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GATE 2021

MECHANICAL ENGINEERING

Memory based

Questions & Solutions

Exam held on 14/02/2021
Forenoon Session

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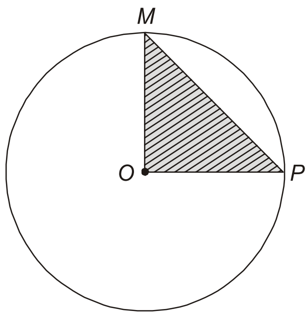
SECTION-A GENERAL APTITUDE

Q.1 Area of traingle MOP = 50 cm^2 and points M and P lie on the circle, then what is the area of circle?



(a) 2π
(b) 50π
(c) 70π
(d) $100\ \pi$

Ans. (d)

End of Solution

Q.2 Five boys P, Q, R, S, T are seated in a row in such a manner that there is only one person between Q and R; S cannot be seated adjacent to Q. In how many ways they can sit?

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

Ans. (#)

End of Solution

Q.3 A girl comes out from front door of her house to see her shadow in the morning time, The sunlight fall on her right handside and front face of house in the back, the in which direction the house is facing to?

(a) East
(b) West
(c) North
(d) South

Ans. (d)

End of Solution

Q.4 Which of the following option is grammatical correct?

(a) After his accident he could barely walk
(b) After his accident he barely could walk
(c) After his accident he could hardly walk
(d) After his accident he hardly could walk

Ans. (a)

End of Solution

Q.5 There were 65 hens, 91 dogs and 169 goats in the farm P and in farm R total number of hens, dogs and goats are 416 and are in ratio of 5 : 14 : 13. If all the hens, dogs and goats are moved from Q to P, find the new ratio?

(a) 15 : 21 : 26
(b) ##
(c) 10 : 21 : 26
(d) ##

Ans. (#)

End of Solution

Q.6 The curve $f(x) = x^2 - 2x + 2$ becomes parallel to the line joining the points $f(1)$ and $f(3)$. The value of x for which $f(x)$ becomes parallel to line is ____

Ans. (#)

By Lagrangian mean value theorem,

$$\frac{f(3) - f(1)}{3 - 1} = f'(c)$$

$$\Rightarrow \quad \frac{5 - 1}{3 - 1} = 2x - 2$$

$$\Rightarrow \quad 2x - 2 = 4$$

$$\Rightarrow \quad x = 2 \in (1, 3)$$

End of Solution

Q.7 $\lim_{x \to 0} \frac{1 - \cos x}{x^2}$. Find the value _____.

Ans. (#)

$$\lim_{x \to 0} \left(\frac{1 - \cos x}{x^2}\right) = ? \qquad \left(\frac{0}{0} \text{ form}\right)$$

$$\text{Applying L-H rule} = \lim_{x \to 0} \frac{\sin x}{2x} \left(\frac{0}{0}\right) = \lim_{x \to 0} \frac{\cos x}{2} = \frac{1}{2}$$

End of Solution

Q.8 If y(x) satisfies the differential equation $\sin x \frac{dy}{dx} + y \cos x = 1$, subject to the condition $y\left(\frac{\pi}{2}\right) = \frac{\pi}{2}$ then $y\left(\frac{\pi}{6}\right)$ is _____.

(a) $\frac{\pi}{3}$
(b) $\frac{\pi}{6}$
(c) $\frac{\pi}{2}$
(d) 0

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Ans. **(#)**

$$\frac{dy}{dx} + y\cot x = \text{cosec}\, x$$

I.F. $= e^{\int \cot x\, dx} = e^{\log \sin x} = \sin x$

$\Rightarrow$ $y(\sin x) = \int \text{cosec}\, x \sin x\, dx + c$

$\Rightarrow$ $y \sin x = x + c$

$\Rightarrow$ $\frac{\pi}{2}\sin\frac{\pi}{2} = \frac{\pi}{2} + c$

$\Rightarrow$ $\frac{\pi}{2} = \frac{\pi}{2} + c \quad \Rightarrow c = 0$

$\Rightarrow$ $y \sin x = x$

$\Rightarrow$ $y \sin\frac{\pi}{6} = \frac{\pi}{6}$

$\Rightarrow$ $y\left(\frac{1}{2}\right) = \frac{\pi}{6}$

$\Rightarrow$ $y = \frac{\pi}{3}$

End of Solution

Q.9 $\oint \frac{\cosh 3z}{2z} = ?$

where $z = x + iy$ about the unit circle passing through origin.

(a) $2\pi i$
(b) πi
(c) 0
(d) 2π

Ans. **(#)**

Pole of $f(c)$ is $z = 0$ simple pole.

Reduce at $z = 0$,

$$R_b f(z)_{\tau=0} = \lim_{z\to 0}(z-0)f(z) = \lim_{z\to 0}\frac{\cosh(3z)}{2} = \lim_{z\to 0}\frac{e^{3z}+e^{-3z}}{2\times 2} = \frac{1}{2}$$

By Cauchy Riemann theorem,

$$I = 2\pi\left(\frac{1}{2}\right) = \pi i$$

End of Solution

Q.10 If $X_1, X_2, X_3, \ldots.. X_n$ are independent and identically samples from distribution of x with sum $y = \sum_{i=1}^{x} X_i$ then the distribution of y as $x \to \infty$ can be approximated as _____.

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

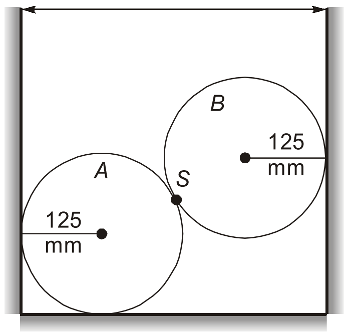
Ans. (#)

End of Solution

SECTION-B TECHNICAL

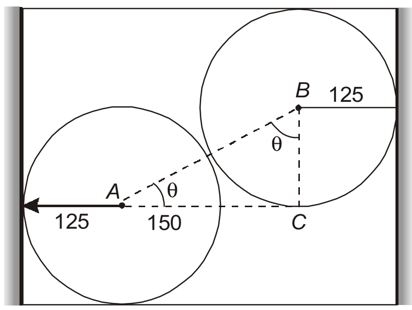
End of Solution

Q.1 Find the reaction at point of contact of two rollers



$W_A = 100$ N; $W_B = 100$ N

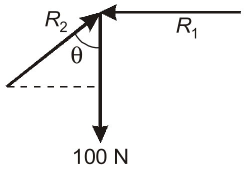
Ans. (#)



$$BC = 250^2 - 150^2$$

$$\cos\theta = \frac{200}{250}$$

$$\theta = 36.869°$$

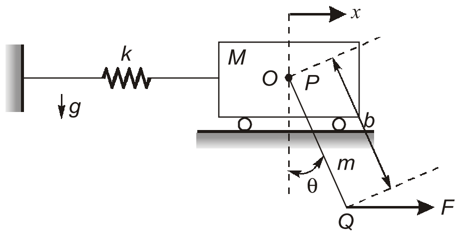


$$R_2 \cos\theta = 100$$

$$R_2 = \frac{100 \times 250}{200} = 125 \text{ N}$$

End of Solution

Q.2 Consider a two degree of freedom system as shown in the figure, where *PQ* is a rigid uniform rod of length *b* and mass *M*.



Assume that the spring deflects only horizontally and force *F* is applied horizontally at *Q* for this system the lagrangian *L* is

(a) $\frac{1}{2}(M+m)\dot{x}^2+\frac{1}{2}Mb\dot{\theta}\dot{x}\cos\theta+\frac{1}{6}Mb^2\dot{\theta}^2-\frac{1}{2}Kx^2+mg\frac{b}{2}\cos\theta$

(b) $\frac{1}{2}M\dot{x}^2+\frac{1}{2}Mb\dot{\theta}\dot{x}\cos\theta+\frac{1}{6}Mb^2\dot{\theta}^2-\frac{1}{2}Kx^2+mg\frac{b}{2}\cos\theta$

(c) $\frac{1}{2}(M+m)\dot{x}^2+\frac{1}{6}Mb^2\dot{\theta}^2-\frac{1}{2}Kx^2+mg\frac{b}{2}\cos\theta+Fb\sin\theta$

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

Ans. **(#)**

End of Solution

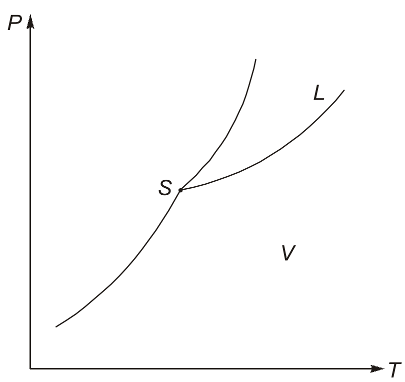
Q.3 In a tripple point regime in P-T curve of ammonia,

liquid-vapour line equation is given by $\ln P = 24.38 - 3063/T$.

and solid vapour line equation given by $\ln P = 27.92 - 3754/T$.

Find the tripple point temperature.

Ans. **(#)**



Liquid vapour, $\ln P = 24.38 - \frac{3063}{T}$

Solid vapour, $\ln P = 27.92 - \frac{3754}{T}$

At triple point temperature of solid, liquid and vapour is same.

∴ equating

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

Multiplying by T on both sides

$$24.38T - 3063 = 27.92T - 3754$$
$$3.54T = 691$$
$$T = 195.197 \text{ K}$$

End of Solution

Q.4 Superheated steam at 1500 kPa has a specific volume of 2.75 m^3/kmol and compressibility factor (z) of 0.95. The temperature of steam is _____ K.

Ans. (#)

$$P = 1500 \text{ kPa}$$
$$V = 2.75 \text{ m3/k-mol}$$
$$Z = 0.95$$
$$PV = n\bar{R}T$$
$$P\bar{v} = \bar{R}T$$
$$P\bar{V} = Z \times n\bar{R}T$$
$$P\frac{\bar{V}}{n} = Z\bar{R}T$$
$$P\bar{v} = Z\bar{R}T$$

$$1500 \text{ KPa} \times 2.75 \text{ m}^3\text{/K-mol} = 0.95 \times 8.314 \text{ kJ/K-molK} \times T$$
$$T = 522.26 \text{ K}$$

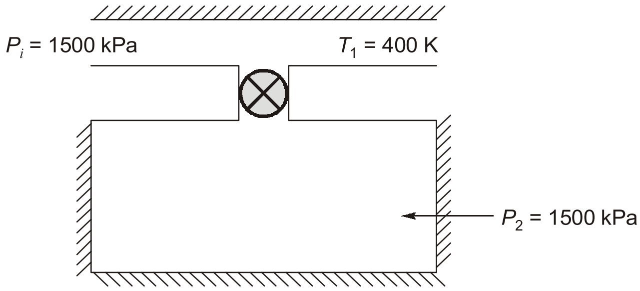
End of Solution

Q.5 An evacuated tank with valve, the valve is opened so that air gets inside the tank at P = 1500 kPa and T = 400 K, from pipe,

$$C_P = 1.005 \text{ kJ/kgK}; \ R = 0.287 \text{ kJ/kgk}$$

After filling tank upto P = 1500 kPa, find the temperature inside the tank ____ °C.

Ans. (#)



$$T_2 = \frac{C_P}{C_V} T_1$$

$$T_2 = \left(\frac{1.005}{0.718}\right) \times 400$$

$$T_2 = 559.888 \text{ K} \approx 560 \text{ K}$$

End of Solution

Q.6 For a rubber, thermodynamic relation is given as follows :

$$dU = TdS + \tau dL$$

where τ = Tension in rubber (N)

L = Length of rubber (m)

Which of the following option is current.

(a) $T = \left(\frac{\partial U}{\partial S}\right)_L$

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

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

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

Ans. (#)

$$dU = Tds + \tau dL$$

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

Comparing with $M = \left(\frac{\partial z}{\partial x}\right)_y$

$$T = \left(\frac{\partial U}{\partial S}\right)_L$$

Comparing with $N = \left(\frac{\partial z}{\partial y}\right)_x$

$$\tau = \left(\frac{\partial U}{\partial L}\right)_S$$

$$M = \left(\frac{\partial z}{\partial x}\right)_y$$

$$N = \left(\frac{\partial z}{\partial y}\right)_x$$

$$dz = Mdx + Ndy$$

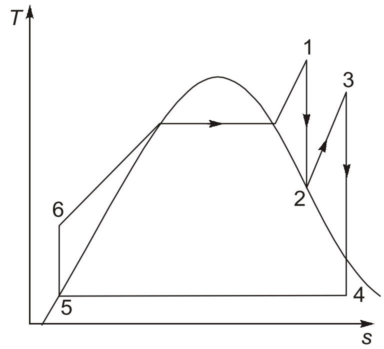
If z is exact different

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

End of Solution

Q.7 Consider a steam power plant operating on an ideal reheat rankine cycle the W_P = 20 kJ/kg, W_{HPT1} = 750 kJ/kg, W_{LPT2} = 1500 kJ/kg, η_{th} = 50%. Enthalpy of saturated liquid and vapour at condenser pressure are 200 kJ/kg and 2600 kJ/hg. Quality of steam at exit of LPT is ____ %.

Ans. (#)



$$h_f = 200 \text{ kJ/kg}$$
$$h_g = 2600 \text{ kJ/kg}$$
$$w_p = 20 \text{ kJ/kg} = h_6 - h_5$$
$$h_1 - h_2 = 750 \text{ kJ/kg}$$
$$h_3 - h_4 = 1500 \text{ kJ/kg}$$

$$\eta = 0.5 = \frac{W_{NET}}{Q_s} = \frac{W_T - W_P}{Q_s}$$

$$0.5 = \frac{750 + 1500 - 20}{Q_s}$$

$$Q_s = 4460 \text{ kJ/kg}$$

$$\eta = 1 - \frac{Q_R}{Q_S}$$

$$\Rightarrow \quad \frac{Q_R}{Q_S} = 0.5$$

$$Q_R = 2230 \text{ kJ/kg}$$
$$Q_R = h_4 - h_5$$

$$2230 = h_4 - 200$$
$$\Rightarrow \quad h_4 = 2430 \text{ kJ/kg}$$
$$h_4 = h_f + x(h_g - h_f)$$
$$2430 = 200 + x(2600 - 200)$$
$$x = 0.9291$$
$$x = 93\%$$

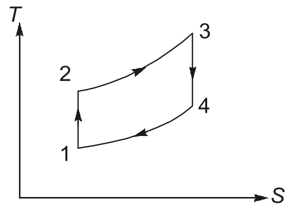
End of Solution

Q.8 The cycle in which there is at least one isothermal process?

(a) Brayton cycle and VCR cycle
(b) Carnot and Stirling cycle
(c) Bell-Colleman and Rankine cycle
(d) Diesel cycle and Otto cycle

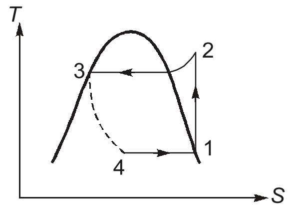
Ans. (b)

1. Brayton



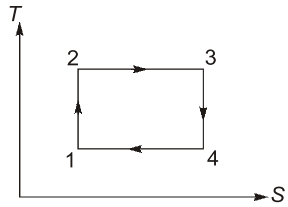
1 to 2 : $S = C$
2 to 3 : $P = C$
3 to 4 : $S = C$
4 to 1 : $P = C$

2. VCRS



1 to 2 : Isentropic compression
2 to 3 : constant pressure ($P = C$)
3 to 4 : Insenthalpic expansion ($h_3 = h_4$)
4 to 1 : Constant pressure ($P = C$)

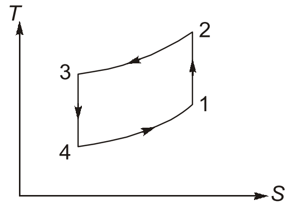
3. Carnot



1 to 2 : Isentropic compression
2 to 3 : Isothermal heat addition
3 to 4 : Isentropic expansion

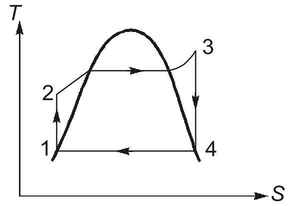
4 to 1 : Isothermal heat rejection

4. Bell Coleman



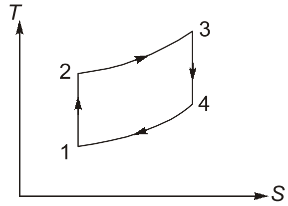
1 to 2 : Isentropic compression
2 to 3 : Constant pressure
3 to 4 : Isentropic expansion
4 to 1 : Constant pressure

5. Rankine



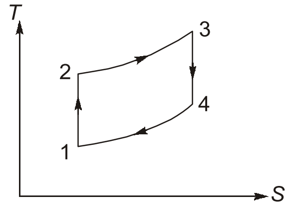
1 to 2 : Isentropic compression
2 to 3 : Constant pressure
3 to 4 : Isentropic expension
4 to 1 : Constant pressure

6. Diesel



1 to 2 : Isentropic compression
2 to 3 : Constant pressure ($P = C$)
3 to 4 : Isentropic expansion
4 to 1 : Constant volume

7. Otto

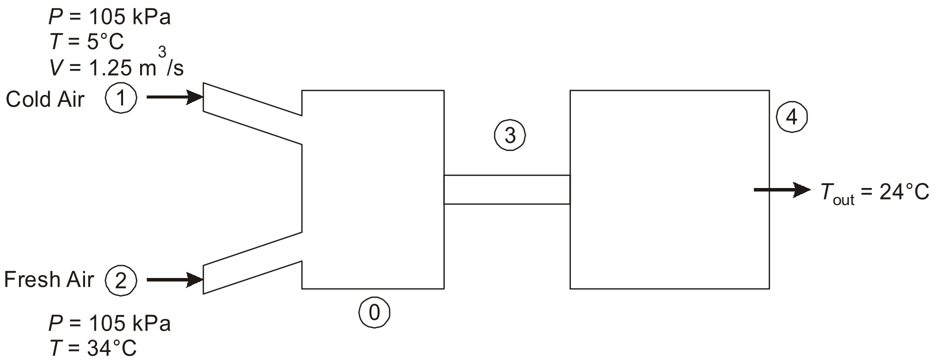


1 to 2 : Isentropic compression
2 to 3 : Constant pressure ($V = C$)
3 to 4 : Isentropic expansion
4 to 1 : Constant volume ($V = C$)

End of Solution

Q.9 If cold and fresh air behaves as ideal gas and rate of mass fresh air 1.6 times of cold air, then the heat gain of the system is _____ kW.

(C_P = 1.005 kJ/kgK; R = 0.287 kJ/kgK)



Ans. **(#)**

1 : Cold air

2 : Hot air

$$P_1V_1 = \dot{m}_1RT_1$$

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

$$\dot{m}_1 = 1.645 \text{ kg/sec}$$

$$\dot{m}_2 = 1.6 \times 1.645 = 2.632 \text{ kg/sec}$$

$$\dot{m}_3 = 4.277 \text{ kg/sec}$$

After mixing : 0

$$\dot{m}_1t_1 + \dot{m}_2t_2 = \dot{m}_3t_3$$

$$1.645 \times 5 + 2.632 \times 34 = 4.277t_3$$

$$t_3 = 22.85\ °\text{C}$$

Heat gain :

$$= h_4 - h_3$$

$$= \dot{m}_3C_P(t_4 - t_3)$$

$$= 4.277 \times 1.005(24 - 22.85)$$

$$= 4.925 \text{ kW}$$

End of Solution

Q.10 Infinite fin maintained at isothermal wall transmit heat Q to the surroundings and if conducting capacity of fin increases 2 times then what is the ratio of new transfer to previous heat transfer?

(a) $\sqrt{2}$

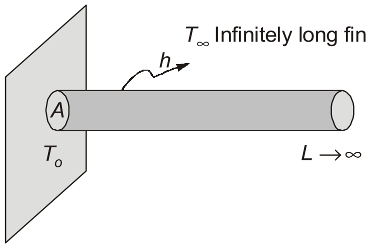
(b) $\frac{1}{\sqrt{2}}$

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

(d) 2

Ans. (a)

Fin problem:



$$q = \sqrt{hPkA}\,(T_o - T_\infty) \text{ wait}$$

If k gets doubled q increases by $\sqrt{2}$ times.

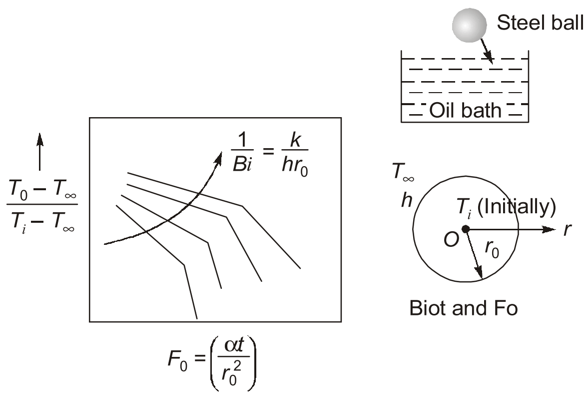
End of Solution

Q.11 A hot steel spherical ball is suddenly dipped into a low temperature oil bath. Which of the following dimensionless parameters are required to determine instantaneous centres temperatures of the ball using Heisler chart.

(a) Biot number and Fourier number
(b) Biot number and Froude number
(c) Reynold's number and Grashof's number
(d) Nusselt number and Prandtl number

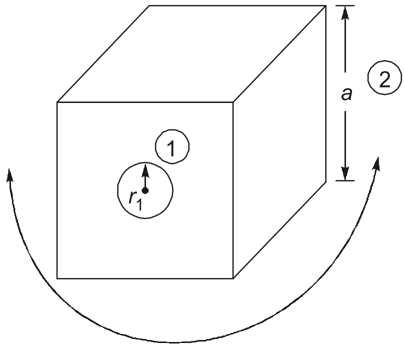
Ans. (a)

Unsteady state

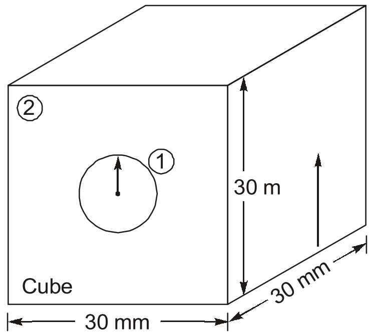


End of Solution

Q.12 If radius of sphere r_1 is 10 mm and side of cube is 30 mm, consider outer surface of sphere as (1) and inner surface of cube as (2). What is shape factor F_{22}?



Ans. (#)



$$r_1 = 10 \text{ mm}$$
$$A_1 = 4\pi r_1^2$$
$$A_2 = 6 \times (30^2)$$
$$F_{12} = 1$$

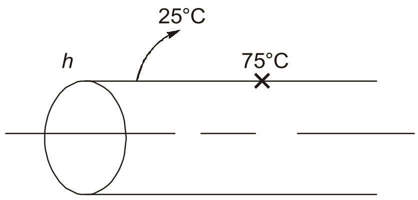
$$A_1F_{12} = A_2F_{21} \Rightarrow F_{21} = \frac{A_1}{A_2} = \frac{4\pi \times (10)^2}{6 \times (30)^2} = 0.2327$$

$$F_{22} = 1 - F_{21} = 0.7672$$

End of Solution

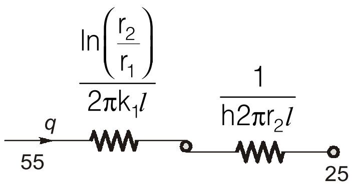
Q.13 A wire of radius 1 mm, heat generation in the wire is 5 W/m. Surface temperature of wire is 75°C and surrounding temperature is 25°C. If PVC insulation of thickness 1 mm is added then the surface temperature of wire becomes 55°C. What is the thermal conductivity of PVC?

Ans. (#)



$$q = 5 \text{ W/m} = h \times 2\pi \times r_1 \times (75 - 25)$$

$$\Rightarrow \quad h = 795.77 \text{ h/m}$$



$$5 = \frac{55-25}{\dfrac{\ln\left(\frac{2}{1}\right)}{2\pi \times k \times 1} + \dfrac{1}{795.77 \times 2\pi \times 0.002}}$$

$$\frac{\ln 2}{2\pi k} + 0.1 = \frac{30}{5}$$

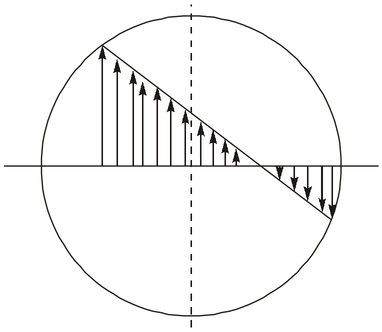
$$\frac{\ln 2}{2\pi k} = 5.9$$

$$\frac{\ln 2}{5.9 \times 2\pi} = k$$

$$k = 0.0186$$

End of Solution

Q.14 Shear stress distribution in wire of spring is given as shown in figure. Then which stresses are acting on the spring?

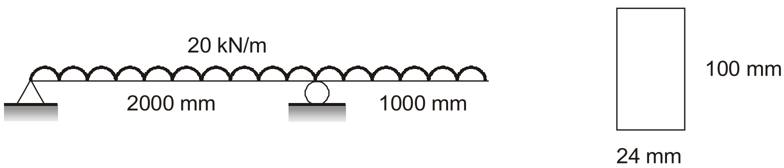


(a) Direct shear stress in spring
(b) Torsional shear stress
(c) Direct shear stress and shear stress due torsion
(d) Direct shear stress and shear stress due torsion considering effect of curvature

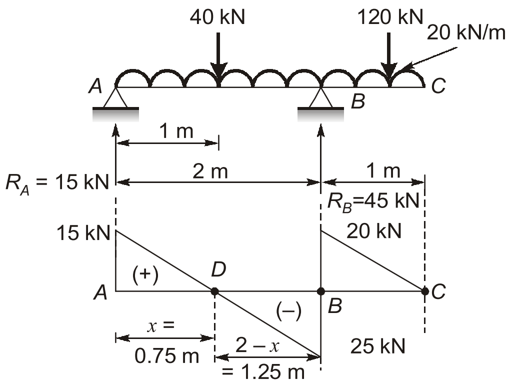
Ans. (c)

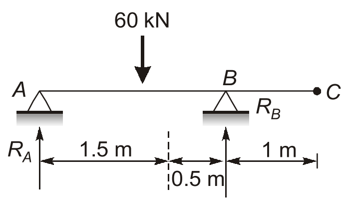
Because resultant shear stress is varying linearly so direct shear stress and shear stress due torsion will be acting on the spring.

Q.15 What is maximum bending stress of the beam as shown in figure?



Ans. (250 MPa)





$$M_D - M_A = \frac{1}{2} \times 15 \times 0.75$$

$$M_D = 5.625 \text{ kN-m(s)}$$

$$\Sigma M_A = 60 \times 1.5 - R_B \times 2 = 0$$

$$R_B = 45 \text{ kN}(\uparrow); \quad R_A = 15 \text{ kN}(\uparrow)$$

Location of D:

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

$$6 - 3x = 5x$$

$$= \frac{3}{4}\text{m}$$

$$M_C - M_B = \frac{1}{2} \times 20 \times 1$$

$$M_B = -10 \text{ kN-m}$$

$$M_B = 10 \text{ kN-m } (+1)$$

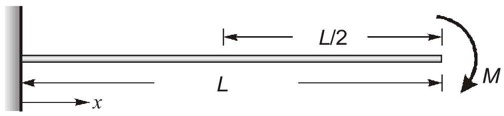
$$\text{Max. B.M.} = \text{Larger of } (M_B \text{ and } M_D)$$

$$M_B = 10 \text{ kN-m } (+1)$$

$$(\sigma_b)_{max} = \frac{M_{max}}{Z_{N.A}} = \frac{6 \times 10 \times 10^6}{24 \times 100^2} = 250 \text{ MPa}$$

End of Solution

Q.16 A cantilever beam of length 'L' and flexural rigidity EI, is subjected to an end moment M then what is the deflection at $x = \frac{L}{2}$?



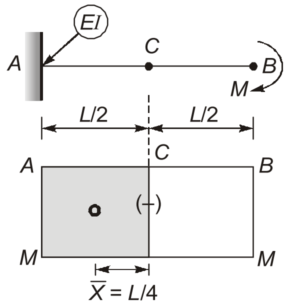
(a) $\frac{ML^2}{2EI}$

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

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

(d) $\frac{ML^2}{8EI}$

Ans. (d)



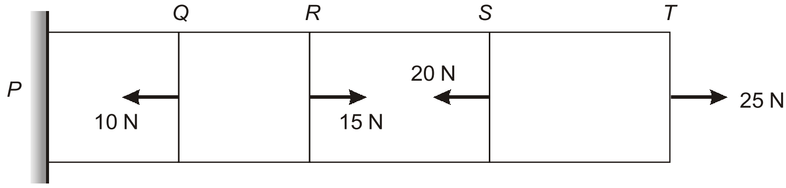
$$Y_C - Y_A = \left(\frac{A\bar{X}}{EI}\right)_{AC}$$

$$Y_C - 0 = \frac{1}{EI}\left[\frac{-ML}{2} \times \frac{L}{4}\right]$$

$$Y_C = \frac{ML^2}{8EI} \text{ (downward)}$$

End of Solution

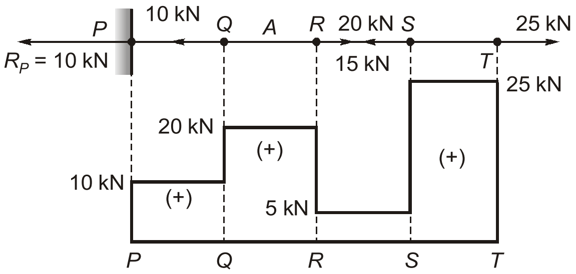
Q.17 As the axial bar is given :



Maximum and minimum axial stress will be in which portion respectively?

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

Ans. (d)



Axial Loading Diagram

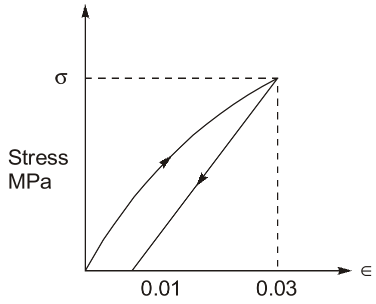
$$P_{max} = P_{ST} = 25 \text{ kN}$$

$$P_{min} = P_{RS} = 5 \text{ kN}$$

Hence, maximum and minimum axial stresses are in ST and RS portions because of prismatic bar. Hence the answer is (d).

End of Solution

Q.18 The loading and unloading response of a metal is shown in figure. The elastic and plastic strain corresponding to 200 MPa stress respectively are _____



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

Ans. (d)

Elastic strain : Which can be recovered = 0.03 – 0.01 = 0.02

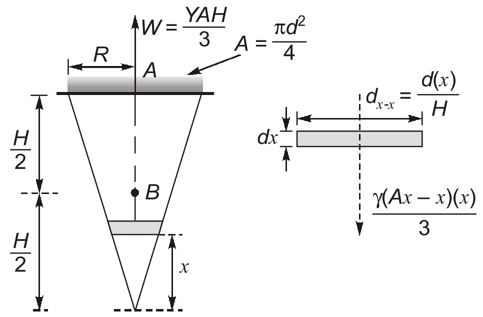
Plastic strain : Permanent strain = 0.01

End of Solution

Q.19 Solid cone is resting on its base having height H and radius R. What is the deflection of cone at its mid height due to its self weight?

(a) $\frac{WRH}{6E}$
(b) $\frac{WH^2}{6E}$
(c) $\frac{WRH}{8E}$
(d) $\frac{WH^2}{8E}$

Ans. (d)



$$A_{x-x} = \frac{\pi}{4}(d_{x-x})^2$$

$$= \frac{\pi}{4}\left[\frac{d(x)}{H}\right]^2$$

$$= \frac{Ax^2}{H^2}$$

$$P_{x\text{-}x} = \frac{\gamma A_{x-x} x}{3}$$

$$(\delta l)_{\text{strip}} = \frac{(P_{x-x})(dx)}{(A_{x-x})(E_{x-x})}$$

$$= \left[\frac{\gamma A_{x-x}(x)}{3}\right]\frac{(dx)}{(A_{x-x})E}$$

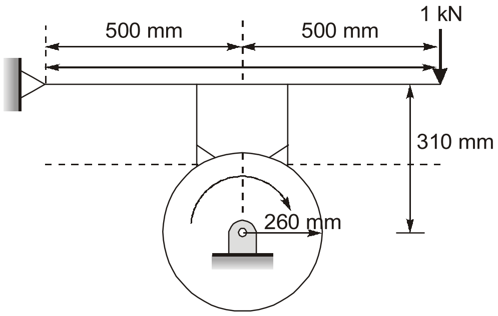
$$(\delta l)_{\text{strip}} = \left(\frac{\gamma x}{3}\right)(dx)$$

$$(\delta L)_{x=\frac{L}{2}} = \int_{H/2}^{H} (\delta L)_{strip} = \frac{\gamma}{3}\int_{H/2}^{H}(x)(dx)$$

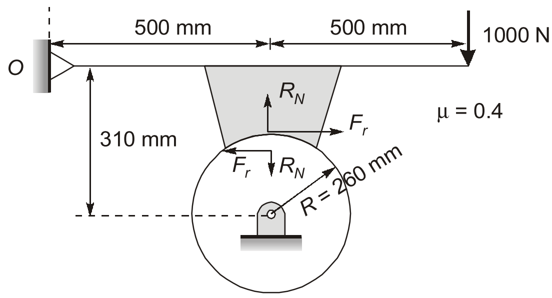
$$(\delta L)_{x=\frac{L}{2}} = \frac{\gamma}{6E}\left[H^2 - \frac{H^2}{4}\right] = \frac{\gamma H^2}{8E}$$

End of Solution

Q.20 Find the braking torque required on the wheel.



Ans. (#)



Taking moment about 'O'

$R_N(500) + F_Y[310 - 260] - 1000 \times 1000 = 0$

$R_N(500) + 0.4(R_N)(50) - 1000 \times 1000 = 0$

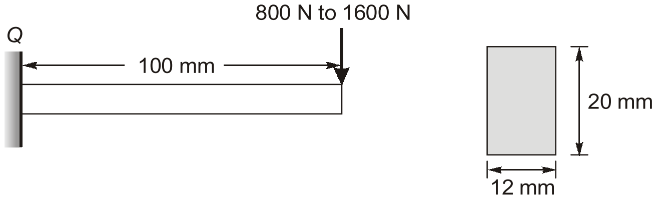
$R_N = 1923.076$ N

$F_r = \mu R_N = 769.23$ N

$T_f = F_r \times R = 200$ N-m

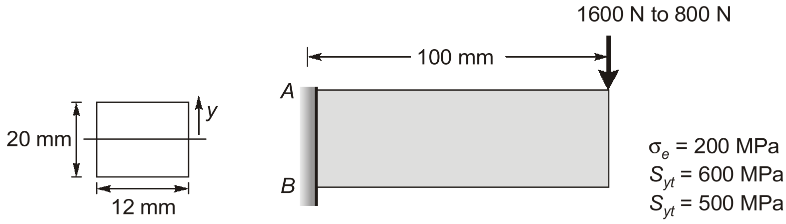
End of Solution

Q.21 Cantilever beam as shown in figure is subjected to fluctuating load as shown.



If corrected endurance strength 200 MPa, yield strength = 500 MPa and ultimate strength 600 MPa, then using modified Goodman theory, the factor of safety of beam ____.

Ans. (#)



A : Critical Point

$$\sigma_{max,A} = \sigma_{b,max} \text{ at } A \text{ due to 1600 N} = \frac{6\,M}{bd^2} = \frac{6\times1600\times200}{12\times(2\sigma)^2}$$

$$\sigma_{max} = 200 \text{ MPa}$$

$$\sigma_{min,A} = \sigma_{b,max} \text{ at } A \text{ due to 800 N}$$

$$= \frac{6\times800\times200}{12\times(20)^2} = 100 \text{ MPa}$$

$$\text{Modified Goodman} = \frac{\sigma_m}{S_{yt}} + \frac{\sigma_a}{\sigma_e} \le \frac{1}{N}$$

$$\sigma_m = \left|\frac{\sigma_{max}+\sigma_{min}}{2}\right| = 150 \text{ MPa}$$

$$\sigma_a = \left|\frac{\sigma_{max}-\sigma_{min}}{2}\right| = 50 \text{ MPa}$$

$$\frac{150}{600} + \frac{50}{200} \le \frac{1}{N}$$

$$N \le 2$$

$$N \approx 2$$

Langer,

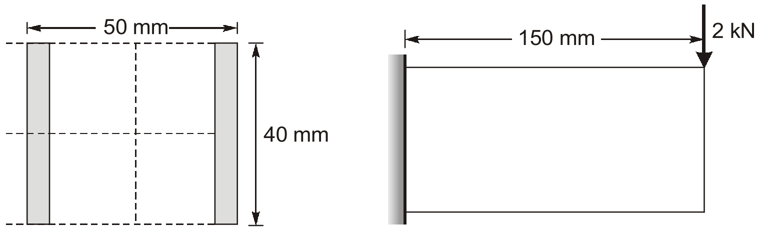
$$\frac{\sigma_m}{S_{yt}} + \frac{\sigma_a}{S_{yt}} \le \frac{1}{N}$$

$$\frac{150}{500} + \frac{50}{500} \le \frac{1}{N} \qquad (N \le 2.5)$$

$$N = 2.5$$

End of Solution

Q.22 Maximum shear stress of weld material 60 MPa. Find the leg thickness of weld ___ mm?



Ans. (#)

$$\tau_{max} = \frac{2\times10^3}{0.707t(40)\times2} = \frac{35.36}{t}\ \text{MPa}$$

$$\sigma_{max} = \frac{M_{max}}{I_{NA}}\cdot\tau_{max} = \frac{2000\times200\times20}{\frac{0.707t(40)^3\times2}{12}}$$

$$\sigma_{max} = \frac{1060.82}{t}\ \text{MPa}$$

MSST, $\sqrt{\sigma_{max}^2+4\tau^2} \le 2\left(\frac{S_{ys}}{N}\right)$

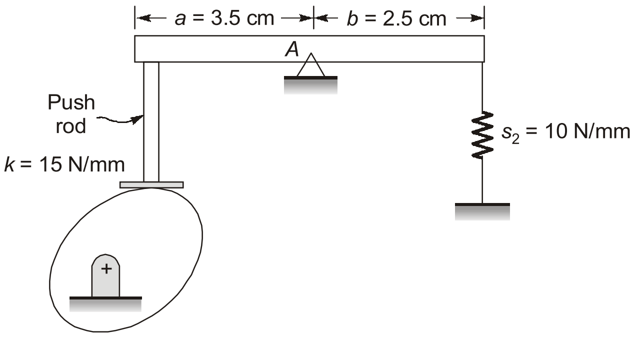
$$\sqrt{\left(\frac{1060.82}{t}\right)^2+4\left(\frac{35.36}{t}\right)^2} \le 2\times60$$

$$\frac{1063.174}{t} \le 2(60)$$

$$t = 8.86\ \text{mm}$$

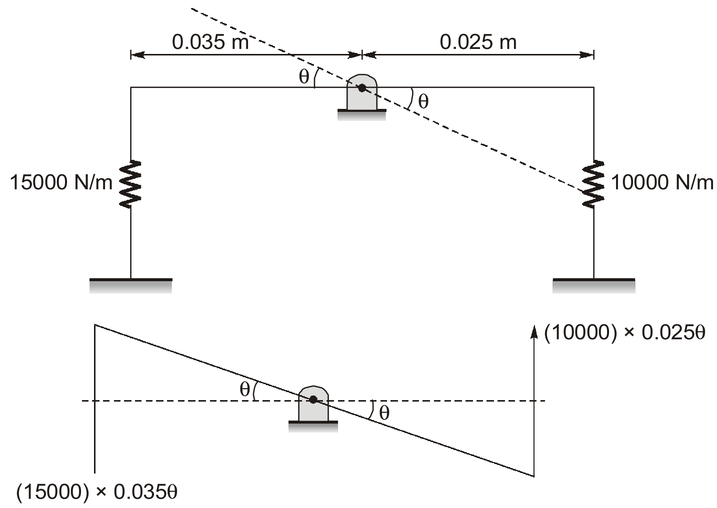
End of Solution

Q.23 At resonance speed of cam N = ____ rpm. $(I_{rod})_A = 10^{-4}$ kg/m²



(a) 4738.64
(b) ##
(c) 496.23
(d) ##

Ans. (#)



$$I = 10^{-4} \text{ kg-m}^2$$

By D'Alembert Principle

$$I\ddot{\theta} + [10000 \times (0.025)^2 + 15000 \times (0.035)^2]\theta = 0$$

θ

$(10000)(0.025)^2\theta$

$(15000)(0.035)^2\theta$

$I\ddot{\theta}$

$$(10^{-4})\ddot{\theta} + (24.625)\theta = 0$$

$$\ddot{\theta} + \left(\frac{24.625}{10^{-4}}\right)\theta = 0$$

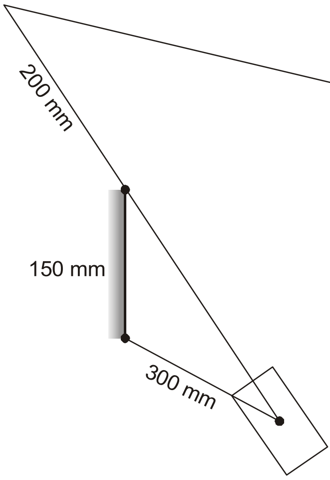
$$\Rightarrow \quad \omega_n^2 = (246250)$$

$$\omega_n = 496.2358 \text{ rad/s}$$

$$\Rightarrow \quad N_C = \frac{496.2358 \times 60}{2\pi} = 4738.7031 \text{ r.p.m.}$$

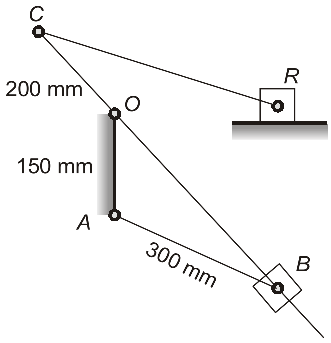
End of Solution

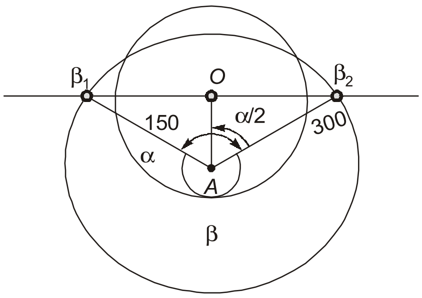
Q.24 What is the quick return ratio of Whitworth quick return mechanism where driving crank is 300 mm and crank radius is 150 mm.



(a) ##
(b) ##
(c) ##
(d) ##

Ans. (#)





$$\cos\frac{\alpha}{2} = \frac{150}{300} = \frac{1}{2}$$

$$\Rightarrow \quad \frac{\alpha}{2} = 60^\circ$$

$$\alpha = 120^\circ$$

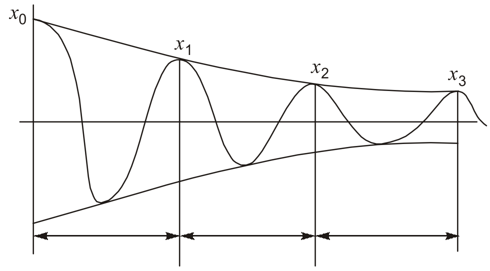
$$\beta = (360^\circ - 120^\circ) = 240^\circ$$

$$\text{QRR} = \left(\frac{\beta}{\alpha}\right) = \frac{240}{120} = 2$$

End of Solution

Q.25 If decrement in amplitude from 8 to 1.5 in 3 cycles. What is damping factor?

Ans. (#)



$$\frac{x_0}{x_3} = \frac{8}{1.5} = \frac{80}{15}$$

$$\frac{x_0}{x_1}\cdot\frac{x_1}{x_2}\cdot\frac{x_2}{x_3} = \frac{80}{15}$$

$$e^{\delta}\cdot e^{\delta}\cdot e^{\delta} = \frac{80}{15}$$

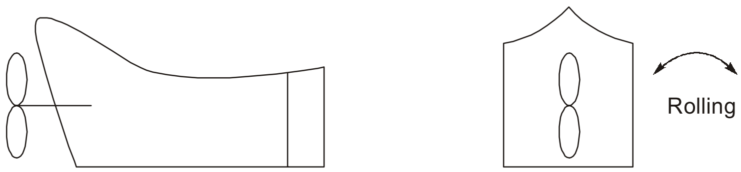
$$e^{3\delta} = \ln\left(\frac{80}{15}\right) = 1.67397$$

$$\delta = 0.55799$$

$$\frac{2\pi}{\sqrt{1-\xi^2}} = 0.55799$$

$$\xi = 0.0884$$

Q.26 Moment of rotor and shaft = 24 kgm^2, ω_{shaft} = 26 rad/s, ω_{spin} = 4 rad/s



The gyroscopic couple to rolling of ship is ________ N.m.

Ans. (#)

End of Solution

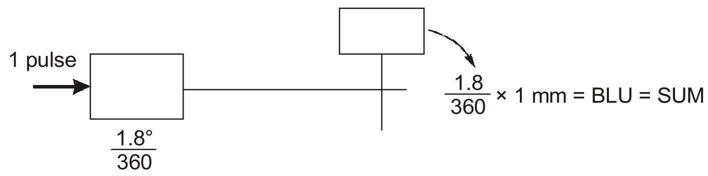
Q.27 The xy table at CNC machine tool is to move from P(1, 1) to Q(51, 1) all coordinates are in (mm). The pitch is 1 mm and step angle is 1.8°, then the total pulse of the table on moving from P to Q is ______.

Ans. (#)

$$1.8° = \alpha$$

200 step = 1 mm pitch

0.005 mm ke line 1 pulse



1 mm for $\frac{1}{0.005}$ pulse

500 mm for $\frac{50}{0.005} = 10000$

End of Solution

Q.28 An orthogonal cutting operation is performed using a single point cutting tool with rake angle, $\alpha = 12°$. Cutting force and thrust force are 1000 N and 600 N. Cut and uncut chip thickness are 1.5 mm and 0.75 mm, then shear force in N is ____.

Ans. (#)

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

$$\tan\phi = \frac{0.5\cos 12°}{1 - 0.5\sin 12°} \Rightarrow \phi = 28.63$$

$$F_s = F_c \cos\phi - F_t \sin\phi$$
$$= 1000 \cos 28.63 - 600 \sin 28.63$$
$$= 590.24 \text{ N}$$

End of Solution

Q.29 In modern CNC machine tool backlash is eliminated by :

(a) rack and pinion
(b) slider and crank
(c) Rachet and Pinion
(d) Preloaded ball screw

Ans. (#)

End of Solution

Q.30 While drilling a through hole the sequence of process should be : Drilling, Boring, Reaming

(a) Reaming, Drilling, Boring
(b) Drilling, Reaming, Boring
(c) Boring, Drilling, Reaming
(d) Drilling, Boring, Reaming

Ans. (#)

End of Solution

Q.31 The resistance spot welding of two 1.55 mm thick metal sheet is performed using I = 10000 A, time = 0.25 second, resistance is 0.0001 Ω. Volume of nugget is to be taken as 70 mm^3, heat energy required for welding is 12 J/mm^3. What is the thermal efficiency of welding process?

Ans. (#)

$$\text{Thickness} = 1.55 \text{ mm}$$
$$I = 10000 \text{ A}$$
$$t = 0.25 \text{ s}$$
$$R = 0.0001\ \Omega$$
$$V_n = 70 \text{ mm}^3$$
$$H_m = 12 \text{ J/mm}^3$$
$$\eta_m = ?$$
$$\eta_m = \frac{H_m}{H_s}$$
$$\text{Melting efficiency} = \text{Thermal efficiency}$$
$$\eta_m = \frac{H_m}{I^2Rt} = \frac{12\times 70}{(10000)^2\times 0.0001\times 0.25}$$
$$= 0.336$$
$$\eta_m = 33.6\%$$

End of Solution

Q.32 In the grinding operation, energy required for grinding is 15 J/mm^3, material removal rate = 6000 mm^3/min, N = 3000 rpm and wheel diameter is 200 mm then what is the tangential force at periphery of wheel?

Ans. (47.746)

$$E_{sp} = 15 \text{ J/mm}^3$$
$$\text{MRR} = 6000 \text{ mm}^3/\text{min}$$
$$N = 3000 \text{ rpm}$$
$$D = 200 \text{ mm}$$
$$E_{sp} = \frac{FcV}{LdV}$$
$$15 = \frac{F\times \frac{m}{\text{min}}}{600\frac{\text{mm}^3}{\text{min}}}$$
$$V = \frac{\pi DN}{1m} = \frac{\pi(200)(3m)}{1000} = 600 \times 3.14$$
$$15 = \frac{F\times 600\times 3\pi y}{6000}$$
$$F = \frac{150}{\pi} = 47.746 \text{ N}$$

End of Solution

Q.33 Centrifugal horizontal casting copper tube outer diameter = 250 mm; Inner diameter = 230 mm; g = 10 m/s^2, G-factor = 60 g.
What is the rpm required?

Ans. (#)

$$D_m = \frac{D_0 + D_i}{2} = 240 \text{ mm}$$

$$R_m = \frac{D_m}{2} = 120 \text{ mm}$$

$$\frac{F_c}{mg} = 60$$

$$\Rightarrow \quad \frac{mR_m\omega^2}{mg} = 60$$

$$R_m\omega^2 = 60 \times 10$$

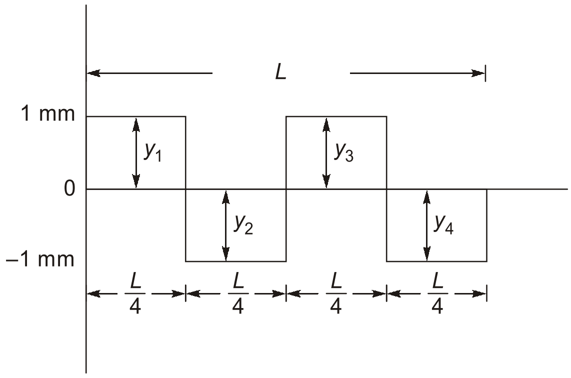
$$\omega^2 = 5000$$

$$\omega = 70.710 \text{ rad/s}$$

$$N = 675.23 \text{ rpm}$$

End of Solution

Q.34 What is the centre line average roughness (R_a)?



(a) 1
(b) 0
(c) $\frac{1}{4}$
(d) $\frac{1}{2}$

Ans. (a)

$$R_G = \frac{\sum_{i=1}^{n} y}{n} = \frac{4}{4} = 1$$

End of Solution

Q.35 A slab 200 mm width and 20 mm thickness, roller radius, r = 300 mm.
Thickness after rolling = 18 mm
Coefficient of friction = 0.1
Strength coefficient, K = 300 MPa
n = 0.2
What is the rolling force required?

Ans. (#)

Rolling:

$$F = 1.15 \times b \times \sqrt{R\Delta h} \times \bar{\sigma}_0 \times \left(1 + \frac{\mu\sqrt{R\Delta h}}{h_o + h_f}\right)$$

$$\bar{\sigma}_0 = \frac{k\sum_f^n}{1+n} = 2020$$

$$= \frac{300 \times (0.1054)^{0.2}}{1+0.2}$$

$$= 159.4 \text{ MPa (Comp.)}$$

$$\varepsilon_f = \ln\left(\frac{h_f}{h_D}\right) = -0.1054$$

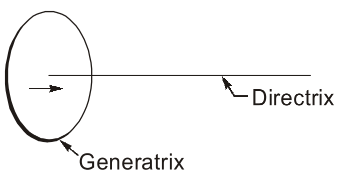
$$= 1.15 \times 200 \times \sqrt{300 \times 2} \times 159.4 \times 1 - \frac{0.1 \times \sqrt{300 \times 2}}{20+18}$$

$$= 955{,}919.3 \text{ N}$$

$$= 955.9 \text{ kN}$$

End of Solution

Q.36 What is the surface generated?



(a) Spherical
(b) Cylindrical
(c) Planar
(d) Surface Revolution

Ans. (#)

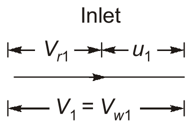
End of Solution

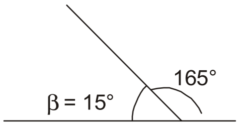
Q.37 A pelton wheel working under head of water such that velocity of jet is 40 m/s and discharge, Q = 5 m^3/s. The diameter wheel is 2 m and rotating at 300 rpm, angle of deflection of jet is 165°. The power developed is ____ MW.

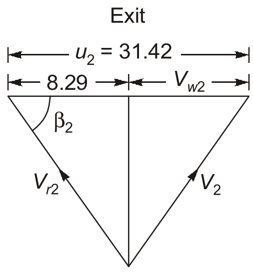
Ans. (#)

$$P = ? \qquad P = \dot{m}\left[V_{w_1} - V_{w_2}\right]u$$

$$N = 300 \text{ rpm}$$
$$D = 2 \text{ m}$$
$$V_1 = 40 \text{ m/s}$$
$$Q = 5 \text{ m}^3\text{/s}$$
$$\beta = 180 - 165 = 15°$$



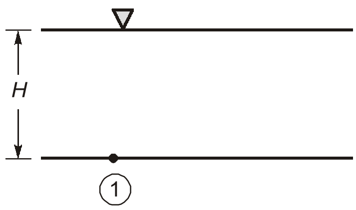




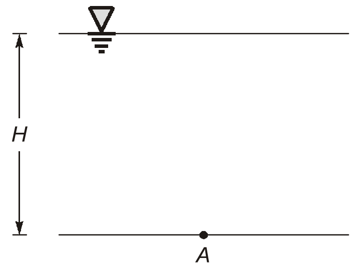
$$u = \frac{\pi DN}{60} = \frac{\pi \times 2 \times 300}{60}$$
$$u_1 = u_2 = u = 31.42 \text{ m/s}$$
$$V_{r1} = V_1 - u$$
$$V_{r1} = 40 - 31.42$$
$$V_{r1} = 8.58$$
$$V_{r1} = V_{r2} = 8.58 \text{ m/s [neglecting blade friction]}$$
$$V_{r2}\cos\beta_2 = u_2 - V_{w2}$$
$$P = \rho Q[V_{w1} - V_{w2}]$$
$$= 2.65$$
$$P = 2.65$$

End of Solution

Q.38 A pressure measurement device is kept on a submarine which is measured 4.2 MPa and atmospheric pressure is 101 kPa. Density of sea water is 1050 kg/m^3 and acceleration due to gravity is 9.8 m/s^2. What is the value of H?



Ans. (#)

1. 

P_A = 4.2 MPa [Absolute pressure]

P_{atm} = 101 kPa

ρ = 1050 kg/m^3

g = 9.8 m/s^2

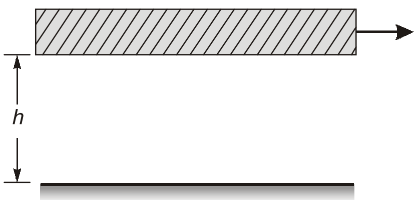
$$P_A = P_{atm} + \rho g H$$

$$4.2 \times 10^6 = (101 \times 10^3) + [1050 \times 9.81 \times H]$$

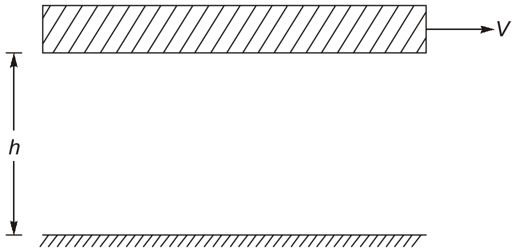
$$H = 397.94 \text{ or } 398 \text{ m}$$

End of Solution

Q.39 A fully developed steady laminar flow of viscous fluid is in between two parallel plates. The bottom plate is fixed and top plate moves at a velocity of 4 m/s. The distance between plates is 5 mm. Density of fluid is 800 m^3/kg and kinematic viscosity is 1.25×10^{-4} m^2/s. Here there is no pressure gradient along the direction of flow. The average shear stress is ____ Pa.



Ans. (#)



V = 4 m/s

ρ = 800 kg/m^3

ν = 1.25×10^{-4} m^2/s

h = 5 mm

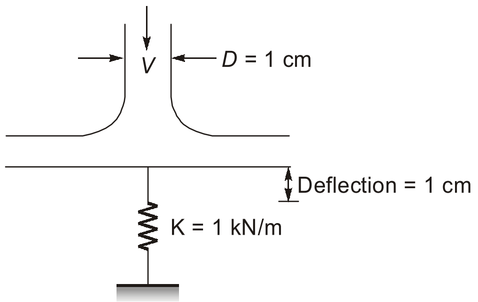
$$\tau = \mu \cdot \frac{du}{dy}$$

$$\tau = [800 \times 1.25 \times 10^{-4}] \times \frac{4}{5 \times 10^{-3}}$$

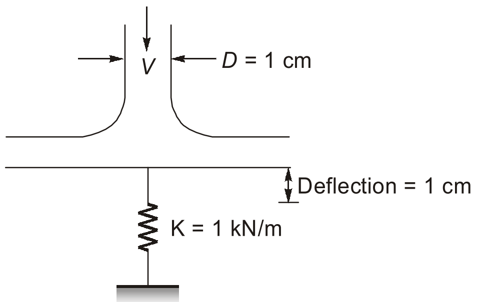
$$\tau = 80 \text{ N/m}^2$$

End of Solution

Q.40 Find the velocity of the stream of the given conditions.



Ans. (#)



$$\delta = 1 \text{ cm}$$
$$D = 1 \text{ cm}$$
$$\rho = 1000 \text{ kg/m}^3$$
$$K = 1 \text{ kN-m}$$
$$\text{Force due to jet} = \text{Spring force}$$
$$\rho A V^2 = kx$$
$$10^3 \times \frac{\pi}{4} \times (0.01)^2 \times V^2 = 1 \times 10^3 \times 0.01$$
$$V = 11.28 \text{ m/s}$$

End of Solution

Q.41 What is the probability of completing task within 40 days?

	A	B	C	D
T(e) (days)	6	11	8	15
σ (day)	4	9	4	9

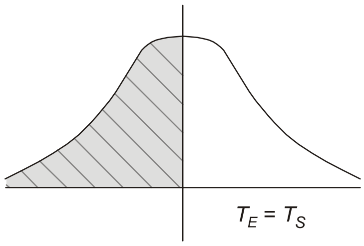
Ans. **(#)**

PERT-CPM

$$T_S = 40 \text{ days}, \quad T_E = 6 + 11 + 8 + 15$$

$$T_E = 40 \text{ days},$$

$$2 = \frac{T_S - T_E}{\sigma} = 0 \rightarrow 50\%$$



Probability of completing project in expected time is always 50%.

End of Solution

Q.42 Arrival rate of job following poisson distribution is 12 jobs/hr and mean service time is 4 minutes. What will be the expected number of job in the system?

Ans. **(#)**

$$\lambda = 12 \text{ per hour}, \quad \frac{1}{\mu} = 4 \text{ min/Jobs}, \quad \mu = 15 \text{ Jobs/hr}$$

$$\delta = \frac{12}{15} = \frac{4}{5}$$

$$L_s = \frac{\delta}{1-\phi} = \frac{\frac{4}{5}}{1-\frac{4}{5}} = \frac{\frac{4}{5}}{\frac{1}{5}}$$

$$\frac{4}{5} \times \frac{5}{1} = 4 \text{ Jobs}$$

End of Solution

Q.43 Machining operation is being performed on a job with a sequence of first turning and then grinding :

Jobs	A	B	C	D	E	F	G	H
Turning Machine	2	4	8	9	7	6	5	10
Grinding Machine	4	1	3	7	9	5	2	4

Find the sequence of jobs by minimizing make span time.

(a) A D E R H C G B
(b) G E D F H C A B
(c) A E D F H C G B
(d) B G C H F D E A

Ans. (c)

Sequencing,

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

A E D F H C G B

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