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H.O: Unit No: 409, 4th floor, Ashoka My Home Chambers, SP Road, Secunderabad - 500003 Student Support Center: 040 44664244 Email: enquiry@gateforum.in

Section-I: General Ability

1. Seven machines take 7 minutes to make 7 identical toys. At the same rate, how many minutes would it take for 100 machines to make 100 toys?

(A) 1 (B) 7 (C) 100 (D) 700

Key: (B)

Sol: $\frac{7\times 7}{7}=\frac{100\times T_2}{100}$

$\Rightarrow T_2 = 7 \text{ minutes}$

2. "Her ______ should not be confused with miserliness; she is ever willing to assist those in need."

The word that best fills the blank in the above sentence is:

(A) cleanliness (B) punctuality (C) frugality (D) greatness

Key: (C)

Sol: The sentence explains that the person spoken of is not miserly, since she is quite prepared to be generous. So for the sentence to make sense, the word filling the blank has to be something that is consistent with generosity and yet might, by those without a full understanding of her behaviour, be mistaken for miserliness. The words "frugality" and thrift fulfill this requirement and yield two sentences that are alike in meaning. Thus the correct answer is **frugality.**

3. A number consists of two digits. The sum of the digits is 9. If 45 is subtracted from the number, its digits are interchanged. What is the number?

(A) 63 (B) 72 (C) 81 (D) 90

Key: (B)

Sol: Let number be 'xy'

$\text{Given } x+y=9 \quad ...(i)$

$\& \; xy-45=yx$

$\Rightarrow (10x+y)-45=10y+x$

$\Rightarrow 9x-9y=45$

$\Rightarrow x-y=5 \quad ...(ii)$

$\text{solving } (i)\,\&\,(ii) \Rightarrow x=7,\ y=2$

$\text{Required number}=72$

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4. Going by the ______ that many hands make light work, the school _______ involved all the students in the task."

(A) principle, principal
(B) principal, principle
(C) principle, principle
(D) principal, principal

Key: (A)

5. A rectangle becomes a square when its length and breadth are reduced by 10 m and 5 m, respectively. During this process, the rectangle loses 650 m^2 of area. What is the area of the original rectangle in square meters?

(A) 1125 (B) 2250 (C) 2924 (D) 4500

Key: (B)

Sol:

Area of rectangle = $(x+10)(x+5) = x^2+15x+50$ ...(1)

Area of square = x^2 ... (2)

By the given condition,

$15x+50=650$

$\Rightarrow 15x=600 \Rightarrow x=40.$

$\therefore$ Area of rectangle $=(40)^2+15\times 40+50=2250$ ($\because$ from(1))

6. Given that a and b are integers and a+ a^2b^3 is odd, which one of the following statements is correct?

(A) a and b are both odd
(B) a and bare both even
(C) a is even and b is odd
(D) a is odd and b is even

Key: (D)

Sol: By verifying options

Let us consider a=1, b=2

$a+a^2b^3=1+1^2\times 2^3=9$ i.e., odd

Only this condition is valid.

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7. Consider the following three statements:

(i) Some roses are red

(ii) All red flowers fade quickly.

(iii) Some roses fade quickly

Which of the following statements can be logically inferred from the above statements?

(A) If (i) is true and (ii) is false, then (iii) is false.

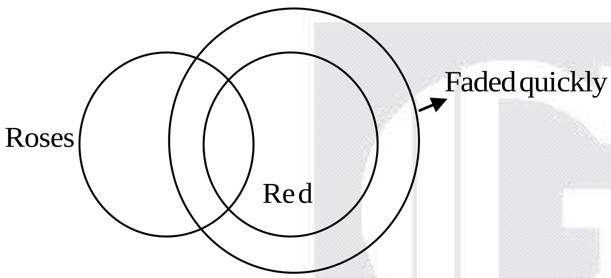
(B) If (i) is true and (ii) is false, then (iii) is true.

(C) If (i) and (ii) are true, then (iii) is true.

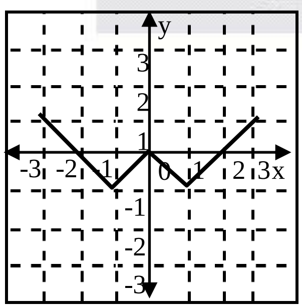
(D) If (i) and (ii) are false, then (iii) is false.

Key: (C)

Sol:



8. Which of the following functions describe the graph shown in the below figure.



(A) $y = ||x| + 1| - 2$ (B) $y = ||x| - 1| - 1$ (C) $y = ||x| + 1| - 1$ (D) $y = ||x - 1| - 1|$

Key: (B)

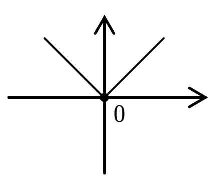
Sol: Given graph passing through X-axis at x= –2, 2

From option (B), y=0 at x= –2, 2

Alternate Method:

Step (1)

$y = |x|$

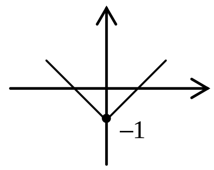


Step(2)

$y+1=|x|$

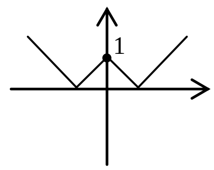
(or)

$y=|x|-1$



Step (3)

$y=||x|-1|$

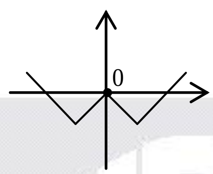


Step(4)

$y+1=||x|-1|$

(or)

$y=||x|-1|-1$



9. From the time the front of a train enters a platform, it takes 25 seconds for the back of the train to leave the platform, while travelling at a constant speed of 54 km/h. At the same speed, it takes 14 seconds to pass a man running at 9 km/h in the same directions as the train. What is the length of the train and that of the platform in meters, respectively?

(A) 210 and 140 (B) 162.5 and 187.5

(C) 245 and 130 (D) 175 and 200

Key: (D)

Sol: Let Train length $= x$

Platform length $= y$

$$\underbrace{\{x+y\}}_{\text{Distance}} = \underbrace{\{25\}}_{\text{Time}} \times \underbrace{\left(54\times\frac{5}{18}\right)}_{\text{Speed}} = 375$$

also, $$\frac{x}{\underbrace{(54-9)}_{\text{Relative speed}}\times\frac{5}{18}}=14$$

$\Rightarrow x=175$ and $y=200$

10. For integers *a*, *b* and *c*, what would be the minimum and maximum values respectively of $a + b + c$ if $\log|a|+\text{lob}|b|+\log|c|=0$?

(A) –3 and 3 (B) –1 and 1 (C) –1 and 3 (D) 1 and 3

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Key: (A)

Sol: Given $\log|a|+\log|b|+\log|c|=0$

$\Rightarrow \log_e |a||b||c|=0$

$\Rightarrow |a||b||c|=1 \Rightarrow a=\pm1,\ b=\pm1, c=\pm1 \ \ (\because a,b,c \text{ are integers})$

Minimum value $=-1-1-1=-3$

Maximum value $=1+1+1=3$

Section-I: Mechanical Engineering

1. An ideal gas undergoes a process from state 1 (T_1 = 300 K, p_1 = 100 kPa) to state 2 (T_2 = 600K, p_2 = 500 kPa). The specific heats of the ideal gas are: c_p = 1 kJ/kg-K and c_v = 0.7 kJ/kgK. The change in specific entropy of the ideal gas from state 1 to state 2 (in kJ/kg-K) is _____ (correct to two decimal places).

Key: (0.21)

Sol: Given that,

$T_1=300\text{K},\ P_1=100\text{kPa}$

$T_2=600\text{K},\ P_2=500\text{kPa}$

$C_p=1\text{kJ/kg-k}$

$C_v=0.7\text{kJ/kg-k},$

$R=C_p-C_v=1-0.7=0.3\text{kJ/kg-k}$

Change in Entropy (s_2-s_1) per unit mass

$$=C_p\ell n\left(\frac{T_2}{T_1}\right)-R\ell n\left(\frac{P_2}{P_1}\right)$$

$$=1\ell n\left(\frac{600}{300}\right)-0.3\ell n\left(\frac{500}{100}\right)$$

$s_2-s_1=0.21\text{kJ/kg-K}$

2. In a linearly hardening plastic material, the true stress beyond initial yielding

(A) increases linearly with the true strain

(B) decreases linearly with the true strain

(C) first increases linearly and then decreases linearly with the true strain

(D) remain constant

Key: (A)

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3. Using the Taylor's tool life equation with exponent n = 0.5, if the cutting speed is reduced by 50%, the ratio of new tool life to original tool life is

(A) 4 (B) 2 (C) 1 (D) 0.5

Key: (A)

Sol: $VT^n = C$

$V_1T_1^n = V_2T_2^n$

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

$$\frac{T_2}{T_1} = \left(\frac{V_1}{0.5V_1}\right)^{\frac{1}{0.5}} \quad (\because V_2 = 0.5V_1)$$

$T_2 = 4T_1$

4. The height (in mm) for a 125 mm sine bar to measure a taper of 27°32' on a flat work piece is________(correct to three decimal places).

Key: (57.77)

Sol: $\theta = 27°32' = 27.53°$

$$\because \sin\theta = \frac{h}{\ell}$$

$h = \ell \sin\theta = (25\sin 27.53) = 57.77\text{mm}$

5. A six-faced fair dice is rolled five times. The probability (in %) of obtaining "ONE" at least four times is

(A) 33.3 (B) 3.33 (C) 0.33 (D) 0.0033

Key: (C)

Sol: $n = 5,\ p(\text{obtaining 'ONE'}) = \frac{1}{6}$

$$\Rightarrow q = 1 - \frac{1}{6} = \frac{5}{6}$$

$p(x \geq 4) = ?$

By Binomial distribution,

$p(x \geq 4) = p(x = 4) + p(x = 5)$

$$= {}^5C_4\left(\frac{1}{6}\right)^4\left(\frac{5}{6}\right)^{5-4} + {}^5C_5\left(\frac{1}{6}\right)^5\left(\frac{5}{6}\right)^{5-5}$$

$$= \frac{26}{6^5} = \frac{26}{6^5} \times 100(\text{in}\%) \simeq 0.33$$

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6. The time series forecasting method that gives equal weightage to each of the m most recent observations is

(A) Moving average method (B) Exponential smoothing with linear trend

(C) Triple Exponential smoothing (D) Kalman Filter

Key (A)

Sol ∵ in Moving Average Method

$$F_{n+1} = \frac{D_n + D_{n-1} + D_{n-2} + \ldots}{n}$$

So, weightage of all past data is $\frac{1}{n}$

i.e., equal weightage provided to all past data.

7. The rank of the matrix $\begin{bmatrix} -4 & 1 & -1 \\ -1 & -1 & -1 \\ 7 & -3 & 1 \end{bmatrix}$ is

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

Key: (B)

Sol: Let $A = \begin{bmatrix} -4 & 1 & -1 \\ -1 & -1 & -1 \\ 7 & -3 & 1 \end{bmatrix}$

$|A| = -4(-1-3) - 1(-1+7) - (3+7) = 0$

consider a 2×2 sub matrix, $\begin{vmatrix} -4 & 1 \\ -1 & -1 \end{vmatrix} = 4 + 1 = 5 \neq 0$

$\Rightarrow$ Rank of $A = 2$

8. Interpolator in a CNC machine

(A) controls spindle speed (B) coordinates axes movements

(C) operates tool changer (D) commands canned cycle

Key: (B)

9. Four red balls, four green balls and four blue balls are put in a box. Three balls are pulled out of the box at random one after another without replacement. The probability that all the three balls are red is

(A) 1/72 (B) 1/55 (C) 1/36 (D) 1/27

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Key: (B)

Sol: 4-Red; 4-Green; 4-Blue

Required probability $=\frac{4}{12}\times\frac{3}{11}\times\frac{2}{10}=\frac{1}{55}$

10. A grinding ratio of 200 implies that the

(A) grinding wheel wears 200 times the volume of the material removed.

(B) grinding wheel wears 0.005 times the volume of the material removed

(C) aspect ratio of abrasive particles used in the grinding wheel is 200

(D) ratio of volume of abrasive particle to that of grinding wheel is 200

Key: (B)

Sol: Grinding ratio $=\frac{\text{MRR}}{\text{wheel wear}}$

$$200=\frac{1}{\text{wheel wear}}$$

$$\text{wheel wear}=\frac{1}{200}=0.005$$

11. Which one of the following statements is correct for a superheated vapour?

(A) Its pressure is less than the saturation pressure at a given temperature.

(B) Its temperature is less than the saturation temperature at a given pressure.

(C) Its volume is less than the volume of the saturated vapour at a given temperature.

(D) Its enthalpy is less than enthalpy of the saturated vapour at a given pressure.

Key: (A)

Sol: At a given temperature the pressure of superheated vapour is less than the saturation pressure. For example let us take100^{o}C, the saturation pressure corresponding to this temperature is 1.01325bar. If the saturation pressure decreases saturation temperature decreases and vice-versa. From this we can easily say that if the superheated temperature has to be 100^{o}C then saturation temperature should be less than 100^{o}C, therefore corresponding saturation pressure will be less.

Hence we can say that for same temperature the pressure of superheated vapour is less than the saturation pressure.

12. If σ_1 and σ_3 are the algebraically largest and smallest principal stresses respectively, the value of the maximum shear stress is

(A) $\frac{\sigma_1+\sigma_3}{2}$ (B) $\frac{\sigma_1-\sigma_3}{2}$ (C) $\sqrt{\frac{\sigma_1+\sigma_3}{2}}$ (D) $\sqrt{\frac{\sigma_1-\sigma_3}{2}}$

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Key: (B)

Sol: Diameter of Mohr circle = $\sigma_1 - \sigma_3$ and

$$\therefore \tau_{max} = \text{Radius} = \frac{\sigma_1 - \sigma_3}{2}$$

13. The number of atoms per unit cell and the number of slip systems, respectively, for a face-centered cubic (FCC) crystal are

(A) 3, 3 (B) 3, 12 (C) 4, 12 (D) 4, 48

Key: (C)

14. A four bar mechanism is made up of links of length 100, 200, 300 and 350 mm. If the 350 mm link is fixed, the number of links that can rotate fully is _______.

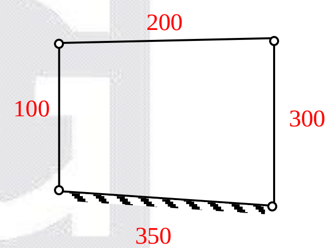
Key: (1)

Sol: $\ell + s < p + q$

$100 + 350 < 200 + 300$

Hence it is crank rocker

(100) link will rotate -1.



So, link whose length is 100 mm will rotate fully. So, only one link will rotate fully.

15. For an Oldham coupling used between two shafts, which among the following statements are correct?

I. Torsional load is transferred along shaft axis.

II. A velocity ratio of 1:2 between shafts is obtained without using gears.

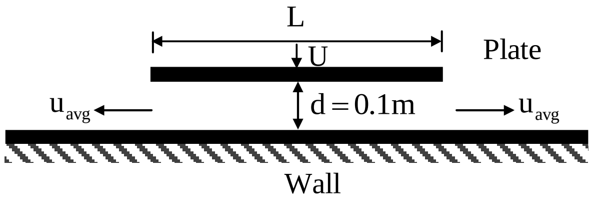
III. Bending load is transferred transverse to shaft axis.

IV. Rotation is transferred along shaft axis.

(A) I and III (B) I and IV (C) II and III (D) II and IV

Key: (B)

16. A flat plate of width L = 1 m is pushed down with a velocity U = 0.01 m/s towards a wall resulting in the drainage of the fluid between the plate and the wall as shown in the figure.



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Assume two-dimensional incompressible flow and that the plate remains parallel to the wall. The average velocity, u_{avg} of the fluid (in m/s) draining out at the instant shown in the figure is ___ (correct to three decimal places).

Key: **(0.05)**

Sol: Let b = length of plate perpendicular to paper

Volume drain out per sec = L.b.U

So, $L.b.U = 2b.u_{avg}.d$

$$u_{avg} = \frac{L.U}{2d} = \frac{1\times 0.01}{2\times 0.1}$$

$$u_{avg} = 0.05\,m/s$$

17. According to the Mean Value Theorem, for a continuous function *f(x)* in the interval [a, *b*], there exists a value ξ in this interval such that $\int_a^b f(x)dx =$

(A) $f(\xi)(b-a)$ (B) $f(b)(\xi-a)$ (C) $f(a)(b-\xi)$ (D) 0

Key: **(A)**

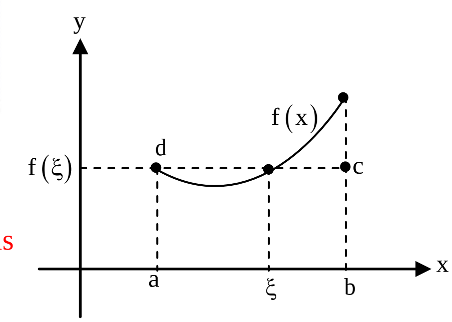
Sol: By using mean value theorem for definite integrals,

$\exists \xi f(a,b)$ s.t $\int_a^b f(x)dx = (b-a)f(\xi)$

$\exists \xi$ in between a & b s.t

Area of rectangle abcd = Area under the curve f(x) with x-axis

i.e., $(b-a)f(\xi) = \int_a^b f(x)dx$



18. A steel column of rectangular section (15 mm × 10 mm) and length 1.5 m is simply supported at both ends. Assuming modulus of elasticity, E = 200GPa for steel, the critical axial load (in kN) is ___ (correct to two decimal places)

Key: **(1.097)**

Sol: $\ell_e = 1500mm, b = 15mm, d = 10mm, E = 200GPa$

$$P_E = \frac{\pi^2 EI}{\ell_e^{\,2}}; \quad I = \frac{15\times 10^3}{12}$$

$$= \frac{\pi^2 \times 200\times 10^3 \times \frac{15\times 10^3}{12}}{(1500)^2} = 1.097kN$$

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19. If the wire diameter of a compressive helical spring is increased by 2%, the change in spring stiffness (in %) is ___ (correct to two decimal places.)

Key: (8.243)

Sol: $d_2 = 1.02d_1$

$$k = \frac{Gd^4}{8WD^3} \Rightarrow k \propto d^4$$

$$\frac{k_1}{k_2} = \left(\frac{d_1}{1.02d_1}\right)^4 \Rightarrow k_2 = 1.082$$

$$\% \text{ change in stiffness} = \frac{k_2 - k_1}{k_1} = \left(\frac{1.082-1}{1}\right) \times 100\% = 8.243\%$$

20. For a two-dimensional incompressible flow field given by $\vec{u} = A\left(x\hat{i} - y\hat{j}\right)$, where $A > 0$, which one of the following statements is FALSE?

(A) It satisfies continuity equation

(B) It is unidirectional when $x \to 0$ and $y \to \infty$,

(C) Its streamlines are given by $x = y$.

(D) It is irrotational

Key: (C)

Sol: $\because$ Equation of streamline

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

$$\int \frac{dy}{y} = \int -\frac{dx}{x} \Rightarrow \ell ny = \ell nx + \ell nc$$

$xy = C$. So, option C is false.

21. The equation of motion for a spring-mass system excited by a harmonic force is

$$m\ddot{x} + Kx = F\cos(\omega t),$$

where M is the mass, K is the spring stiffness, F is the force amplitude and ω is the angular frequency of excitation. Resonance occurs when ω is equal to

(A) $\sqrt{\frac{M}{K}}$ (B) $\frac{1}{2\pi}\sqrt{\frac{K}{M}}$ (C) $2\pi\sqrt{\frac{K}{M}}$ (D) $\sqrt{\frac{K}{M}}$

Key: (D)

Sol: Resonance will occur when, $r = 1$.

i.e., when $\omega = \omega_n = \sqrt{\frac{K}{M}}$

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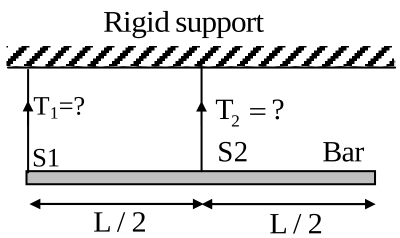
22. A bar of uniform cross section and weighing 100 N is held horizontally using two massless and inextensible strings S1 and S2 as shown in the figure.



The tensions in the strings are

(A) T_1 = 100 N and T_2 = 0 N
(B) T_1 = 0 N and T_2 = 100 N
(C) T_1 = 75 N and T_2 = 25 N
(D) T_1 = 25 N and T_2 = 75 N

Key: (B)

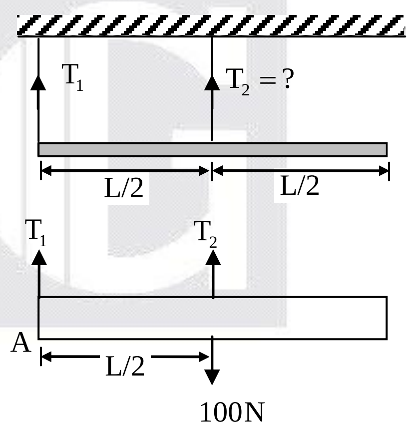
Sol: $\Sigma M_A = 0$

$$T_2 \times \frac{L}{2} = 100 \times \frac{L}{2}$$

$$T_2 = 100$$

$$T_1 + T_2 = 100$$

$$T_1 = 0N,\ T_2 = 100N$$



23. *F (z)* is a function of the complex variable *z* = *x* + *i y* given by

$$F(z) = iz + k\,Re(z) + i\,Im(z)$$

For what value of k will *F (z)* satisfy the Cauchy-Riemann equations?

(A) 0
(B) 1
(C) –1
(D) *y*

Key: (B)

Sol:
$$F(z) = iz + k\,Re(z) + iI_m(z)$$
$$= i(x+iy) + kx + iy$$
$$= ix - y + kx + iy$$
$$= (kx - y) + i(x+y)$$
$$= u + iv\,(say)$$

Applying C-R equations, i.e., $\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}$ & $\frac{\partial u}{\partial y} = \frac{\partial v}{\partial x} \Rightarrow k = 1$

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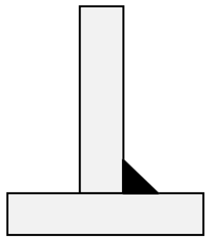
24. The type of weld represented by the shaded region in the figure is



(A) groove (B) spot (C) fillet (D) plug

Key: (C)

25. For a Pelton wheel with a given water jet velocity, the maximum output power from the Pelton wheel is obtained when the ratio of the bucket speed to the water jet speed is _____ (correct to two decimal places).

Key: (0.5)

Sol: $\because$ Efficiency of Pelton wheel is maximum,

when $\frac{u}{v}=0.5$

Where u = velocity of blade

v = velocity of jet (Absolute) at inlet.

26. Let X_1, X_2 be two independent normal random variables with means μ_1, μ_2 and standard deviations σ_1, σ_2 respectively. Consider $Y = X_1 - X_2$; $\mu_1 = \mu_2 = 1$, $\sigma_1 = 1$, $\sigma_2 = 2$, Then,

(A) Y is normal distributed with mean 0 and variance 1

(B) Y is normally distributed with mean 0 and variance 5

(C) Y has mean 0 and variance 5, but is NOT normally distributed

(D) Y has mean 0 and variance 1, but is NOT normally distributed

Key: (B)

Sol: Sum or difference of normal random variables is again a normal random variable

$$\text{Mean of 'y'} = E(y) = E(x_1 - x_2) = E(x_1) - E(x_2)$$
$$= \mu_1 - \mu_2$$
$$= 1 - 1 = 0$$

$$\text{Variance of 'y'} = v(y) = v(x_1 - x_2) = v(x_1) + v(x_2)$$
$$= \sigma_1^2 + \sigma_2^2$$
$$= 1 + 4 = 5$$

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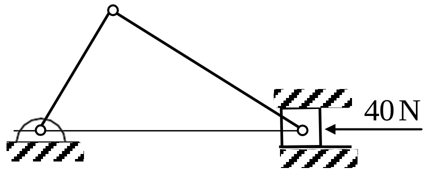
27. A slider crank mechanism is shown in the figure. At some instant, the crank angle is 45° and a force of 40 N is acting towards the left on the slider. The length of the crank is 30 mm and the connecting rod is 70 mm. Ignoring the effect of gravity, friction and inertial forces, the magnitude of the crankshaft torque (in Nm) needed to keep the mechanism in equilibrium is ___ (correct to two decimal places).



Key: (1.117)

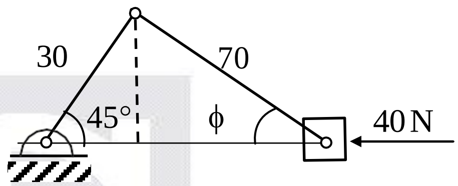
Sol: $F_p = 40N$

$30\sin 45° = 70\sin\phi$

$\sin\phi = 0.303 \Rightarrow \phi = 17.6°$

$\text{Torque} = \dfrac{F_p}{\cos\phi}\sin(\theta+\phi)\times r$

$= \dfrac{40\times\sin(17.6+45°)}{\cos 17.6}\times 0.03 = 1.117\,N - mts$



28. The value of integral

$$\oiint_S \vec{r}.\vec{n}\,dS$$

over the closed surface S bounding a volume V, where $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ is the position vector and $\vec{n}$ is the normal to the surface S, is

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

Key: (C)

Sol: By Gauss divergence theorem,

$$\oiint_s \vec{r}.\vec{n}\,ds = \int_v \operatorname{div}\vec{r}\,dv$$

$$= \int_v 3dv = 3V \qquad \left[\begin{array}{l} \because \vec{r} = x\hat{i} + y\hat{j} + z\hat{k} \\ \Rightarrow \operatorname{div}\vec{r} = 1+1+1 = 3 \end{array}\right]$$

29. A plane slab of thickness L and thermal conductivity k is heated with a fluid on one side *(P)*, and the other side (Q) is maintained at a constant temperature, T_Q of 25°C, as shown in the figure. The fluid is at 45°C and the surface heat transfer coefficient, h, is 10 W/m^{2}K. The steady state temperature, T_P (in °C) of the side which is exposed to the fluid is ____ (correct to two decimal places).

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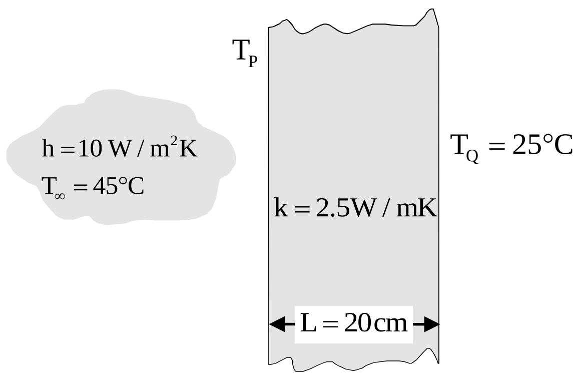


Key: (33.89)

Sol: For the steady state heat transfer,

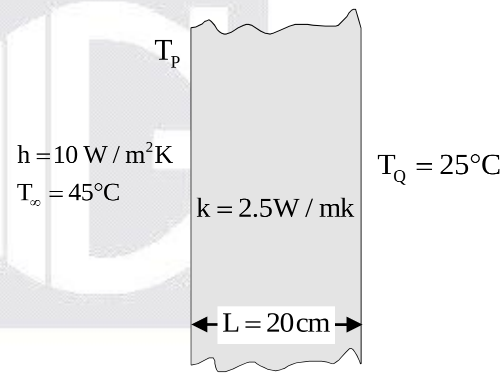
$$\dot{Q} = \frac{T_\infty - T_p}{\left(\frac{1}{hA}\right)} = \frac{T_P - T_Q}{\left(\frac{L}{kA}\right)}$$

$$\dot{Q} = \frac{45 - T_p}{\left(\frac{1}{10 \times A}\right)} = \frac{T_P - 25}{\left(\frac{0.2}{2.5 \times A}\right)}$$

$$\Rightarrow 10(45 - T_p) = \frac{2.5(T_p - 25)}{0.2}$$

$$\Rightarrow (90 - 2T_p) = (2.5)T_p - 62.5$$

$$\Rightarrow T_p = 33.89°C, \text{ So answer is } 33.89$$



30. F(s) is the Laplace transform of the function

$$f(t) = 2t^2e^{-t}$$

F(1) is ____ (correct to two decimal places).

Key: (0.5)

Sol: $L(2t^2e^{-t}) = 2L[t^2e^{-t}]$

$$= 2 \times \frac{2}{(s+1)^3} \quad \left(\because L[t^2] = \frac{2!}{s^3} = \frac{2}{s^3} \ \& \ L[e^{-at}f(t) = F(s+a)]\right)$$

$$= \frac{4}{(s+1)^3} = F(s)$$

$$\Rightarrow F(1) = \frac{4}{8} = 0.5$$

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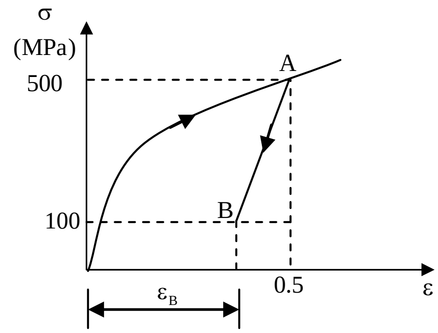
31. The true stress (σ) - true strain (ε) diagram of a strain hardening material is shown in figure. First, there is loading up to point A, i.e. up to stress of 500 MPa and strain of 0.5. Then from point A, there is unloading up to point *B*, i.e., to stress of 100 MPa, Given that the Young's modulus *E* = 200GPa, the natural strain at point B (ε_B) ____ (correct to two decimal places).

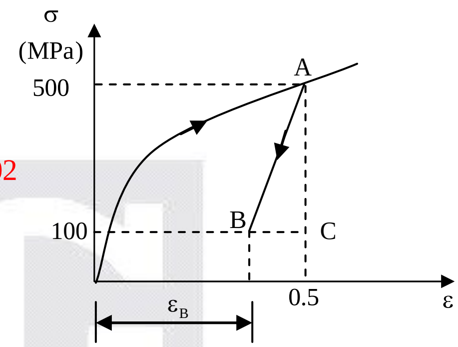


Exp: (0.498)

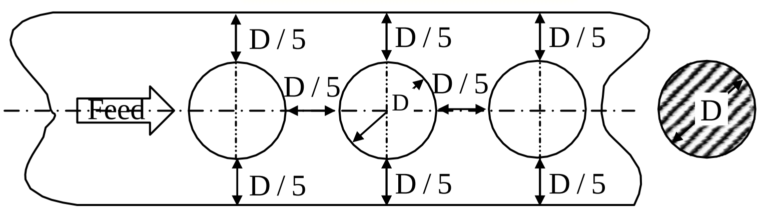
Sol: $\because E = \text{slope} = \dfrac{AC}{BC}$

$$200\times10^9 = \frac{400\times10^6}{BC} \Rightarrow BC = 2\times10^{-3} = 0.002$$

$$\text{So}, \varepsilon_B = 0.5 - 0.002 = 0.498$$



32. The percentage scrap in a sheet metal blanking operation of a continuous strip of sheet metal as shown in the figure is___ (correct to two decimal places).



Key: (53.27)

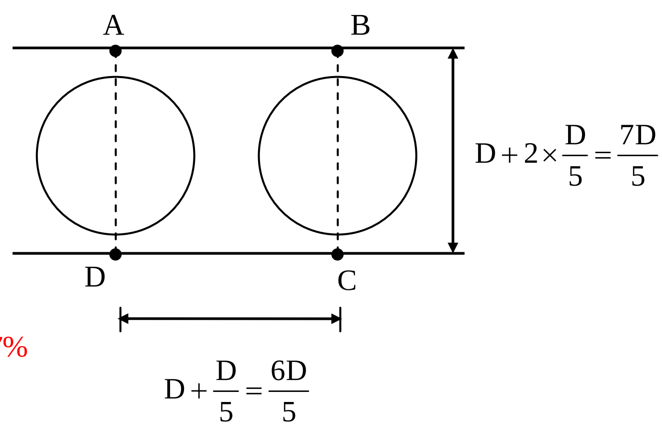
Sol: Area of rectangle

$$ABCD = \frac{6D}{5}\times\frac{7D}{5} = \frac{42}{25}D^2 = 1.68D^2$$

and

$$\text{Area of blank} = \frac{\pi}{4}D^2 = 0.785D^2$$

$$\text{So, \% scrap} = \frac{1.68D^2 - 0.785D^2}{1.68D^2}\times100 = 53.27\%$$



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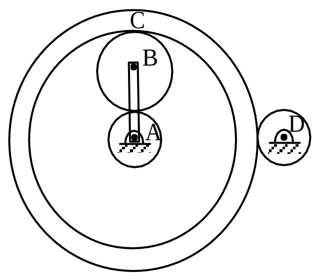
33. An epicyclic gear train is shown in the figure below. The number of teeth on the gears *A*, *B* and *D* are 20, 30 and 20 respectively. Gear *C* has 80 teeth on the inner surface and 100 teeth on the outer surface. If the carrier arm *AB* is fixed and the sun gear *A* rotates at 300 rpm in the clockwise direction, then the rpm of *D* in the clockwise direction is

(A) 240

(B) –240

(C) 375

(D) –375



Key: (C)

Sol: $N_A = 300\text{rpm};\ T_A = 20;\ T_B = 30;\ T_{c_{in}} = 80$

$T_{c_{ext}} = 100$

$$N_B = \frac{N_A T_A}{T_B} = \frac{300\times 20}{30} = 200$$

$$N_C = \frac{N_B T_B}{T_C} = \frac{200\times 30}{80} = 75$$

$$N_D = \frac{N_C T_C}{T_D} = \frac{75\times 100}{20} = 375 \text{ rpm}$$

34. The minimum value of 3x + 5y such that:

$3x + 5y \le 15$

$4x + 9y \le 8$

$13x + 2y \le 2$

$x \ge 0, y \ge 0$

is ________.

Key: (0)

Sol: $\because$ All main constraints are of $\le$ type and

Non-negativity constraints are of $\ge$ type.

So, feasible region contain origin (0, 0) as corner point.

So, at origin (0, 0)

$z_{min} = 3\times 0 + 5\times 0 = 0$

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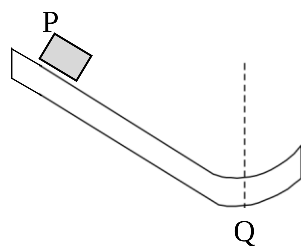
35. Block P of mass 2 kg slides down the surface and has a speed 20 m/s at the lowest point, Q, where the local radius of curvature is 2 m as shown in the figure. Assuming g = 10 m/s^2, the normal force (in N) at Q is ____ (correct to two decimal places).

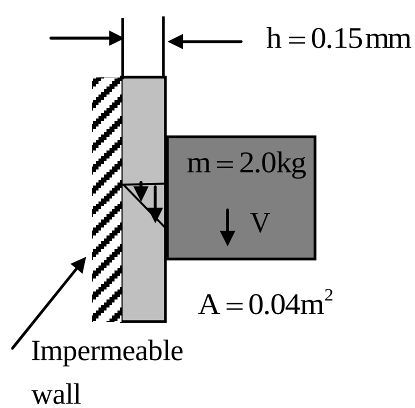


Key: (420)

Sol: $R_Q = mg + \frac{mv^2}{R}$

$$=(2\times10)+\left(\frac{2\times20^2}{2}\right)=20+400=420N$$

36. A solid block of 2.0 kg mass slides steadily at a velocity *V* along a vertical wall as shown in the figure below. A thin oil film of thickness *h* = 0.15 mm provides lubrication between the block and the wall. The surface area of the face of the block in contact with the oil film is 0.04 m^2. The velocity distribution within the oil film gap is linear as shown in the figure. Take dynamic viscosity of oil as 7 × 10^{-3} Pa-s and acceleration due to gravity as 10 m/s^2. Neglect weight of the oil. The terminal velocity V (in m/s) of the block is ___ (correct to one decimal place).



Key: (10.714)

Sol: $\because F = \tau.A$

$$F=\mu\left(\frac{du}{dy}\right).A \Rightarrow F=\mu.\frac{V}{h}.A$$

$$\Rightarrow 2\times10 = 7\times10^{-3}\times\frac{V}{0.15\times10^{-3}}\times0.04$$

$$\Rightarrow V = 10.714\,m/s$$

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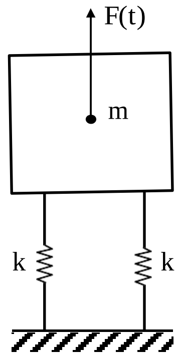
37. A machine of mass m = 200 kg is supported on two mounts, each of stiffness k = 10 kN/m. The machine is subjected to an external force (in N) F(t) = 50 cos5t. Assuming only vertical translatory motion, the magnitude of the dynamic force (in N) transmitted from each mount to the ground is ___ (correct to two decimal places).



Key: (33.33)

Sol: $k = 10kN/m,\ m=200kg$

$F=50\cos 5t,\ \omega = 5\,rad/sec$

$F=50$

$$\omega_n = \sqrt{\frac{20000}{200}} = 10\,rad/sec$$

$\xi = 0$

$$\in = \frac{F_T}{F} = \frac{\sqrt{1+(2\xi r)^2}}{\sqrt{(1-r^2)^2+(2\xi r)^2}}$$

$$\frac{F_T}{50} = \frac{1}{1-\left(\frac{5}{10}\right)^2}$$

$$\frac{F_T}{50} = \frac{1}{\left(\frac{3}{4}\right)} \Rightarrow F_T = \frac{200}{3} = 66.66$$

$$\text{Force on each mount} = \frac{66.66}{2} = 33.33$$

38. A bar is compressed to half of its original length. The magnitude of true strain produced in the deformed bar is ____ (correct to two decimal places).

Key: (0.693)

Sol: $\varepsilon = \ell n\left(\frac{\ell_f}{\ell_i}\right) \Rightarrow \varepsilon = \ell n 0.5$

$\varepsilon = -0.693$

But magnitude of true strain = 0.693

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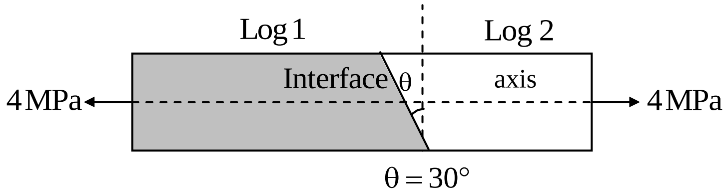
39. A carpenter glues a pair of cylindrical wooden logs by bonding their end faces at an angle of θ = 30° as shown in the figure.



The glue used at the interface fails if

Criterion 1: the maximum normal stress exceeds 2.5MPa.

Criterion 2: the maximum normal stress exceeds 1.5MPa.

Assume that the interface fails before the logs fail. When a uniform tensile stress of 4 MPa is applied, the interface

(A) fails only because of criterion 1

(B) fails only because of criterion 2

(C) fails because of both criterion 1 and 2

(D) does not fail

Key: (C)

Sol: $\theta = 30^{o} \Rightarrow \sigma = \frac{P}{A} = 4\text{MPa}$

$$\sigma_\theta = \frac{P}{A}\cos^2\theta$$

$$= 4\cos^2 30 = 3\text{MPa} > 2.5\text{MPa}$$

$$\tau_\theta = \frac{P}{2A}\sin 2\theta \Rightarrow \tau_\theta = \frac{4}{2}\sin 60° = 1.732 > 1.5\text{MPa}$$

Fails by both Criterion 1 and 2

40. In a Lagrangian system, the position of a fluid particle in a flow is described as $x = x_0 e^{-kt}$ and $Y = y_0 e^{kt}$ where t is the time while x_0, y_0, and k are constants. The flow is

(A) unsteady and one-dimensional

(B) steady and two-dimensional

(C) steady and one-dimensional

(D) unsteady and two-dimensional

Key: (B)

Sol: $\because u = \frac{dx}{dt}$

$$u = -kx_o e^{-kt} \Rightarrow u = -kx$$

$$\&v = \frac{dy}{dt} \Rightarrow v = ky$$

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So, $\vec{V} = -kxi + kyj$

i.e, $\vec{V} \neq f(t)$

So, steady flow & $\vec{V} = f(x, y)$. So, 2D flow.

41. Processing times (including setup times) and due dates for six jobs waiting to be processed at a work centre are given in the table. The average tardiness (in days) using shortest processing time rule is ___ (correct to two decimal places).

Job	Processing time (days)	Due date (days)
A	3	8
B	7	16
C	4	4
D	9	18
E	5	17
F	13	19

Key: (6.33)

Sol: By SPT rule

Job Sequence	P.T	Machining		D.D	Tardiness
		In	Out		
A	3	0	3	8	0
C	4	3	7	4	3
E	5	7	12	17	0
B	7	12	19	16	3
D	9	19	28	18	10
F	13	28	41	19	22

Total Tardiness = 38

Average Tardiness $= \frac{38}{6} = 6.33\text{days}$

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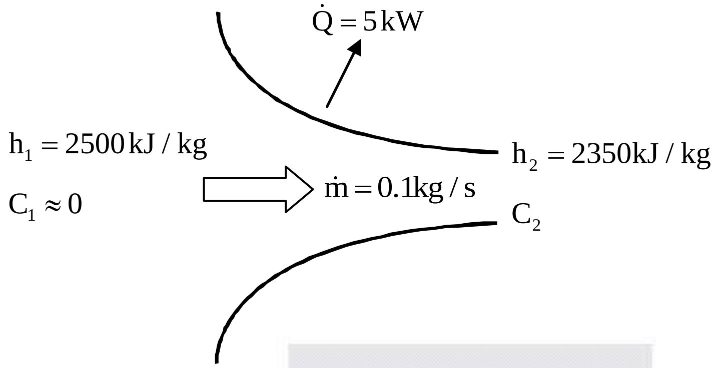
42. Steam flows through a nozzle at mass flow rate of $\dot{m} = 0.1$ kg/s with a heat loss of 5 kW. The enthalpies at inlet and exit are 2500 kJ/kg and 2350 kJ/kg, respectively. Assuming negligible velocity at inlet ($C_1 \approx 0$), the velocity (C_2) of steam (in m/s) at the nozzle exit is ___ (correct to two decimal places)

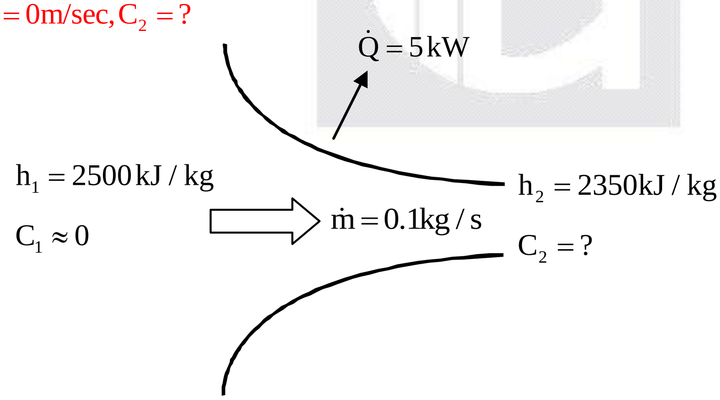


Key: (447.21)

Sol: $\dot{m} = 0.1 kg/sec,\ Q = -5kW\,(\text{Heat Rejected})$

$h_1 = 2500\,kJ/kg,\ h_2 = 2350 kJ/kg$

$C_1 = 0 m/sec, C_2 = ?$



Applying steady flow energy equation

$$\dot{m}\left(h_1 + \frac{C_1^2}{2000}\right) + \dot{Q} = \dot{m}\left(h_2 + \frac{C_2^2}{2000}\right) + W$$

$W = 0$, since no work done, $C_1 = 0$

$$\Rightarrow 0.1(2500) - 5 = 0.1\left(2350 + \frac{C_2^2}{2000}\right)$$

$$245 = 0.1\left(2350 + \frac{C_2^2}{2000}\right) \Rightarrow 2450 = 2350 + \frac{C_2^2}{2000}$$

$$\Rightarrow C_2 = 447.21 m/sec$$

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43. A point mass is shot vertically up from ground level with a velocity of 4 m/s at time, t = 0. It loses 20% of its impact velocity after each collision with the ground. Assuming that the acceleration due to gravity is 10 m/s^2 and that air resistance is negligible, the mass stops bouncing and comes to complete rest on the ground after a total time (in seconds) of

(A) 1 (B) 2 (C) 4 (D) ∞

Key: (C)

Sol: $V_1 = 4\text{m/sec},\ V_2 = 0.8\times4 = 3.2\text{m/sec}$

$$V_1 = V \Rightarrow t_1 = \frac{2V_1}{g}$$

$$V_2 = 0.8V \Rightarrow t_2 = \frac{2V_2}{g}$$

$$V_3 = 0.64V \Rightarrow t_3 = \frac{2V_3}{g}$$

$$T = t_1 + t_2 + \ldots\ldots\ldots\ldots$$

$$= \left[\frac{2V_1}{g} + \frac{2V_2}{g} + \frac{2V_3}{g} + \ldots\ldots\right]$$

$$= \frac{2}{10}\times4[1+0.8+0.64+\ldots..]$$

$$= \frac{2}{10}\times4\left[1+0.8+(0.8)^2+\ldots..\infty\right]$$

$$= 0.8\times\frac{1}{1-0.8} = \frac{0.8}{0.2} = 4 = 4\text{sec}$$

44. A tank of volume 0.05 m^3 contains a mixture of saturated water and saturated steam at 200°C. The mass of the liquid present is 8 kg. The entropy (in kJ/kgK) of the mixture is _____ (correct to two decimal places)

Property data for saturated steam and water are:

At 200°c, P_{sat} = 1.5538 MPa

v_f = 0.001157 m^3/kg, v_g = 0.12736 m^3/kg

s_{fg} = 4.1014 kJ/kgK, s_f = 2.3309 kJ/kgK

Key: (2.49)

Sol: $V = 0.05\text{m}^3, T_{sat} = 200°\text{C},\ m_L = 8\text{kg}$

At 200°C, $P_{sat} = 1.5538\text{MPa}$

$v_f = 0.001157\text{m}^3/\text{kg},\ v_g = 0.12736\text{m}^3/\text{kg}$

$s_{fg} = 4.1014\text{kJ/kgK},\ s_f = 2.3309\text{kJ/kgK}$

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Given container has both water vapor & liquid

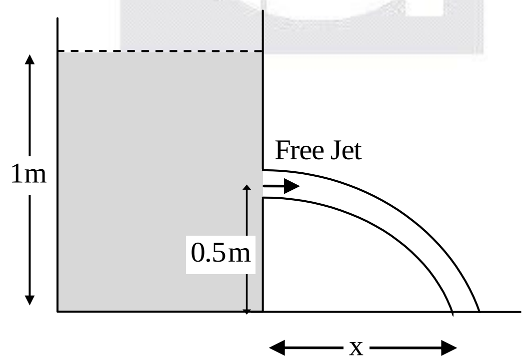
i.e., it is in wet-vapour region,

In that case entropy of mixture is $s = s_f + xs_{fg}$

Where x=dryness fraction= $\dfrac{m_v}{m_v + m_L}$

$$v_{f(\text{liquid})} = m_L v_f = (8)(0.001157)$$
$$v_{f(\text{liquid})} = 0.01$$
$$v_{\text{vapour}} = v - v_{f(\text{liquid})} = 0.05 - 0.01 = 0.04\text{m}^3$$
$$m_v = \frac{v_{\text{vapour}}}{v_g} = \frac{0.04}{0.12736} = 0.31\text{kg}$$
$$x = \frac{0.31}{(0.31+8)} = 0.04$$
$$\therefore s = 2.3309 + 0.04(4.1014) = 2.49\,\text{kJ/kgK}$$

45. A tank open at the top with a water level of 1 m, as shown in the figure, has a hole at a height of 0.5 m. A free jet leaves horizontally from the smooth hole. The distance *X* (in m) where the jet strikes the floor is



(A) 0.5 (B) 1.0 (C) 2.0 (D) 4.0

Key: (B)

Sol:
$$u_x = \sqrt{2\times 9.81\times 0.5} = 3.13$$
$$u_y = 0$$
$$\because s_y = u_y t + \frac{1}{2}a_y t^2 \Rightarrow t = \sqrt{\frac{1}{g}}$$
$$s_x = u_x + \frac{1}{2}a_x t^2 \Rightarrow s_x = 3.13\times\sqrt{\frac{1}{g}} \qquad (\text{here } a_x = 0)$$
$$s_x = 1\text{m}$$

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46. A self-aligning ball bearing has a basic dynamic load rating (C_{10}, for 10^6 revolutions) of 35 kN. If the equivalent radial load on the bearing is 45kN, the expected life (in 10^6 revolutions) is

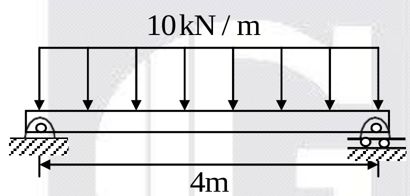
(A) below 0.5 (B) 0.5 to 0.8 (C) 0.8 to 1.0 (D) above 1.0

Key: (A)

Sol: $P_e = 45\text{kN};\ C = 35\text{kN}$

$$L_{10} = \left(\frac{C}{P_e}\right)^3 = \left(\frac{35}{45}\right)^3 = 0.47 < 0.5$$

47. A simply supported beam of width 100 mm, height 200 mm and length 4 m is carrying a uniformly distributed load of intensity 10kN/m. The maximum bending stress (in MPa) in the beam is __ (correct to one decimal place)



Key: (30)

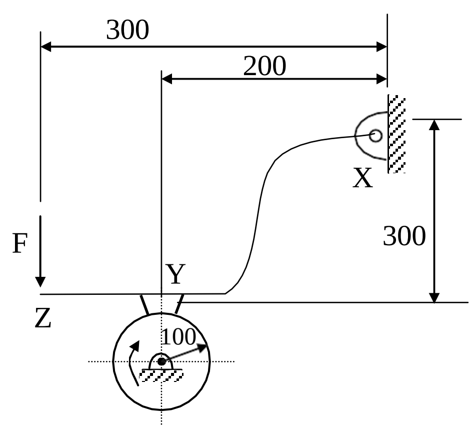
Sol: $\sigma = \frac{M}{I}y,\ M = \frac{wL^2}{8} = \frac{10 \times 4^2}{8} = 20\text{kN-m}$

$$I = \frac{100 \times 200^3}{12} = 66.67 \times 10^6$$

$$y = \frac{200}{2} = 100;$$

$$\sigma = \frac{20 \times 10^6}{66.67 \times 10^6} \times \left(\frac{200}{2}\right) = 30\,\text{MPa}$$

48. The schematic of an external drum rotating clockwise engaging with a short shoe is shown in the figure. The shoe is mounted at point Y on a rigid lever XYZ hinged at point X. A force F = 100 N is applied at the free end of the lever as shown. Given that the coefficient of friction between the shoe and the drum is 0.3, the braking torque (in Nm) applied on the drum is ____ (correct to two decimal places).



(All dimensions are in mm)

Key: (8.18)

Sol: $\Sigma M_x = 0$

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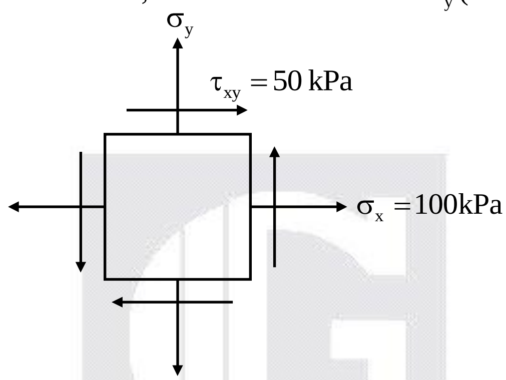
$$(R_N \times 200) - (\mu R_N \times 300) - (F \times 300) = 0$$
$$(R_N \times 200) - (0.3 \times R_N \times 300) - (100 \times 300) = 0$$
$$R_N = \frac{(100 \times 300)}{(200 - (0.3 \times 300))} = 272.72\,N$$
$$T = \mu R_N \times \text{Radius} = 8.18\,N - mts$$

49. The state of stress at a point, for a body in plane stress, is shown in the figure below. If the minimum principal stress is 10 kPa, then the normal stress σ_y (in kPa) is



(A) 9.45 (B) 18.88 (C) 37.78 (D) 75.50

Key: (C)

Sol: $$\sigma_2 = \left[\frac{\sigma_x + \sigma_y}{2}\right] - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + T_{xy}^2}$$

$$10 = \left[\frac{100 + \sigma_y}{2}\right] - \sqrt{\left(\frac{100 - \sigma_y}{2}\right)^2 + 50^2}$$

$$\left[10 - \left[\frac{100 + \sigma_y}{2}\right]\right]^2 = \left(\frac{100 - \sigma_y}{2}\right)^2 + 50^2$$

$$100 - 2 \times 10 \times \left(\frac{100 + \sigma_y}{2}\right) = \left(\frac{100 - \sigma_y}{2}\right)^2 - \left(\frac{100 + \sigma_y}{2}\right)^2 + 2500$$

$$100 - 1000 - 10\sigma_y = \frac{-4 \times 100 \times \sigma_y}{4} + 2500$$

$$90\sigma_y = 2500 + 1000 - 100 \Rightarrow \sigma_y = 37.77\,MPa$$

50. An electrochemical machining (ECM) is to be used to cut a through hole into a 12 mm thick aluminium plate. The hole has a rectangular cross-section, 10 mm × 30 mm. The ECM operation will be accomplished in 2 minutes, with efficiency of 90%. Assuming specific removal rate for aluminium as 3.44×10^{-2} mm^3/ (A s), the current (in A) required is ____ (correct to two decimal places).

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Key: (968.99)

Sol: Volume to be removed = $10\times30\times12=3600\,\text{mm}^3$

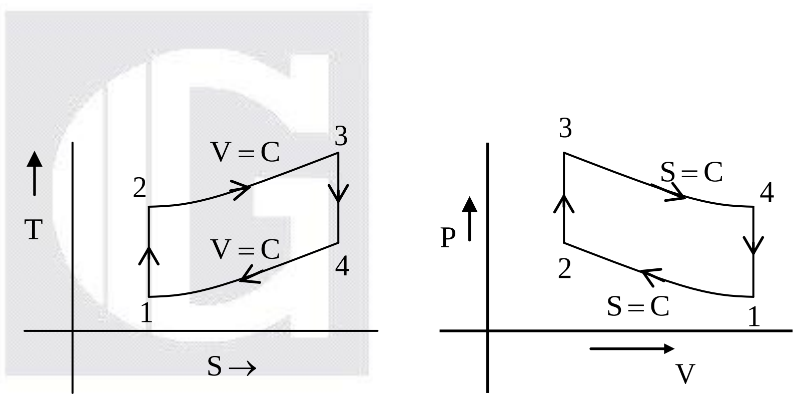
Energy required = $=\dfrac{3600}{3.44\times10^{-2}\times0.9}$ =116279 As

Current $=\dfrac{116279}{120}=968.99\,\text{A}$

51. An engine working on air standard Otto cycle is supplied with air at 0.1 MPa and 35^{o}C. The compression ratio is 8. The heat supplied is 500kJ/kg. Property data for air: c_p = 1.005 kJ/kgK, c_v = 0.718 kJ/kg K, R = 0.287 kJ/kg K. The maximum temperature (in K) of the cycle is _____ (correct to one decimal place).

Key: (1403.98)

Sol: $P=0.1\text{MPa}, T_1=35°\text{C}, r_c=8$



$Q_{\text{supplied}}=500\,\text{kJ/kg}$

$C_p=1.005\text{kJ/kgK},$

$C_V=0.718\text{kJ/kgK},$

$R=0.287\text{kJ/kgK}$

$T_1=35+273=308\text{K}$

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

$\Rightarrow T_2=(308)(8)^{(1.4-1)}=707.60\text{K}$

$Q_{\text{supplied}}=C_v\left(T_3-T_2\right)$

$500=(0.718)(T_3-707.60)$

$T_3=1403.98\text{K}$

52. An orthogonal cutting operation is being carried out in which uncut thickness is 0.010 mm, cutting speed is 130 m/min, rake angle is 15° and width of cut is 6 mm. It is observed that the chip thickness is 0.015 mm, the cutting force is 60 N and the thrust force is 25 N. The ratio of friction energy to total energy is ____ (correct to two decimal places).

Key: (0.4406)

Sol: $t_1=0.01\text{mm};\ v=130\text{m/min};\ \alpha=15°$

$b=6\text{mm};\ t_c=0.015\text{mm},$

$\text{cutting force}=F_H=60\text{N}$

$\text{Thrust force}=F_V=25\text{N}$

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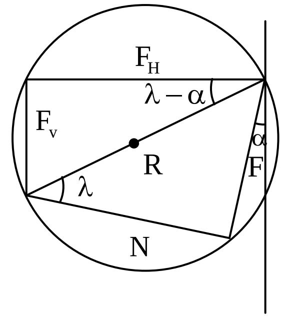
$$R = \sqrt{60^2 + 25^2} = 65N$$
$$F = R\sin\lambda = 39.66N$$
$$\tan(\lambda - \alpha) = \frac{F_v}{F_H} = \frac{25}{60} = 22.61$$
$$\lambda = 37.61$$
$$\frac{\text{Friction energy}}{\text{Total energy}} = \frac{F}{F_H}.\frac{t_1}{t_c} = 0.4406$$



53. An explicit forward Euler method is used to numerically integrate the differential equation

$$\frac{dy}{dt} = y$$

using a time step of 0.1. With the initial condition y (0) = 1, t he value of y (1) computed by this method is ___ (correct to two decimal places).

Key: (2.59)

Sol: By Euler method,

$$y_{n+1} = y_n + nf(t_n, y_n)$$
$$\text{where given } f(t, y) = y$$
$$\therefore y_{n+1} = y_n + hy_n$$
$$\Rightarrow y_{n+1} = (1+h)y_n$$
$$y_1 = y(0.1) = (1+0.1)\times 1 = 1.1 \qquad (\because y_0 = 1)$$
$$y_2 = y(0.2) = 1.1\times 1.1$$
$$y_3 = y(0.3) = 1.1\times(1.1\times 1.1)$$
$$\vdots$$
$$y_{10} = y(1) = (1.1)^{10} \simeq 2.59$$

54. The maximum reduction in cross-sectional area per pass (R) of a cold wire drawing process is

$$R = 1 - e^{-(n+1)}$$

where n represents the strain hardening coefficient. For the case of a perfectly plastic material, *R* is

(A) 0.865 (B) 0.826 (C) 0.777 (D) 0.632

Key: (D)

Sol: $\because$ for perfectly plastic material, n=0

So, $R = 1 - e^{-1} \Rightarrow R = 0.632$

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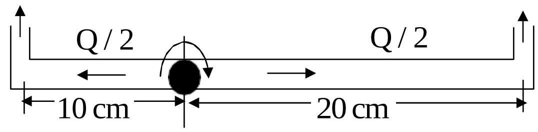
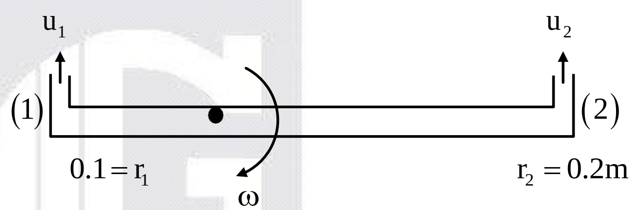
55. A sprinkler shown in the figure rotates about its hinge point in a horizontal plane due to water flow discharged through its two exit nozzles.



The total flow rate Q through the sprinkler is 1 litre/sec and the cross-sectional area of each exit nozzle is 1 cm^2. Assuming equal flow rate through both arms and a frictionless hinge, the steady state angular speed of rotation (rad/s) of the sprinkler is ________ (correct to two decimal places).

Key: (10)

Sol: $u_1 = u_2 = \dfrac{Q}{2A} = \dfrac{1\times10^{-3}}{2\times10^{-4}} = 5\text{m/s}$



Now Absolute velocity

$v_1 = u_1 + r_1\omega$

$v_2 = u_2 - r_2\omega$

$\because$ external Torque $= 0$

$\dot{m}_1 v_1 r_1 - \dot{m}_2 v_2 r_2 = 0 \qquad (\because \dot{m}_1 = \dot{m}_2)$

$\Rightarrow \omega = 10\text{rad / s}$

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