{2}\right)\sin 2\theta$$

$$(\varepsilon_n)_\theta = \frac{1}{2}[0.001 + 0.002] + \frac{1}{2}[0.001 - 0.002][-0.27999] + \left(\frac{0.003}{2}\right)(0.96)$$

$$(\varepsilon_n)_{\theta\,=\,53.13°} = 0.00308$$

$$(\varepsilon_n)_{\theta\,=\,53.13°} = \frac{\text{Change in length of diagonal}}{\text{Original length of diagonal}} = 0.00308$$

Hence, change in length of diagonal = (0.00308)5 = 0.0154 mm

defirmed length of diagonal = 5 + 0.0154 = 5.0154 mm

End of Solution

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MADE EASY Students Top in ESE-2016

84% Selections in ESE 2016

AIR 1 — Civil — Jatin Kumar

AIR 1 — Mechanical — M. Idul Ahmad

AIR 1 — Electrical — Gaurav

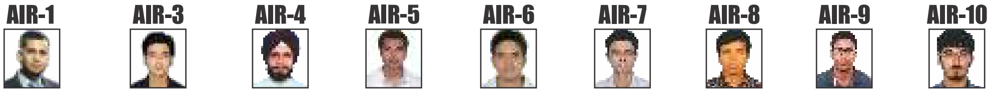
AIR 1 — Electronics & Tel. — Naveen Sharma

4 Streams, 4 Toppers all 4 MADE EASY Students

CE — 10 Selections in Top 10

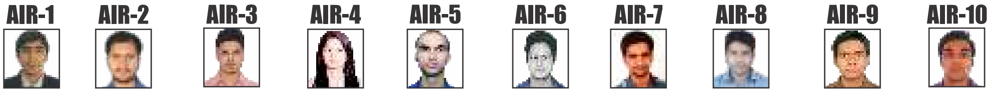
AIR-1	AIR-2	AIR-3	AIR-4	AIR-5	AIR-6	AIR-7	AIR-8	AIR-9	AIR-10
Jatin Kumar	Bivek Joishi	Rachit Jain	Adarsh R.S.	Mahipal Singh	Nitish Garg	Shivam D.	Amrit Anand	Avdhesh	Himanshu Tiwari

ME — 9 Selections in Top 10



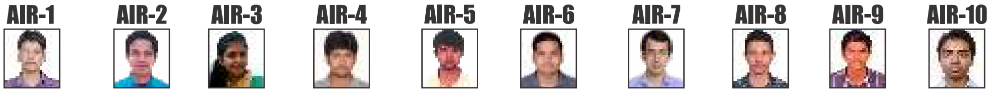
AIR-1	AIR-3	AIR-4	AIR-5	AIR-6	AIR-7	AIR-8	AIR-9	AIR-10
Mohd Idul Ahmad	Chirag Srivastav	Taronjot Singh	Deepak Vijay	Dheeraj Kumar	Tarun Kumar	JGMV Pramod	Gaurav Kant	Jivitesh Anand

EE — 10 Selections in Top 10



AIR-1	AIR-2	AIR-3	AIR-4	AIR-5	AIR-6	AIR-7	AIR-8	AIR-9	AIR-10
Gaurav	B Venkatesh	Tanuj K Sharma	Varsha	Ashish Verma	Mufeed Khan	Shyamji D.	Sk Taushifur R.	Arvind Biswal	Gaurav Tyagi

E&T — 10 Selections in Top 10



AIR-1	AIR-2	AIR-3	AIR-4	AIR-5	AIR-6	AIR-7	AIR-8	AIR-9	AIR-10
Naveen B. Sharma	Amit Rawat	Aswathy S.	Thaduri Naveen	Vinit Ranjan	Harshit Jain	Akash Chhikara	Vivek Jain	Jadugurla N.	Prabhakar

39 Selections in Top 10 | **76** Selections in Top 20 | **505** Selections out of total 604 vacancies

CE	Selections in Top 10 **10**	MADE EASY Selections **182** Out of **225** Vacancies	MADE EASY Percentage **81%**
ME	Selections in Top 10 **9**	MADE EASY Selections **159** Out of **179** Vacancies	MADE EASY Percentage **89%**
EE	Selections in Top 10 **10**	MADE EASY Selections **86** Out of **106** Vacancies	MADE EASY Percentage **81%**
E&T	Selections in Top 10 **10**	MADE EASY Selections **78** Out of **94** Vacancies	MADE EASY Percentage **83%**

"2 out of every 3 selected students, are from CLASSROOM COURSE"

Detailed results are available at : www.madeeasy.in

Q.31 For a steady flow, the velocity field is $\vec{V} = \left(-x^2+3y\right)\hat{i}+\left(2xy\right)\hat{j}$. The magnitude of the acceleration of a particle at (1, – 1) is

(a) 2 (b) 1

(c) $2\sqrt{5}$ (d) 0

Ans. **(c)**

Given velocity field,

$$\vec{V} = (-x^2+3y)\hat{i}+(2xy)\hat{j}$$

where $u = -x^2 + 3y$ and $v = 2xy$

The acceleration components along x and y-axis.

$$a_x = u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y} \quad \text{and} \quad a_y = u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}$$

$$= (-x^2 + 3y) \times (-2x) + 2xy \times 3 = 2x^3 - 6xy + 6xy = 2x^3$$

and $a_y = (-x^2 + 3y) \times 2y + 2xy \times 2x$

$$= -2yx^2 + 6y^2 + 4x^2y = 2yx^2 + 6y^2$$

At point (1, –1),

$$a_x = 2$$

and $a_y = 2 \times (-1) \times 1 + 6 \times (-1)^2 = -2 + 6 = 4$

$$\vec{a} = a_x\hat{i}+a_y\hat{j} = 2i+4\hat{j}$$

Resultant acceleration: $a = \sqrt{4+16} = \sqrt{20} = \sqrt{4\times 5} = 2\sqrt{5}$

End of Solution

Q.32 Moist air is treated as an ideal gas mixture of water vapor and dry air (molecular weight of air = 28.84 and molecular weight of water = 18). At a location, the total pressure is 100 kPa, the temperature is 30°C and the relative humidity is 55%. Given that the saturation pressure of water at 30°C is 4246 Pa, the mass of water vapor per kg of dry air is __________ grams.

Ans. **(14.92)**

Relative humidity: $\phi = \dfrac{p_v}{p_{vs}}$

$$0.55 = \frac{p_v}{4246}$$

or $p_v = 2335.3 \text{ Pa} = 2.335 \text{ kPa}$

$\therefore$ $$\omega = \frac{(\text{Mol. wt})_{H_2O}}{(\text{Mol. wt})_{air}}\times\left(\frac{p_v}{p-p_v}\right) = \frac{18}{28.84}\times\left(\frac{2.335}{100-2.335}\right)$$

$$= 0.01492 \text{ kg/kg of d.a}$$

also $\omega = \dfrac{m_v}{m_a}$

$\therefore$ $0.01492 = \dfrac{m_v}{1}$

or $m_v = 0.01492 \text{ kg} = 14.92 \text{ gm}$

End of Solution

Q.33 Air contains 79% N_2 and 21% O_2 on a molar basis. Methane (CH_4) is burned with 50% excess air than required stoichiometrically. Assuming complete combustion of methane, the molar percentage of N_2 in the products is __________.

Ans. (73.83)

Stoichiometric raction $CH_4 + 2\cdot\left[O_2 + \frac{79}{21}N_2\right] \rightarrow 2H_2O + CO_2 + 2\times\frac{79}{21}\times N_2$

50% excess air:

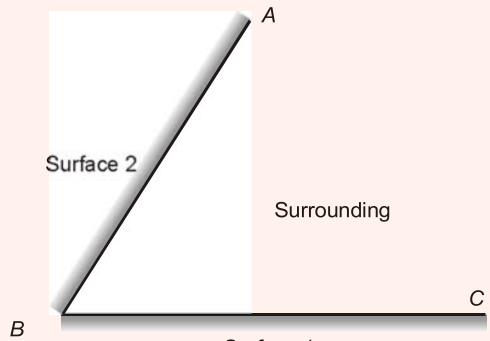
$$CH_4 + 3\cdot\left[O_2 + \frac{79}{21}N_2\right] \rightarrow 2H_2O + CO_2 + 3\times\frac{79}{21}\times N_2 + O_2$$

$$\%N_2 = \frac{\frac{3\times 79}{21}}{2+1+1+3\times\frac{79}{21}}\times 100$$

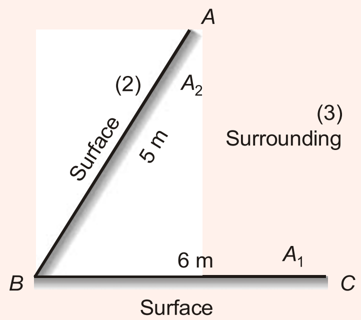
$$= 73.83\%$$

End of Solution

Q.34 Two black surfaces, *AB* and *BC*, of length 5 m and 6 m, respectively, are oriented as shown. Both surfaces extend infinitely into the third dimension. Given that view factor F_{12} = 0.5. T_1 = 800 K, T_2 = 600 K, $T_{surrounding}$ = 300 K and Stefan Boltzmann constant, σ = 5.67 × 10^{-8} W/(m^2K^4), the heat transfer rate from Surface 2 to the surrounding environment is __________ kW.



Ans. (13.778)



$$F_{12} = 0.5$$
$$T_1 = 800 \text{ K}$$
$$T_2 = 600 \text{ K}$$
$$T_{surrounding} = 300 \text{ K}$$

Let (3) denote the surrounding environment

(Assume unit width perpendicular to plane of Fig.)

From summation rule:

$$F_{21} + \cancel{F_{22}}^{\,0} + F_{23} = 1$$

$$A_1F_{12} = A_2F_{21} \Rightarrow 6 \times 1 \times 0.5 = (5 \times 1) \times F_{21}$$

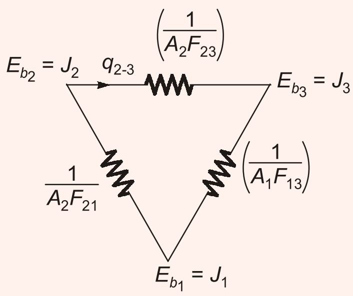
$$F_{21} = \frac{6 \times 0.5}{5} = 0.6$$

$$\therefore \qquad F_{23} = 1 - F_{21} = 0.4$$

Since surrounding environment being large,

No surface has a surface resistance

Heat transfer rate from (2) and (3) $= \dfrac{E_{b_2} - E_{b_3}}{\dfrac{1}{A_2F_{23}}}$



$$= \frac{\sigma\left(T_2^4 - T_3^4\right)}{\dfrac{1}{A_2F_{23}}}$$

$$= \frac{5.67 \times 10^{-8}\left(600^4 - 300^4\right)}{\left(\dfrac{1}{5 \times 1 \times 0.4}\right)} \text{ watt/metre} = 13.778 \text{ kW/metre}$$

Assume that heat exchange is per unit width perpendicular to plane of figure.

End of Solution

Q.35 Consider steady flow of an incompressible fluid through two long and straight pipes of diameters d_1 and d_2 arranged in series. Both pipes are of equal length and the flow is turbulent in both pipes. The friction factor for turbulent flow though pipes is of the for, $f = K(\text{Re})^{-n}$, Where K and n are known positive constants and Re is the Reynolds number. Neglecting minor losses, the ratio of the frictional pressure drop in pipe 1 to that in pipe 2. $\left(\dfrac{\Delta P_1}{\Delta P_2}\right)$, is given by

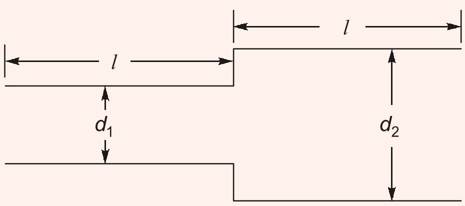
(a) $\left(\dfrac{d_2}{d_1}\right)^{(5-n)}$

(b) $\left(\dfrac{d_2}{d_1}\right)^{5}$

(c) $\left(\dfrac{d_2}{d_1}\right)^{(3-n)}$

(d) $\left(\dfrac{d_2}{d_1}\right)^{(5+n)}$

Ans. (a)



For series connection,

$$Q_1 = Q_2 = Q$$

As given $l_1 = l_2 = l$

For horizontal pipe, $h_f = \Delta p$

$$h_{f_1} = \frac{f_1 L Q^2}{12.1 d_1^5}$$

$$h_{f_2} = \frac{f_2 L Q^2}{12.1 d_2^5}$$

$$\frac{\Delta P_1}{\Delta P_2} = \frac{f_1}{d_1^5} \times \frac{d_2^5}{f_2} \quad \ldots(i)$$

$$f = \frac{k}{\text{Re}^n} = \frac{k}{\left(\frac{VD}{\nu}\right)^n}$$

$$Q = \frac{\pi}{4} D^2 \times V$$

$$V \propto \frac{1}{D^2}$$

$$f \propto \frac{1}{\left(\frac{1}{D^2} D\right)^n}$$

By equation (i) $f \propto D^n$

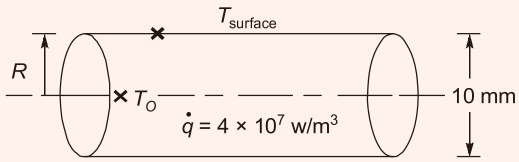
$$\frac{\Delta P_1}{\Delta P_2} = \frac{D_1^n}{D_1^5} \times \frac{D_2^5}{D_2^n}$$

$$\frac{\Delta P_1}{\Delta P_2} = \frac{D_2^{5-n}}{D_1^{5-n}}$$

End of Solution

Q.36 Heat is generated uniformly in a long solid cylindrical rod (diameter = 10 mm) at the rate of 4×10^7 W/m^3. The thermal conductivity of the rod material is 25 W/mK. Under steady state conditions, the temperature difference between the centre and the surface of the rod is ________°C.

Ans. (10)



T_O = Temp. of cylinder at the axis
T_S = Surface Temp. of Rod (cylinder)

$T_O - T_S = \dfrac{\dot{q}}{4k}R^2$ $\dot{q}$ uniform heat generation rate per unit volume (w/m^3)

$$T_O - T_S = \frac{4 \times 10^7}{4 \times 25} \times \left(\frac{5}{1000}\right)^2 = 10°\text{C}$$

End of Solution

Q.37 Two cutting tools with tool life equations given below are being compared:
Tool 1 : $VT^{0.1} = 150$
Tool 2 : $VT^{0.3} = 300$
where V is cutting speed in m/minute and T is tool life in minutes. The breakeven cutting speed beyond which Tool 2 will have a higher tool life is_________ m/minute.

Ans. (106.066)

Let us assume the speed is x m/min.

$$xT_1^{0.1} = 150$$

$$\Rightarrow \quad T_1 = \left(\frac{150}{x}\right)^{\frac{1}{0.1}} \quad \text{and} \quad xT_2^{0.3} = 300$$

$$T_2 = \left(\frac{300}{x}\right)^{\frac{1}{0.3}}$$

Now $T_2 > T_1$

or $$\left(\frac{300}{x}\right)^{\frac{1}{0.3}} = \left(\frac{150}{x}\right)^{\frac{1}{0.1}}$$

For solving inequality

$$\left(\frac{300}{x}\right)^{\frac{1}{0.3}} = \left(\frac{150}{x}\right)^{\frac{1}{0.1}}$$

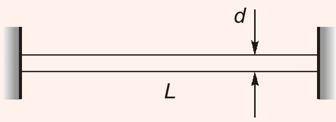
or $$\left(\frac{300}{x}\right)^{0.1} = \left(\frac{150}{x}\right)^{0.3}$$

or $$\frac{x^{0.3}}{x^{0.1}} = \frac{150^{0.3}}{300^{0.1}}$$

or $$x = 106.066 \text{ m/min}$$

End of Solution

Q.38 An initially stress-free massless elastic beam of length L and circular cross-section with diameter $d(d << L)$ is held fixed between two walls as shown. The beam material has Young's modulus E and coefficient of thermal expansion α.



If the beam is slowly and uniformly heated, the temperature rise required to cause the beam to buckle is proportional to

(a) d (b) d^2
(c) d^3 (d) d^4

Ans. (b)

Condition for buckling,

(Reaction offered by the fixed support) > Buckling load

i.e. $R > Pe$

$$\sigma_{Th}\ A > \frac{\pi^2 EI_{min}}{L_e^2}$$

$$\alpha\ (\Delta T)\ EA > \frac{\pi^2 EI_{min}}{(L_e)^2}$$

for cicular cross-section

$$\alpha(\Delta T)E\frac{\pi}{4}d^2 > \frac{\pi^2 E}{(L_e)^2}\frac{\pi}{64}d^4$$

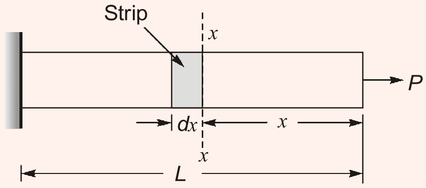
$$\Delta T > \frac{\pi^2 d^2}{16\alpha(L_e)^2}$$

Hence, $\Delta T \propto d^2$

End of Solution

Q.39 A horizontal bar, fixed at one end ($x = 0$), has a length of 1 m, and cross-sectional area of 100 mm^2. Its elastic modulus varies along its length as given by $E(x) = 100e^{-x}$ GPa, where x is the length coordinate (in m) along the axis of the bar. An axial tensile load of 10 kN is applied at the free end ($x = 1$). The axial displacement of the free end is ______ mm.

Ans. (1.7183)



Change in length of small strip,

$$\delta = \frac{P_{x-x}(dx)}{A_{x-x}E_{xx}}$$

Total change in length of bar,

$$\delta_{\text{total}} = \int_0^L \delta = \int_0^L \frac{(P_{x-x})(dx)}{(A_{x-x})E_{x-x}}$$

$$P_{x-x} = P = \text{Constant}$$

$$A_{x-x} = A = \text{Constant}$$

$$E_{x-x} = 100\ e^{-x}\ \text{GPA}$$

$$\delta_{\text{total}} = \frac{P}{A}\int_0^L \frac{dx}{100e^{-x}} = \frac{P}{10^9 \times 100\ A}\int_0^L \frac{dx}{e^{-x}}$$

$$= \frac{10000}{1000 \times \dfrac{100\times 10^9}{10^6}}\int_0^{1\text{m}} \frac{dx}{e^{-x}} = \frac{1}{1000}[1.7183]\,\text{m}$$

Hence, $\delta_{\text{total}} = 1.7183$ mm

End of Solution

Q.40 Two disc A and B with identical mass (m) and radius (R) are initially at rest. They roll down from the top of identical inclined planes without slipping. Disc A has all of its mass concentrated at the rim, while Disc B has its mass uniformly distributed. At the bottom of the plane, the ratio of velocity of the center of disc A to the velocity of the center of disc B is

(a) $\sqrt{\frac{3}{4}}$ (b) $\sqrt{\frac{3}{2}}$

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

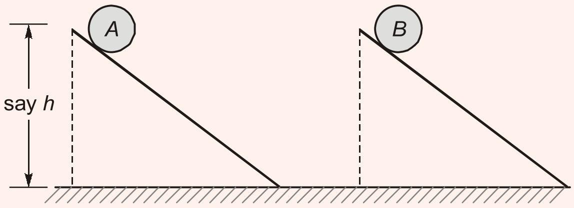
Ans. (a)

$$m_A = m_B = m$$

Outer circumferential radius of both disc A and B is also same i.e. R

$$I_A = mR^2$$

$$I_B = \frac{mR^2}{2}$$



Identical inclined planes

$\frac{V_A}{V_B}$ at bottom of plane = ?

$$mgh = (K \cdot E) \text{ of disc } A = K \cdot E \text{ of disc } B$$

$$\frac{1}{2}mV_A^2 + \frac{1}{2}I_A\omega_A^2 = \frac{1}{2}mV_B^2 + \frac{1}{2}I_B\omega_B^2$$

$$\frac{1}{2}mV_A^2 + \frac{1}{2}mR^2\frac{V_A^2}{R^2} = \frac{1}{2}mV_B^2 + \frac{1}{2}\frac{mR^2}{2} \times \frac{V_B^2}{R^2}$$

$$\frac{V_A^2}{2} + \frac{V_A^2}{2} = \frac{V_B^2}{2} + \frac{V_B^2}{4}$$

$$V_A^2 = \frac{3}{4}V_B^2$$

$$\frac{V_A}{V_B} = \sqrt{\frac{3}{4}}$$

End of Solution

Q.41 The velocity profile inside the boundary layer for flow over a plate is given as $\frac{u}{U_\infty} = \sin\left(\frac{\pi}{2}\frac{y}{\delta}\right)$, where U_∞ is the free stream velocity and δ is the local boundary layer thickness. If δ^* is the local displacement thickness, the value of $\frac{\delta^*}{\delta}$ is

(a) $\frac{2}{\pi}$

(b) $1-\frac{2}{\pi}$

(c) $1+\frac{2}{\pi}$

(d) 0

Ans. (b)

Given $\frac{u}{U_\infty} = \sin\left(\frac{\pi}{2}\frac{y}{\delta}\right)$

where δ = Boundary layer thickness

Local displacement thickness,

$$\delta^* = \int_0^\delta \left(1 - \frac{u}{U_\infty}\right)dy = \int_0^\delta \left[1 - \sin\left(\frac{\pi y}{2\delta}\right)\right]dy$$

$$= \left[y + \frac{2\delta}{\pi} \times \cos\left(\frac{\pi y}{2\delta}\right)\right]_0^\delta = \left[\delta + 0 - 0 - \frac{2\delta}{\pi}\right]$$

$$\delta^* = \delta\left(1 - \frac{2}{\pi}\right)$$

or, $$\frac{\delta^*}{\delta} = 1 - \frac{2}{\pi}$$

End of Solution

Q.42 P(0, 3), Q(0.5, 4) and R(1, 5) are three points on the curve defined by $f(x)$. Numerical integration is carried out using both Trapezoidal rule and Simpson's rule within limits x = 0 and x = 1 for the curve. The difference between the two results will be

(a) 0 (b) 0.25
(c) 0.5 (d) 1

Ans. **(a)**

x	0	0.5	1
y	3_{y0}	4_{y1}	5_{y2}

By Trapezoidal rule

$$\int_0^1 f(x)dx = \frac{h}{2}[(y_0 + y_2) + 2y_1] = \frac{0.5}{2}[(3+5)+2(4)] = 4$$

By Simpson rule

$$\int_0^1 f(x)dx = \frac{h}{3}[(y_0 + y_2) + 4y_1] = \frac{0.5}{3}[(3+5)+4(4)] = 4$$

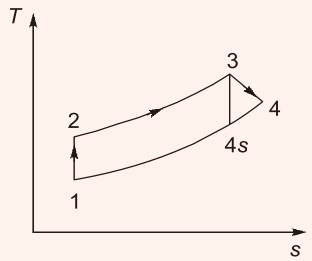
The difference between the two results will be zero.

End of Solution

Q.43 The pressure ratio across a gas turbine (for air, specific heat at constat pressure, c_p = 1040 J/kgK and ratio of specific heats γ = 1.4) is 10. If the inlet temperature to the turbine is 1200 K and the isentropic efficiency is 0.9, the gas temperature at turbine exit is ________ K.

Ans. **(679.4)**

Given data: c_p = 1040 J/kgK; γ = 1.4; r_p = 10; T_3 = 1200 K; η_T = 0.9



$$\frac{T_3}{T_{4s}} = (r_p)^{\frac{\gamma-1}{\gamma}}$$

$$\frac{1200}{T_{4s}} = (10)^{(1.4 - 1)/1.4}$$

or $$T_{4s} = 621.53 \text{ K}$$

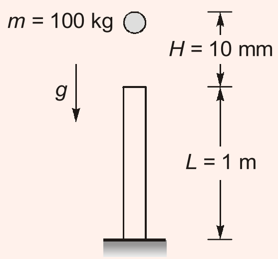
$$\eta_T = \frac{T_3 - T_4}{T_3 - T_{4s}}$$

$$0.9 = \frac{1200 - T_4}{1200 - 621.53}$$

or $$T_4 = 679.4 \text{ K}$$

End of Solution

Q.44 A point mass of 100 kg is dropped onto a massless elastic bar (cross-sectional area = 100 mm^2, length = 1 m, Young's modulus = 100 GPa) from a height H of 10 mm as shown (Figure is not to scale). If g = 10 m/s^2, the maximum compression of the elastic bar is ________ mm.



Ans. (1.5178)

Given loading is impact loading

$$\delta_{impact} = \delta_{static} \times \text{Impact factor}$$

$$\delta_{static} = \frac{WL}{AE} = \frac{100 \times 10 \times 1000}{100 \times 100 \times 10^3} = 0.1 \text{ mm}$$

$$\text{Impact factor (I.F.)} = 1+\sqrt{1+\frac{2h}{\delta_{static}}} = 1+\sqrt{1+\frac{2\times 10}{0.1}} = 15.178$$

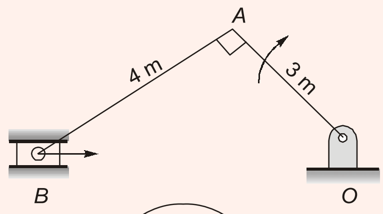
Hence maximum compression of bar

$$= \text{Impact elongation} = 0.1 \times 15.178 = 1.5178 \text{ mm}$$

End of Solution

Q.45 For an inline slider-crank mechanism, the length of the crank and connecting rod are 3 m and 4 m, respectively. At the instant when the connecting rod is perpendicular to the crank, if the velocity of the slider is 1 m/s, the magnitude of angular velocity (upto 3 decimal points accuracy) of the crank is ________ radian/s.

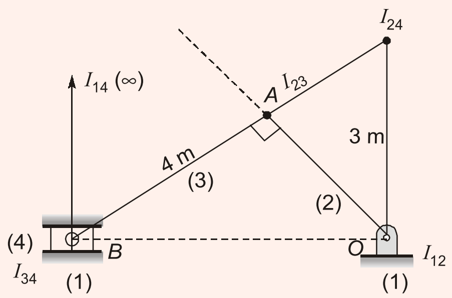
Ans. (0.266)

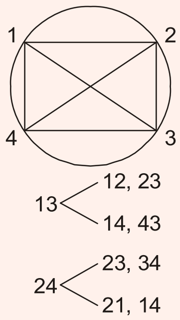


Here $V_B = 1$ m/s

$\omega_{crank} = ?$

Let us draw the I-centres





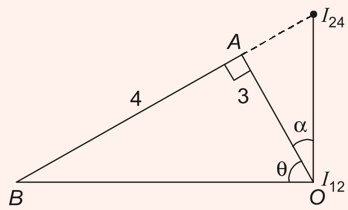
Applying angular velocity theorem at I_{24}

$\therefore$ $\omega_2(I_{24}\, I_{12}) = V_4 = V_B = 1$

$\omega_2(I_{24}\, I_{12}) = 1$

$\theta = \tan^{-1}(4/3) = 53.13010$

$\alpha = 90° - \theta = 36.869$



$$\cos\alpha = \frac{3}{I_{12}\, I_{24}}$$

$$I_{12}\, I_{24} = \frac{3}{\cos 36.869} = 3.7499 \text{ meter}$$

Now, $\omega_2\,(3.7499) = 1$

$$\omega_2 = \frac{1}{3.7499} = 0.266 \text{ rad/s}$$

End of Solution

Q.46 For the vector $\vec{V} = 2yz\hat{i} + 3xz\hat{j} + 4xy\hat{k}$, the value of $\nabla \cdot (\nabla \times \vec{V})$ is ________.

Ans. **(0)**

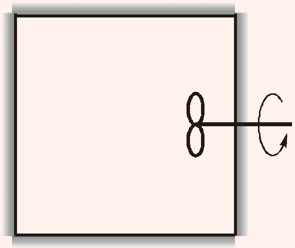
By vector identities

$$\text{div. (curl } \bar{F}) = 0$$

End of Solution

Q.47 One kg of an ideal gas (gas constant, R = 400 J/kgK; specific heat at constant volume, c_p = 1000 J/kgK) at 1 bar, and 300 K is contained in a sealed rigid cylinder. During an adiabatic process, 100 kJ of work is done on the system by a stirrer. The increase in entropy of the system is _______ J/K.

Ans. **(287.682)**



$$m = 1 \text{ kg}; \quad R = 400 \text{ J/kg-K}$$
$$c_v = 1000 \text{ J/kg-K}$$
$$T_i = 300 \text{ K}; \quad P_i = 100 \text{ kPa}$$
$$W = 100 \text{ kJ}$$

Applying first law:

$$Q = \Delta U + W$$
$$\Rightarrow \quad 0 = mc_v(T_f - T_i) + (-100) \times 10^3 \text{ J}$$
$$\Rightarrow \quad 0 = 1 \times 1000 \times (T_f - 300) - 100 \times 10^3$$
$$\Rightarrow \quad T_f = 400 \text{ K}$$

Entropy change for ideal gas

$$\Delta S = m\left[C_v \ln\frac{T_f}{T_i} + R\ln\frac{V_f}{V_i}\right] \qquad \because V_i = V_f$$
$$= 1 \times \left[1000 \ln\frac{400}{300} + 0\right]$$
$$= 287.682 \text{ J/K}$$

End of Solution

Q.48 A block of length 200 mm is machined by a slab milling cutter 34 mm in diameter. The depth of cut and table feed are set at 2 mm and 18 mm/minute, respectively. Considering the approach and the over travel of the cutter to be same, the minimum estimated machining time per pass is ________ minutes.

Ans. **(12)**

Feed rate F = 18 mm/min

Block length L = 200 mm

Approach length = over travel length = L_i

$$= \sqrt{d(D-d)} = \sqrt{2 \times (34-2)} = 8 \text{ mm}$$

Machining time per pass,

$$t = \frac{L + 2L_i}{F} = \frac{200 + 2 \times 8}{18} = 12 \text{ min.}$$

End of Solution

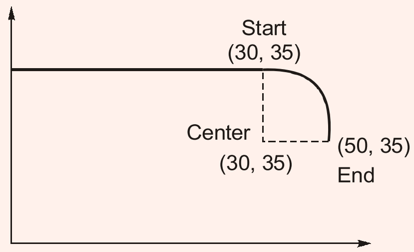
Q.49 Circular arc on a part profile is being machined on a vertical CNC milling machine, CNC part program using metric units with absolute dimensions is listed below:

....
N60 G01 X 30 Y 55 Z 5 F50
N70 G02 X 50 Y 35 R 20
N80 G01 Z 5
....

The coordinates of the centre of the circular arc are:

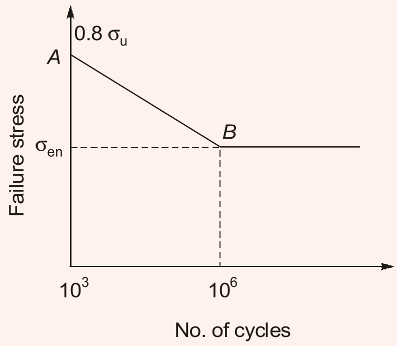
(a) (30, 55)
(b) (50, 55)
(c) (50, 35)
(d) (30, 35)

Ans. (d)



End of Solution

Q.50 A machine element has an ultimate strength (σ_u) of 600 N/mm^2, and endurance limit (σ_{en}) of 250 N/mm^2. The fatigue curve for the element on a log-log plot is shown below. If the element is to be designed for a finite life of 10000 cycles, the maximum amplitude of a completely reversed operating stress is ________ N/mm^2.



Ans. (386.195)

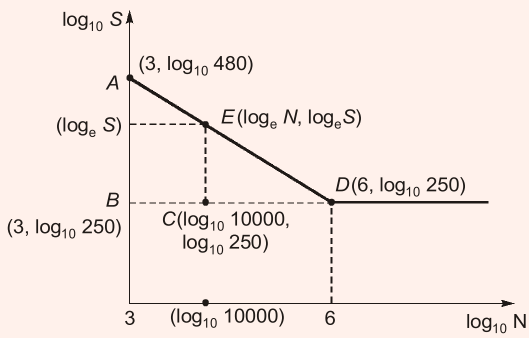
From two similar triangles,
(i.e. ΔABD and ΔECD)

$$\frac{AB}{EC} = \frac{BD}{CD}$$

$$\frac{(\log_{10} 480 - \log_{10} 250)}{(\log_{10} S - \log_{10} - 250)} = \frac{6-3}{6 - \log_{10} 10000}$$

$$\frac{2.68124 - 2.39794}{\log_{10} S - 2.39794} = 1.5$$

$$S = 386.195 \text{ N/mm}^2$$



End of Solution

Q.51 Two models, P and Q of a product earn profits of Rs. 100 and Rs. 80 per piece, respectively. Production times for P and Q are 5 hours and 3 hours, respectively, while the total production time available is 150 hours. For a total batch size of 40, to maximize profit, the member of units of P to be produced is ________.

Ans. (15)

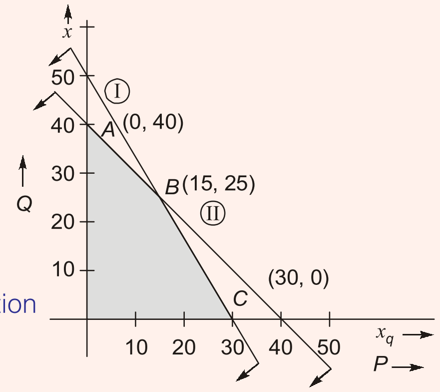
$$\text{Max. } Z = 100 \cdot P + 80 \cdot Q$$

$$5P + 3Q \leq 150$$

$$P + Q \leq 40$$

$$\frac{P}{30} + \frac{Q}{50} = 1$$

$$\frac{P}{40} + \frac{Q}{40} = 1$$



Putting value of corner point in objective function

$$Z(A) = 3200$$
$$Z(B) = 3500$$
$$Z(C) = 3000$$

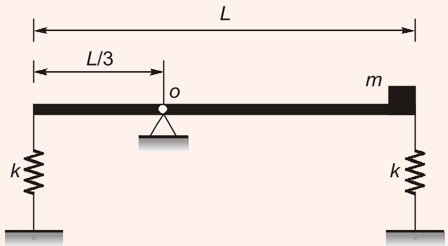
Maximum at B, $P = 15$, $Q = 25$

End of Solution

Q.52 A thin uniform rigid bar of length L and M is hinged at point O, located at a distance of $L/3$ from one of its ends. The bar is further supported using springs, each of stiffness k, located at the two ends. A particle of mass $m = M/4$ is fixed at one end of the bar, as shown in the figure. For small rotations of the bar about O, the natural frequency of the system is

(a) $\sqrt{\frac{5k}{M}}$ (b) $\sqrt{\frac{5k}{2M}}$

(c) $\sqrt{\frac{3k}{2M}}$ (d) $\sqrt{\frac{3k}{M}}$



Ans. (b)

Taking Mass moment of inertia about point O,

$$I = \frac{Ml^2}{12} + M\left(\frac{l}{2} - \frac{l}{3}\right)^2 + m \times \left(\frac{2l}{3}\right)^2$$

$$= \frac{Ml^2}{12} + \frac{Ml^2}{36} + \frac{4Ml^2}{9} = \frac{Ml^2}{9} + \frac{4Ml^2}{4 \times 9} = \frac{2Ml^2}{9}$$

Now we will balance torque about O,

$$I\alpha = K \times \frac{2L}{3} \times \left(\frac{2L}{3}\theta\right) + K \times \frac{L}{3} \times \left(\frac{L}{3}\theta\right)$$

$$\frac{2Ml^2}{9}\frac{d^2\theta}{dt^2} = \frac{5K}{2M} = \omega_n^2\theta$$

$$\therefore \quad \omega_n = \sqrt{\frac{5K}{2M}}$$

End of Solution

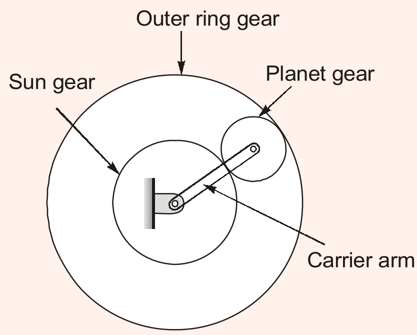
Q.53 A 10 mm deep cylindrical cup with diameter of 15 mm is drawn from a circular blank. Neglecting the variation in the sheet thickness, the diameter (upto 2 decimal points accuracy) of the blank is ________ mm.

Ans. (28.723)

$$D = \sqrt{d^2 + 4dh} = \sqrt{15^2 + 4 \times 15 \times 10} = 28.723 \text{ mm}$$

End of Solution

Q.54 In an epicyclic gear train, shown in the figure, the outer ring gear is fixed, while the sun gear rotates counterclockwise at 100 rpm. Let the number of teeth on the sun planet and outer gears to be 50, 25 and 100, respectively. The ratio of magnitude of angular velocity of the planet gear to the angular velocity of the carrier arm is ______.



Ans. (3)

We take convention clockwise (+ve)

$N_D = 0$

$N_S = -100$

$T_S = 50, \quad T_P = 25, \quad T_D = 100$

$\dfrac{N_P}{N_{ARM}} = ?$

Motions	Arm	S (50)	P (25)	D (100)
1. Arm fixed let sun rotates by $+x$ r.p.m. clockwise	0	$+x$	$\dfrac{-x \times 50}{25}$	$-x \times \left(\dfrac{50}{25}\right) \times \left(\dfrac{25}{100}\right)$
2. Amr free	y	$(y + x)$	$(y - 2x)$	$\left(y - \dfrac{x}{2}\right)$

$y + x = -100 \quad \ldots \text{(i)}$

$y - \dfrac{x}{2} = 0 \quad \ldots \text{(ii)}$

By equation (i) – (ii),

$$\frac{3x}{2} = -100 = x = \frac{-200}{3}$$

$$y = -100 - x = -100 + \frac{200}{3} = \frac{-100}{3}$$

$$N_P = y - 2x = \frac{-100}{3} + \frac{400}{3} = \frac{300}{3} = 100$$

$$N_{ARM} = y = \frac{-100}{3}$$

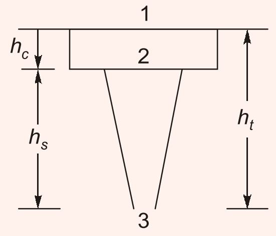
$$\frac{N_P}{N_{ARM}} = \frac{100}{\frac{-100}{3}} = -3$$

$$\left|\frac{N_P}{N_{ARM}}\right| = 3$$

End of Solution

Q.55 A sprue in a sand mould has a top diameter of 20 mm and height of 200 mm. The velocity of the molten metal at the entry of the sprue is 0.5 m/s. Assume acceleration due to gravity as 9.8 m/s^2 and neglect all losses. If the mould is well ventilated, the velocity (upto 3 decimal points accuracy) of the molten metal at the bottom of the sprue is _________ m/s.

Ans. (2.043)



$$d_2 = 20 \text{ mm}$$
$$h_s = 200 \text{ mm}$$
$$u_2 = 0.5 \text{ m/s}$$
$$g = 9.8 \text{ m/s}^2$$
$$u_3 = ?$$
$$u_2 = \sqrt{2gh_c}$$
$$0.5 = \sqrt{2 \times 9.81 \times h_c}$$
$$\Rightarrow \quad h_c = 0.01274 \text{ m}$$
$$h_t = h_s + h_c = 0.200 + 0.01274 = 0.2127 \text{ m}$$
$$u_3 = \sqrt{2gh_t} = \sqrt{2 \times 9.81 \times 0.2127} = 2.043 \text{ m/s}$$

End of Solution

GENERAL APTITUDE

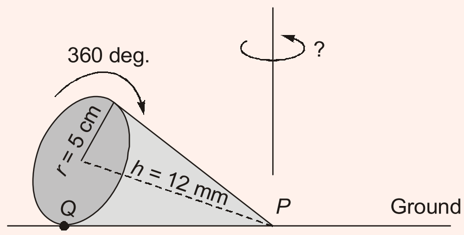
Q.1 He was one of my best _________ and I felt his loss _________.

(a) friend, keenly
(b) friends, keen
(c) friend, keener
(d) friends, keenly

Ans. (d)

End of Solution

Q.2 A right-angled cone (with base radius 5 cm and height 12 cm), as shown in the figure below, is rolled on the ground keeping the point P fixed until the point Q (at the base of the cone, as shown) touches the ground again.



By what angle (in radians) about P does the cone travel?

(a) $\frac{5\pi}{12}$
(b) $\frac{5\pi}{24}$
(c) $\frac{24\pi}{5}$
(d) $\frac{10\pi}{13}$

Ans. (d)

Distance travelled by cone in one rotation

$$= 2\pi r = 2\pi\ (5) = 10\pi \qquad \text{... (i)}$$

$\Rightarrow$ point Q touches ground again after going (10π) distance.

2π order to make complete revolution now slant height will be acting as a radius

$$R = \sqrt{5^2 + 12^2} = 13 \text{ (Radius of larger complete revolution)}$$

$$2\pi R = 2\pi \times 13 = (26\pi) \qquad \text{... (ii)}$$

Now this one rotation angle inscribed in radians will be (i)/(ii)

$$\frac{10\pi}{20\pi} \times 2\pi \text{ radians} = \frac{10\pi}{13} \text{ radians}$$

End of Solution

Q.3 P, Q, and R talk about S's car collection, P states that S has at least 3 cars. Q believes that S has less than 3 cars, R indicates that to his knowledge. S has at least one car. Only one of P, Q and R is right. The number of cars owned by S is

(a) 0
(b) 1
(c) 3
(d) Cannot be determined

Ans. (a)

P says $\rightarrow$ S has atleast 3 Cars
Q says $\rightarrow$ S has less than 3 Cars
R says $\rightarrow$ S has atleast 1 Car

Solve by options

A (0)		B (1)		C (3)	
P	✗	P	✗	P	✓
Q	✓	Q	✓	Q	✗
R	✗	R	✓	R	✓

as given in question only has to be right so answer is 0 (car).

End of Solution

Q.4 As the two speakers became increasingly agitated, the debate became ______.

(a) lukewarm
(b) poetic
(c) forgiving
(d) heated

Ans. (d)

Heated means angry, vehement
Which is reflected by speakers becoming agitated.

End of Solution

Q.5 In a company with 100 employees, 45 earn Rs. 20000 per month, 25 earn Rs. 30000, 20 earn Rs. 40000, 8 earn Rs. 60000, and 2 earn Rs. 150000. The median of the salaries is

(a) Rs. 20000
(b) Rs. 30000

(c) Rs. 32300 (d) Rs. 40000

Ans. (b)

$$45\,p \rightarrow 20K$$
$$25\,p \rightarrow 30K$$
$$20p \rightarrow 40K$$
$$8p \rightarrow 60K$$
$$2p \rightarrow 150K$$

Median will be arithmatic mean 50th and 51st term, so both are in 30K bracket. So average or arithmatic mean of,

$$\frac{30000 + 30000}{2} = \text{Rs. } 30000$$

End of Solution

Q.6 What is the sum of the missing digits in the subtraction problem below?

$$\begin{array}{r} 5\ldots\ldots\ldots \\ -48\_89 \\ \hline 1111 \end{array}$$

(a) 8 (b) 10

(c) 11 (d) Cannot be determined

Ans. (d)

The following Two possibiles exists.

$$\begin{array}{r} 5\ 0\ 1\ 0\ 0 \\ -\ 4\ 8\ 9\ 8\ 9 \\ \hline 0\ 1\ 1\ 1\ 1 \end{array} \quad \text{and} \quad \begin{array}{r} 5\ 0\ 0\ 0\ 0 \\ -\ 4\ 8\ 8\ 8\ 9 \\ \hline 0\ 1\ 1\ 1\ 1 \end{array}$$

Sum = 1 + 9 = 10 Sum = 0 + 8 = 8

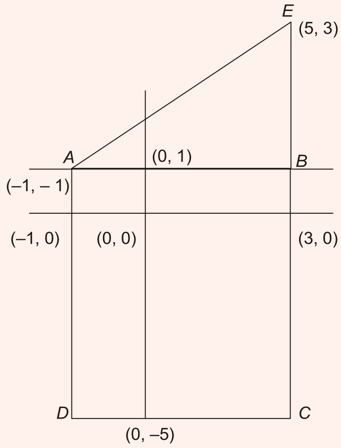
End of Solution

Q.7 Let S_1 be the plane figure consting of the points (x, y) given by the inequalities $|x-1| \le 2$ and $|y+2| \le 3$. Let S_2 be the plane figure given by the inequalities $x - y \ge -2$, $y \ge 1$, and $x \le 3$. Let S be the union of S_1 and S_2. The area of S is

(a) 26 (b) 28

(c) 32 (d) 34

Ans. (c)



$|x-1| \leq 2 \qquad |y+2| \leq 3 \qquad x - y \geq -2$

$x \leq 3 \qquad y \leq 1$

$x \geq -1 \qquad -5 \leq y$

Total area = Area of rectangle ABCD + Area of ΔABE

$$= 4 \times 6 + \frac{1}{2}(4 \times 4) = 32$$

End of Solution

Q.8 Two very famous sportsmen Mark and Steve happened to be brothers, and played for country K. Mark teased James, and opponent from country E. There is no way you are good enough to play for your country. James replied, 'May be not, but at least I am the best player in my own family'.

Which one of the following can be inferred from this conversation.

(a) Mark was known to play better than James
(b) Steve was known to play better than Mark
(c) James and Steve were good friends
(d) James played better than Steve

Ans. (b)

Steve was known to be better player than Mark.

End of Solution

Q.9 Here, throughout the early 1820s, Stuart continued to fight his losing battle to allow his sepoys to year their caste-marks and their own choice of facial hair on parade, being again reprimanded by the commander-in-chief. His retort that A stronger instance than this of European prejudice with relation to this country has never come under my observations had no effect on his superiors.

According to this paragraph, which of the statements below is most accurate?

(a) Stuart's commander-in-chief was moved by this demonstration of his prejudice.
(b) The Europeans were accommondating of the sepoys desire to were their caste-marks

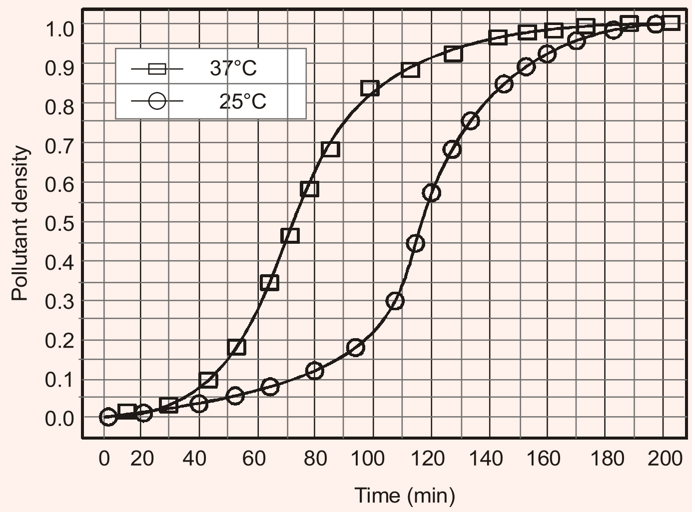
(c) Stuart's losing battle refers to his inability to succeed in enabling sepoys to wear caste-marks.

(d) The commander-in-chief was exempt from the European prejudice that dictated how the sepoys were to dress

Ans. (c)

End of Solution

Q.10 The growth of bacteria (lactobacillus) in milk leads to curd formation. A minimum bacterial population density of 0.8 (in suitable) is needed to form curd. In the graph below, the population density of lactobacillus in 1 litre of milk is plotted as a function of time, at two different temperature, 25°C and 37°C.



Consider the following statements based on the data shown above:

i. The growth in bacterial population stops earlier at 37°C as compared to 25°C

ii. The time taken for curd formation at 25°C is twice the time taken at 37°C

Which one of the following options is correct?

(a) only i
(b) only ii
(c) both i and ii
(d) neither i nor ii

Ans. (a)

We can see graph only (i) follows.

■■■■