GATE 2020

Mechanical Engineering

Forenoon Shift

Solution

GENERAL APTITUDE

1.

Ans. D

Sol.

Build : Building :: Grow : Growth

2.

Ans. D

Sol.

He is known for his unscrupulous ways. He always sheds crocodile tears to deceive people.

3.

Ans. B

Sol.

4.

Ans. C

Sol.

Jofra Archer, the England fast bowler, is more fast than accurate.

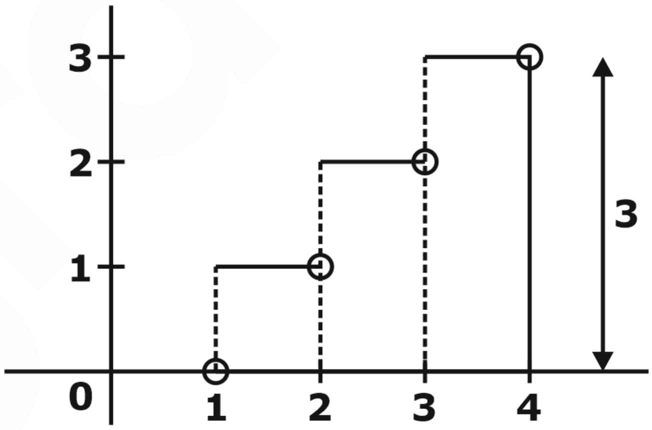
5.

Ans. D

Sol.

y = [x]

Area under the curve y = [x].



Area = 1 × 1 + 1 × 2 + 1 × 3

= 1 + 2 + 3

= 6

6.

Ans. C

Sol.

$$\text{Sucess Rate (P)} = \frac{280}{500} \times 100 = 56\%$$

$$\text{Sucess Rate (Q)} = \frac{330}{600} \times 100 = 55\%$$

$$\text{Sucess Rate (R)} = \frac{455}{700} \times 100 = 65\%$$

$$\text{Sucess Rate (S)} = \frac{240}{400} \times 100 = 60\%$$

$$\text{Average Success Rate} = \frac{56 + 55 + 65 + 60}{4}$$

= 59%

7.

Ans. B

Sol.

Summery of the above paragraph

Funds raised through voluntary contributions on web-based platforms.

8.

Ans. C

Sol.

9.

Ans. C

Sol.

Sum of first n term is

= 8 + 88 + 888 + 8888 + ……

= 8[1 + 11 + 111 + 1111 + …..]

$$= \frac{8}{9}\left[9 + 99 + 999 + 9999 + ...\right]$$

$$=\frac{8}{9}\left[(10-1)+\left(10^2-1\right)+\left(10^3-1\right)+\left(10^4-1\right)\right]$$

$$=\frac{8}{9}\left[10+10^2+10^3+10^4......n\right]$$

$$=\frac{8}{9}\left[10+10^2+10^3+10^4.....n-(1+1.....n)\right]$$

$$\frac{8}{9}\left[10.\frac{\left(10^n-1\right)}{10-1}-n\right]$$

$$=\frac{80}{81}\left(10^n-1\right)-\frac{8}{9}n$$

10.

Ans. A

Sol. Put m = 2, so y = x^2 and y = $x^{\frac{1}{2}}$

And x= 0.5

$Y=x^m= 0.5^2= 0.25$

$y=x^{1/m} =0.5^{0.5}= 0.707$

so $x^{1/m}$ will be above than x^m

Satisfy option C.

TECHNICAL

11.

Ans. C

Sol. Velocity for incompressible fluid flow,

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

From above velocity relation

$u = 2(x^2 - y^2)$

$V = V$

$\omega = 3$

If the flow is incompressible continuity equation has to be satisfied,

$$\frac{\partial u}{\partial x} + \frac{\partial V}{\partial y} + \frac{\partial \omega}{\partial z} = 0$$

$$\frac{\partial}{\partial x}\left(2\left(x^2 - y^2\right)\right) + \frac{\partial V}{\partial y} + \frac{\partial}{\partial z}(3) = 0$$

$$\Rightarrow 4x + \frac{\partial V}{\partial y} + 0 = 0$$

$$\Rightarrow \frac{\partial V}{\partial y} = -4x$$

$$\Rightarrow \boxed{V = -4xy + C}$$

12.

Ans. (1.264)

Sol. Given

$C_1 = 1$ mm $\quad (HRC)_1 = 250$

$C_2 = ?$ $\quad (HRC)_2 = 400$

$$C = 0.0032t\sqrt{\tau}$$

$$C \propto \sqrt{C} \propto \sqrt{HRC}$$

$$\frac{C_2}{C_1} = \sqrt{\frac{(HRC)_2}{(HRC)_1}}$$

$$\Rightarrow \frac{C_2}{1} = \sqrt{\frac{400}{250}}$$

$C_2 = 1.264$mm

13.

Ans. A

Sol. Joule Thomson coefficient for real gas,

$$\mu = \left(\frac{\partial T}{\partial P}\right)_h = \frac{1}{C_P}\left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right]\ldots(1)$$

For an ideal gas, PV = RT

$$T\left(\frac{\partial V}{\partial T}\right)_P - V$$

So, $T\left(\frac{\partial V}{\partial T}\right)_P \times P = R$

$$\left(\frac{\partial V}{\partial T}\right)_P = \frac{R}{P}\ldots\ldots(2)$$

Putting eqn (2) in eq (1)

$$\mu = \frac{1}{C_P}\left[T \times \frac{R}{P} - V\right]$$

Now, since, $\frac{12T}{P} = V$

$$\mu = \frac{1}{C_P}\left[V - V\right] = 0$$

$\mu = 0$ (for ideal gas)

14.

Ans. (244.94)

Sol. Pressure after 1st stage compression (P_2) for perfect intercooling.

Overall pressure ratio (r_p) overall = 6

$$\left(r_p\right)_{overall} = \frac{P_3}{P_1}$$

For perfect intercooling, intermediate pressure (P_2) = $\sqrt{P_1P_3}$

P_1 = 100 kPa

$P_3 = 6P_1$ = 600 kPa

$$P_2 = \sqrt{100 \times 600}$$

= P_2 = 244.9 kPa

15.

Ans. (6)

Sol. $\vec{A} = 2\hat{j} - 3\hat{k}, \quad \vec{B} = -2\hat{i} + \hat{k}$

$\vec{C} = 3\hat{i} - \hat{j}$

$\vec{A}(\vec{B}\times\vec{C})$

$$=\begin{vmatrix} 0 & 2 & -3 \\ -2 & 0 & 1 \\ 3 & -1 & 0 \end{vmatrix}$$

= −2 (−3) −3(2)

= 0

$\therefore \vec{A}(\vec{B}\times\vec{C})+6=6$

16.

Ans. C

Sol.

Reynolds No.	Inertia force/Viscous force
Grashoff	Buoyant/viscous
Nusselt	Conv. H.T/cond. H.T.
Prandtl No.	Momentum diffusivity /thermal diffusivity

17.

Ans. A

Tds equation are

Tds = dU + pdv → (1)

Tds = dU + pdV → (2)

From 1st Tds relation

Tds = dU + pdV

At constant volume, dV = 0

Tds = dU = CvdT

$\boxed{\left(\frac{dT}{ds}\right)_V = \frac{T}{C_V}}$ at constant volume

So, at constant volume, slope of (T −S) is T/C_V

From 2nd Tds relation, Tds = dH − vdP

At constant pressure, dP = 0

Tds = dH = C_pdT

$$\left(\frac{\partial T}{\partial S}\right)_{p=c} = \frac{T}{C_p}$$

So, ratio of slope of constant pressure & volume = $\frac{T}{C_p} / \frac{T}{C_v} = \frac{C_v}{C_p}$

18.

Ans. C

Sol. The crystal of γ iron (austenite phase) is FCC

19.

Ans. D

Sol. The normal force can be resolved into three components as shown in figure.

Due to f_a = axial force axial stress is Present in shaft

Due to f_T = thrust force torsion will be present in shaft.

Due to for bending stress.

But due to fu also bending will be there but in different plane to that due to hence bending stress in two planes.

20.

Ans. C

Sol. f(z) = log z

At z = 0

f(z) = logz ⇒ not defined Hence out of all other functions logz is not analytic at z = 0.

21.

Ans. D

Sol. apply L hospital rule, you get answer as C/C+A.

It is direct formula of effectiveness in the case of counter flow heat exchanger when hate capacity ratio is 1

22.

Ans. C

Sol. $\text{cos t time slope} = \frac{\text{Crash Cost} - \text{Normal cos t}}{\text{Normal time} - \text{Crash time}}$

23.

Ans. (49.33)

Sol. $\text{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ell n\left(\frac{\Delta T_1}{\Delta T_2}\right)}$

$\Delta T_1 = T_{hi} - T_{co} = 60°$

$\Delta T_2 = T_{ho} - T_{ci} = 40°$

$\text{LMTD} = \frac{60 - 40}{\ell n\left(\frac{60}{40}\right)} = 49.33°C$

24.

Ans. C

Sol. Froud Number is the ratio of inertia force/gravity force.

25.

Ans. B

Sol.

$$\in = \frac{F_t}{F_0}$$

$F_t = F_0 \Rightarrow \epsilon = 1$

$\epsilon = 1$

$\frac{\omega}{\omega_n} = 0 \Rightarrow$ Not possible

$\frac{\omega}{\omega_n} = \sqrt{2}$

$$\omega = \sqrt{2} \times \omega_n$$

$$= \sqrt{2} \times \sqrt{\frac{k}{m}}$$

$$\omega = \sqrt{\frac{2k}{m}}$$

26.

Ans. D

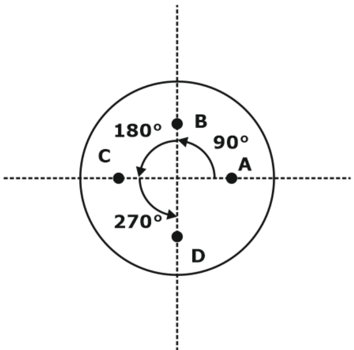
Sol.

Heat treatment process	Effect
P: Tempering	B. Toughening
Q: Quenching	C. Hardening
R: Annealing	D. Softening
S: Normalizing	A. Strengthening

27.

Ans. (0.1)

Sol. If mass A is removed, then system becomes unbalanced.



$F_{resultant}$ = Net unbalanced force

$$= \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2}$$

$\Sigma F_x = mr\omega^2(\cos 90° + \cos 180° + \cos 270°)$

$= mr\omega^2(0 - 1 + 0)$

$\Sigma f_x = -0.1$

Similarly,

$\Sigma F_y = mr\omega^2(\sin 90° + \sin 180° + \sin 270°)$

$\Sigma f_y = 0$

$$F_r = \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2}$$

$F_r = 0.1N$ = Net unbalanced force.

28.

Ans. D

Sol. $Lf(t) = \dfrac{1}{S^2 + \omega^2}$

$$L^{-1}\left(\frac{1}{S^2 + \omega^2}\right) = f(t)$$

or

$$L \sin at = \frac{a}{S^2 + a^2}$$

$$\therefore L \sin \omega t = \frac{\omega}{S^2 + \omega^2}$$

$$\therefore L^{-1}\left(\frac{1}{S^2 + \omega^2}\right) = \frac{\sin \omega t}{\omega}$$

29.

Ans. D

Sol. Matrix multiplication is Associative but not commutative.

eg. AB ≠ BA

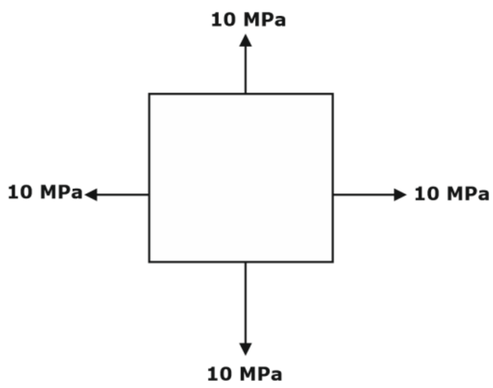
But

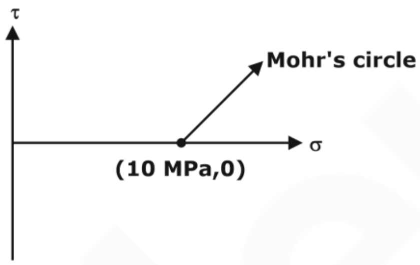
A (BC) = (AB) C ⇒ Associative

30.

Ans. B

Sol.





31.

Ans. (0.93)

m(number of men) = 5

n(number of woman) = 3

number of vacancy = 4

Probability that at least one woman is selected

= 1 – probability that no woman is selected

$$= 1 - \frac{^5C_4}{^8C_4}$$

$$= 1 - \frac{5}{70}$$

= 0.928

32.

Ans. 1

ω_{max} = 110 rad/s

ω_{min} = 100 rad/s

ΔE = A.05 kJ = 1050 J

I = ?

$$\Delta E = \frac{1}{2} I(\omega^2{}_{max} - \omega_{min}{}^2)$$

$$1050 = \frac{1}{2} I(110^2 - 100^2)$$

I = 1

33.

Ans. D

For crank rocker, PQ should be shortest

$(s + l) \leq P + Q$

600 mm → longest link

P = 300 mm, Q = 400 mm

$S + 600 \leq (300 + 400)$

$S \leq 100$

34.

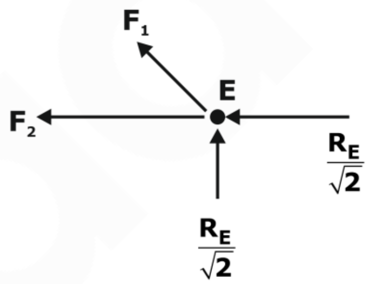
Ans. C

Sol. Moment at A

$$(P \times 2\ell) = \frac{R_E}{\sqrt{2}} \times 4\ell$$

$$\Rightarrow R_E = \frac{P}{\sqrt{2}}$$

Pt. E



$$F_1 \sin 45^\circ + \frac{R_E}{\sqrt{2}} = 0$$

$$\frac{F_1}{\sqrt{2}} + \frac{R_E}{\sqrt{2}} = 0$$

$F_1 = -R_E$

$$\boxed{F_1 = -\frac{P}{\sqrt{2}}}$$

$$F_1 \cos 45 + F_2 + \frac{R_E}{\sqrt{2}} = 0$$

$$\frac{-P}{2} + F_2 + \frac{P}{2} = 0$$

$\boxed{F_2 = 0}$

Correction option D

BF = 0

DH = 0

GC = 0

35.

Ans. D

Grinding → for rough operations → open structure wheels are preferred

0 to 16 so 12 will give more open

For rough operations brass tool with material is generally SiC

so C30Q12V will be the right choice

36.

Ans. B

Sol. r = 0.5 mm

$T_0 = 100°C$

$T_\infty = 20°C$

T = 28°C after t = 4.35 sec.

$\rho = 8500\ kg/m^3$

$C_P = 400$ J/kgk

h = ?

As it is lumped system

$$\frac{T - T_\infty}{T_0 - T_\infty} = e^{-\frac{hA}{\rho V C_P}\times t}$$

$$\frac{28 - 20}{100 - 20} = e^{-\left(\frac{h\times 4\pi r^2}{\rho\times\frac{4}{3}\pi r^3\times C_P}\times t\right)}$$

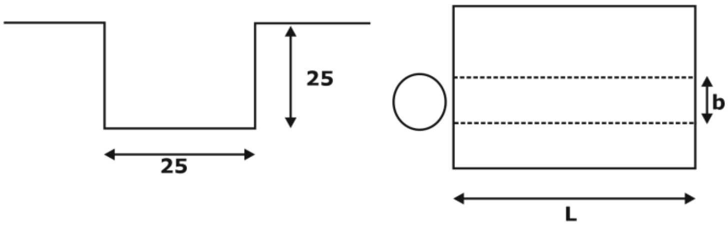
$$\frac{8}{80} = e^{-\frac{h\times 4.35}{8500\times\frac{0.5\times 10^{-3}}{3}\times 400}}$$

h = 299.95 w/m^2k

37.

Ans. (6.99)

Sol. Given



D = 100 mm

L = 300 mm

b = 25 mm

T = 20

A (Approach) = 5 mm

O (Overtravel) = 5 mm.

d = 5 mm.

$(f)_t$ = 0% mm

$(V)_S$ = 35 m/min.

Since d < slot dimension, the complete milling has to be done in 5 passes.

Necessary approach = Necessary overtravel

$$= \frac{D}{2} - \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{b}{2}\right)^2}$$

$$AN = \frac{100}{2} - \sqrt{\left(\frac{100}{2}\right)^2 - \left(\frac{25}{2}\right)^2}$$

AN = A.587 mm

Time Per Cut

$$= \frac{L + AN + A + O}{f_T NT}$$

V = π D N

$$N = \frac{V}{\pi D} = \frac{35}{\pi \times 0.1}$$

N = 111.4 RPM

$$(T)_{per\ cut} = \frac{300 + 1.587 + 5 + 5}{0.1 \times 111.4 \times 20}$$

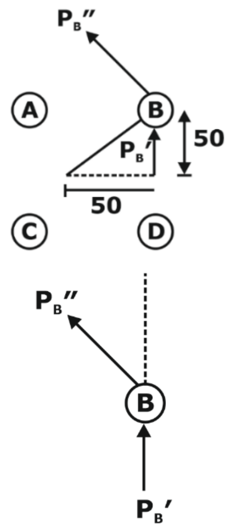
(T)per cut = 1.398 min.

Total time = $(T)_{per\ cut}$ × Number of cut

Total time = 1.398 × 5

= 6.99 minutes

38.
Ans. (16)
Sol.



$$r_B = \sqrt{50^2 + 50^2} = 50\sqrt{2}$$

$$P_B^{'} = \frac{P}{\text{No. of bolt}} = \frac{10}{4} = 2.5\,kN$$

$$P_B^{''} = \frac{P_e r_B}{\left(r_a^2 + r_b^2 + r_c^2 + r_d^2\right)}$$

$$= \frac{10\times10^3\times0.4\times\left(50\sqrt{2}\times10^{-3}\right)}{4\times\left(50\sqrt{2}\times10^{-3}\right)^2}$$

= 14.14 kN

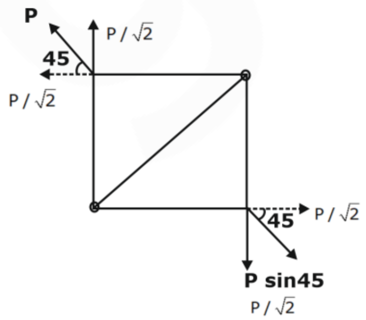
$$\text{Resultant} = \sqrt{\left(P_B^{'}\right)^2 + \left(P_B^{''}\right)^2 + 2P_B^{'}\times P_B^{''}\cos45^\circ}$$

= 16 kN

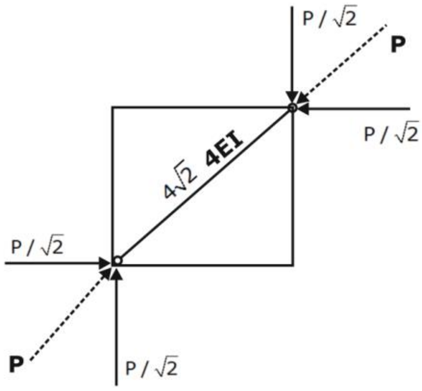
39.

Ans. A

Sol.



By shifting force



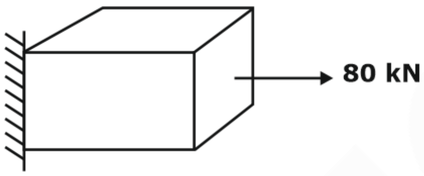
$$P = \frac{\pi^2 EI}{L^2} = \frac{\pi^2(4EI)}{(\sqrt{2}L)^2}$$

$$P = \frac{2\pi^2 EI}{L^2}$$

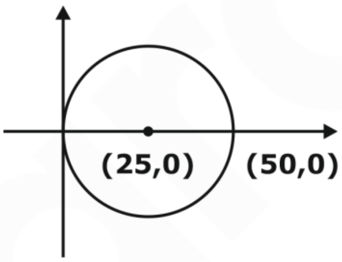
40.

Ans. A

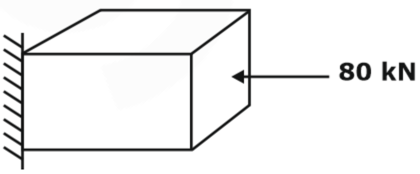
Sol.

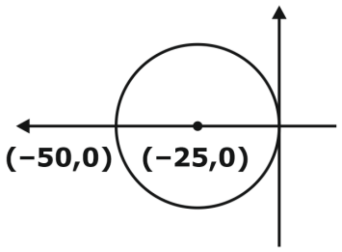


$$\sigma = \frac{80 \times 10^3}{40 \times 40} = 50 \text{ MPa}$$

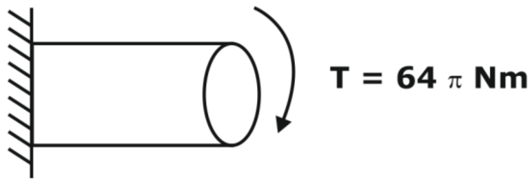


τ_{max} = 25 MPa which is greater than shear strength of material





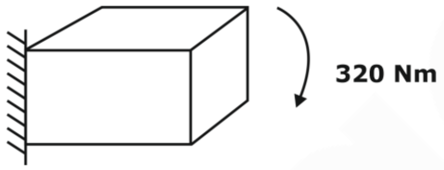
τ_{max} = –25 MPa which is greater than shear strength of material



$$\tau = \frac{16T}{\pi d^3}$$

$$= \frac{16 \times 64\pi \times (100)^3}{\pi \times 4^3}$$

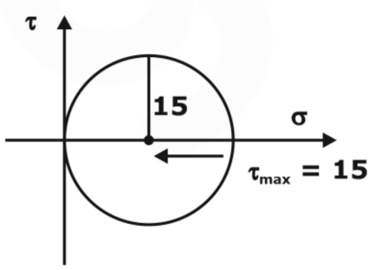
τ = 16 MPa which is less than shear strength of material



$$\frac{\sigma}{y} = \frac{M}{I}$$

$$\sigma = \frac{My}{I}$$

$$= \frac{320 \times \frac{4}{2}}{\frac{a^4}{12}} = 30 \times (100)^3 = 30\text{MPa}$$



τ = 15 MPa which is less than shear strength of material

41.

Ans. B

Sol.

$\Delta h = \mu^2 R$

$40 - 20 = \mu^2 \times 100$

$$\mu^2 = \frac{20}{100} \approx 0.45$$

$\mu = 0.45$

$$1 - \frac{\Delta h}{D} = \cos\alpha \Rightarrow \cos\alpha = 1 - \frac{20}{200}$$

$\alpha = 0.451$

Arc length = $R\alpha$

$= 100 \times 0.451$

Arc length 45.1 mm

42.

Ans. (2)

Sol.

$f(z) = (x^2 - y^2) + \xi\,(x, y)$

$Z = 1 + i$

$x = 1, y = 1$

$$\partial v = \frac{\partial v}{\partial x} dx + \frac{\partial v}{\partial y} dy$$

Those term of which not containing x for analytic f^n

$$\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}, \frac{\partial v}{\partial x} = -\frac{\partial u}{\partial y}$$

$\Rightarrow u = x^2 - y^2$

$$2x = \frac{\partial v}{\partial y} \quad \frac{\partial v}{\partial x} = (-2y)$$

$$\frac{\partial v}{\partial y} = 2x \quad \frac{\partial v}{\partial x} = 2y$$

$$\partial v = 2y\,dx + 2\underset{0}{\underset{\|}{x}}\,dy$$

$\partial v = 2y\,dx$

$v = 2xy$

$v(1, 1) = 2 \times 1 \times 1$

$v\,(1, 1) = 2$

43.

Ans. *

44.

Ans. (23.53)

$$r = \frac{l_c}{l} = \frac{100}{250} = 0.4$$

Shear angle, $\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}$

$$= \frac{0.4\cos(20^\circ)}{1 - 0.4\sin(20^\circ)}$$

φ = 23.53

45.

Ans. (4)

Sol.

specific steam consumption (ssc) = $\frac{3600}{W_{net}}$

Net work (W_{net}) = Turbine work – Pump work

= 903 – 3 = 900 KJ/Kg

specific steam consumption = $\frac{3600}{W_{net}}$

$$= \frac{3600}{900}$$

= 4 Kg/Kwh

46.

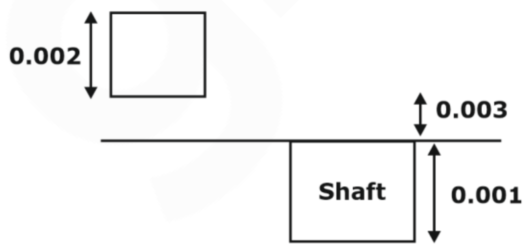
Sol.

Tolerance of hole = 0.002 mm

Tolerance of shaft = 0.001 mm

allowance = 0.003 mm ⇒ minimum

basic size = 50mm



Max hole size

=50 + 0.003 + 0.002

= 50.005 mm

47.

Ans. (-1)

Sol.

$\mu(x) = \mu(y) = 0.5$

$\therefore \sigma^2(x) = \sigma^2(y) = 0.5 = 0.25$

$Z = X + Y$

Var(z) = var x + var y + 2 cov (x,y)

$$\therefore \text{cov}(x, y) = \frac{-0.25 - 0.25}{2}$$

$= -0.25$

$$\therefore r = \frac{\text{cov}(x, y)}{\sigma_x \sigma_y}$$

$$= \frac{-0.25}{\sqrt{0.25}\sqrt{0.25}}$$

$= -1$

48.

Ans. (B)

Sol.

$$\text{div } F = \frac{(x^2 + y^2 + z^2)^{\frac{1}{2}}}{(x^2 + y^2 + z^2)^3}\begin{bmatrix} -2x^2 + y^2 + z^2 + x^2 - 2y^2 + z^2 \\ +x^2 + y^2 - 2z^2 \end{bmatrix}$$

$= 0$

$$\int\int \vec{F} \cdot d\vec{s} = \iiint \text{div } F \, dv = 0$$

49.

Ans. (0.375)

Sol. Given

$P_1 = 0.36$ KPa (At Inlet)

$P_2 = 0$ (At outlet)

$A_1 = 0.1$ m2 $\quad \rho_{\text{ air}} \; P_o = \frac{f_x}{A} = \rho v^2 = A.2 \text{ kg/m}^3$

$A_2 = 0.02$ m2 [Constant]

$P_o = ?$

Apply Bernoulli's equation at Inlet and outlet section.

$$\frac{P_1}{\rho_g} + \frac{V_1^2}{2_g} + z_1 = \frac{P_2}{\rho_g} + \frac{V_2^2}{2_g} + z_2$$

$Z_1 + Z_2$, $\quad P_2 = 0$

$$\frac{P_1}{\rho_g}+\frac{V_1{}^2}{2_g}=\frac{V_2{}^2}{2_g} \quad ....(1)$$

By Continuity equation.

$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$

$\rho 1 = \rho 2$

$$V_1 = \frac{A_2}{A_1}V_2$$

$$V_1 = \frac{0.02}{0.1}V_2$$

$V1 = 0.2 V_2$

Putting in equation

$$\frac{360}{1.2}=\frac{V_2^2-(0.2V_2)^2}{2}$$

$$300=\frac{0.96V_2 2}{2}$$

$V_2 = 25$ m/s

Apply Bernoulli's equation between 2 and 0.

$$\frac{P_2}{\rho g}+\frac{V_2{}^2}{2g}+Z_1=\frac{P_0}{\rho g}+\frac{V_0{}^2}{2g}+\tau_0$$

$Z_1 = z_0$

$P_2 = 0$

$V_0 = 0$

$$\frac{V_2{}^2}{2g}=\frac{P_0}{\rho g}$$

$$P_0=\frac{\rho V_2{}^2}{2}$$

$$P_0=\frac{1.2\times(25)^2}{2}$$

$P_0 = 375\ P_a$

$P_0 = 0.375$ KPa

50.

Ans. (A)

Sol. f(x) = x(x)

a = –1

b = 1.4

h = 0.6

number of Interval $= \frac{b-a}{h} = \frac{1.4+1}{0.6}$

n = 4

y_o	y_1	y_2	y_3	y_n
−1	−0.16	0.04	0.64	A.96

By Simpson's $\frac{1}{3}$rd Rule.

$$\int_{-1}^{1.4} x|x| = \frac{h}{3}\left[y_o + y_n + 2\{y_2\} + 4(y_1 + y_3)\right]$$

$$= \frac{0.6}{3}\left[-1 + 1.96 + 2(0.04) + 4(-0.16 + 0.64)\right]$$

= 0.592

51.

Ans. (A)

Sol.

Production = 4 units

2nd case

Production

= 4 × 0.7 = 2.8

2.8 units

% reduction $= \left(\frac{4-2.8}{4}\right) \times 100$

= 0.3 × 100

= 30%

52.

Ans. (8)

Sol. Given

$$v = -c\left(r^2 - \frac{D^2}{4}\right) = -c(r^2 - R^2)$$

$v = c(R^2 - r^2)$

$$d(KE) = \frac{1}{2}dm(v^2) = \frac{1}{2}v^2\rho dv = \frac{1}{2}\rho v^2 \times vdA$$

$$d(KE) = \frac{1}{2}\rho v^3 dA$$

$$KE\int d(KE) = \int \frac{1}{2}\rho c(R^2 - r^2)^3 \times 2\pi r\, dr$$

$$= \frac{1}{2}\rho c^3 \int R^6 + r^6 - 3R^2r^2 - 3R^2r^2(R^2 - r^2)2\pi r dr$$

$$\frac{1}{2}^{2\pi\rho c^3} \int_o^R R^6 r + r^7 - 3R^4r^3 + 3R^2r^5 dr$$

KE = $\pi\rho c^3 R^8 \times 0.625$

KE = $0.625 \times \pi\rho c^3 \times R^8$

KE $\propto R^8$

KE $\propto D^8$

KE $\propto D^n \Rightarrow n = 8$

53.

Ans. (0.87)

Sol.

U.PT

$$T_1 = \frac{\mu P}{3}\left(\frac{D^3 - d^3}{D^2 - d^2}\right)$$

$$P_1 = \frac{F_1}{\frac{\pi}{4}\left(D^2 - d^2\right)}$$

$$T_2 = \frac{\mu P}{4}(D + d)$$

D = 250 mm

d = 50 mm

$$\frac{T_1}{T_2} = \frac{\frac{\mu P_1}{3}\left(\frac{D^3 - d^3}{D^2 - d^2}\right)}{\frac{\mu P_2}{4}(D + d)}$$

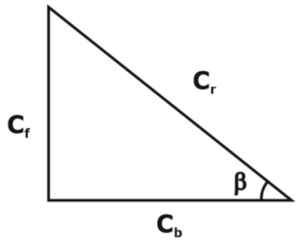
$$\frac{P_1}{P_2} = \frac{\frac{(D+d)}{4}}{\frac{1}{3}\left(\frac{D^3 - d^3}{D^2 - d^2}\right)} = \frac{\frac{300}{4}}{\frac{1}{3}\left(\frac{250^3 - 50^3}{250^2 - 50^2}\right)} = \frac{75}{86.11} = 0.871$$

$$\frac{P_1}{P_2} = 0.871$$

54.

Ans. (12.69)

Sol.



From, the above velocity diagram, Blade outlet angle (β) can be found by, $\tan\beta = \frac{C_f}{C_b}$

where, C_f is flow velocity C_b is blade velocity

$$\text{Blade velocity } (C_b) = \frac{\pi D_{mean} N}{60}$$

$$= \frac{\pi \times 3 \times 300}{60}$$

47.12 m/sec.

$$\text{Flow velocity } (C_f) = \frac{\text{volume flow rate}}{\text{net change in area}}$$

Net change in area A.

$$= \frac{\pi}{4}\left(4^2 - 2^2\right)$$

$$= \frac{\pi}{4} \times (16 - 4)$$

$$= \frac{\pi}{4} \times 12 = 3\pi$$

$$\text{Flow velocity } (C_f) = \frac{100}{3\pi} = 10.61 \text{m/sec}$$

So, blade outlet angle (β),

$$\tan\beta = \frac{C_f}{C_b} = \frac{10.61}{47.12} = 0.225$$

$\beta = \tan^{-1}(0.225)$

$\beta = 12.69°$

55.

Ans. (5.04)

Sol. Given

A_S = 125 cm2

$A_S = 125 \times 10^2 \text{ mm}^2$

$(\eta)_{cathode} = 0.15$

I = 12 + 0.2 t

t = 20 minutes.

C (Plating Constant) = B.5 × 10^{-2} mm^3/As

C = A.5 mm^3/A min.

Since current is changing with time we have to Integrate

T → thickness of coating

$$\frac{dT}{dt} = \frac{CI}{A_s} h_c$$

$$\frac{dT}{dt} = \frac{(1.5)(12+0.2t)(0.15)}{125 \times 100}$$

$$dT = \frac{(1.5)(12+0.2t)(0.15)dt}{125 \times 100}$$

$$T = \int dT = \int_0^{20} \frac{(0.15)(1.5)(12+0.2t)dt}{125 \times 100}$$

$$T = \frac{(1.5)(0.15)}{125 \times 100}\left[12t + \frac{0.2t^2}{2}\right]_0^{20}$$

$$T = \frac{(1.5)(0.15)}{125 \times 100}[240 + 0.1 \times 400]$$

$T = 0.504 \times 10^{-2}$ mm

$T = 5.04$ μm

56.

Ans. (48)

Sol. Follower motion equation

$y = 4(2\pi\theta - \theta^2)$

Velocity, $v = \frac{dy}{d\theta}$

$= 8(\pi - \theta)$

Acceleration, $a = \frac{d^2y}{d\theta^2}$

$= -8$

For max. value of y,

$\frac{dy}{d\theta} = 0$

$8(\pi - \theta) = 0$

$\theta = \pi$

for minimum value of y

at $\theta = 0, 2\pi$

$y = 0 = y_{min}$

$R_{curvature} = R_{Base} + (y + a)_{min}$

$40 = R_{Base} + (0 - 8)$

$R_{Base} = 48$ mm

57.

Ans. (4.51)

Sol. Thermal efficiency of Otto engine = $1-\frac{1}{(r)^{\gamma-1}}$

Where, r is compression ratio $\eta = 1-\frac{1}{(8)^{1.4-1}}$

= 0.5647 = 56.47 %

$\eta = \frac{\text{I.P}}{\text{Heat input}}$

Indicated Power (I.P) = η × Heat input

= 0.5647 × 10 = 5.647 kw

Mechanical efficiency (η_m) = $= \frac{\text{Brake powe (B.P.)}}{\text{Indicated power (I.P.)}}$

$0.8 = \frac{\text{B.P.}}{5.647}$

B.P. = 4.51 kW

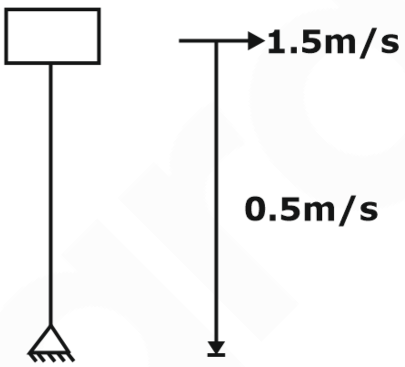
Brake power is 4.51 kW.

58.

Ans. (A)

Sol. m = 2 kg   k = 5 N/m

By applying energy balance



$\frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2 + \frac{1}{2}kx^2$

= 2 × $(1.5)^2$ = 2 × v^2_f + 5 × $(.4)^2$

V_b = 1.360 m/s

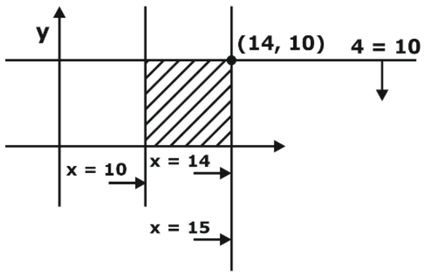
59.

Ans. (10)

Sol. Let units of A = x

Let units of B = y

For Aakash.



X < 15

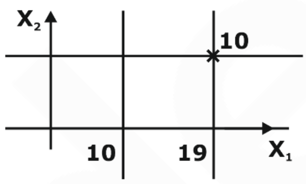
Given y ≤ 10

But x ≥ y

10 ≤ x ≤ 15

Given above the feasible regions max. revenue will happen at (15, 10) ∴ max revenue = 14 × 2000 + 10 × 3000 …….(i)

For Shweta



Let units of A = X_1

Let units of B = Y_2

Given $X_2 \leq 10$ & $X_1 < 20$ & $X_1 \geq X_2 \geq 10$.

$X_2 \leq 10$ & $10 \leq X_1 < 20$.

Maxima will occur at (19, 10).

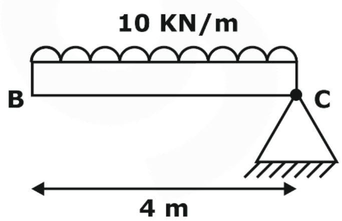
Max revenue = 19 × 2000 + 10 × 3000…….. (ii)

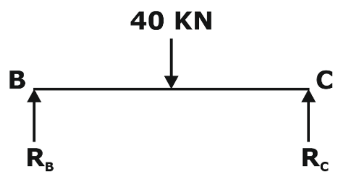
Difference = (ii) – (i) = 5 × 2000 = 10000 Rs. = 10 Thousands

60.

Ans. (20 kN)

Sol. Whenever we have internal hinge point, separate that portion





Moment at B

40 × 2 = R_C × 4

R_C = 20 kN

61.

Ans. (114.8 KJ)

Sol. For a constant pressure process,

work done (W) = $p(V_2 - V_1)$

$W = mR(T_2 - T_1)$

[from ideal gas, eqn. pV = mRT)

$$= mRT_1\left[\frac{T_2}{T_1} - 1\right]$$

$$= 1 \times 0.287 \times 400\left[\frac{T_2}{T_1} - 1\right] \quad ...(i)$$

Now, at constant pressure, Ideal gas eqn. becomes

$$\frac{V_2}{V_1} = \frac{T_2}{T_1}$$

Since, $V_2 = 2V_1$

$$\frac{T_2}{T_1} = \frac{2V_1}{V_1}$$

$$\frac{T_2}{T_1} = 2 \quad ...(ii)$$

Putting eqn. (ii) in eqn. (i) we get

$W = 1 \times 0.287 \times 400[2 - 1]$

= 114.8 KJ

62.

Ans. (1167.04 KN)

Sol. Given

K = 210 MPa

Hi = 20 mm

H_f = 15 mm

R = 450 mm

$(V)_R$ = 28 m/min

B = 200 mm

n = 0.25

$$(\sigma)_o = \frac{K E_T{}^n}{n+1}$$

E_T = True Strain $= \ln\frac{A_i}{A_f} = \ln\frac{l_f}{l_i}$

$A_i = B\ H_i$

$A_f = B\ H_f$

$$\varepsilon_T = \ln\frac{H_i}{H_f} = \ln\frac{20}{15}$$

$\epsilon_T = 0.2876$

$$\sigma_o = \text{Average flow stress} = \frac{210.(0.2876)^{0.25}}{1.25}$$

$\sigma_o = 123.028$ mPa

Rolling Force = σ_o.l.B

$$l = \text{Contact length} = \sqrt{R\Delta h}$$

$$l = \sqrt{450 \times 5}$$

l = 47.43 mm

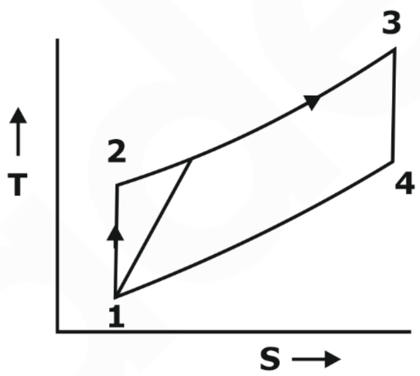
f = 123.028 × 47.43 × 200

f = 1167.04 KN

63.

Ans. (245 kJ/kg)

Sol. Temperature at inlet of compressor (T_1) = 310 k



For above (T-S) diagram of Brayton cycle,

Isentropic efficiency (η_{isen}) = 0.85 = $\frac{\text{Isentropic work}}{\text{Actual work}}$

$$0.85 = \frac{h_2 - h_1}{h_2' - h_1}$$

$$h_2' - h_1 = \frac{h_2 - h_1}{0.85} = \frac{C_p(T_2 - T_1)}{0.85}$$

Now for (1 – 2) isentropic process = $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{y-1/y}$

$\Rightarrow T_2 = 517.22$k

So actual difference in enthalpy $\left(h_2' - h_1\right) = \frac{C_p\left(T_2 - T_1\right)}{0.85}$

$= \frac{1.005\left(517.22 - 310\right)}{0.85}$

= 245 kJ/kg

64.

Ans. (105 KNm)

Sol. Hydrostatic force in 1st & 2nd reservoir = $\rho g A\bar{x}$

A = h × 1 as width is unity

A = h

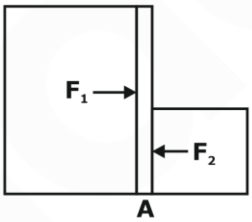
$\bar{x}$ → centroid of centre of gravity

$= \frac{h}{2}$

$F_1 = F_2 = \rho g A \frac{h}{2} = \frac{\rho g h^2}{2}$

$F_1 = \frac{\rho g h_1^2}{2}$

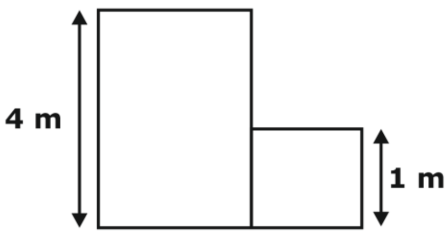
$F_2 = \frac{\rho g h_2^2}{2}$



Moment around A = $F_1 \times h^* - F_2 h^*$

Centre of pressure $(h^*) = \frac{I_G}{A\bar{X}} + \bar{X}$

$I_G = \frac{bh^3}{12} = \frac{h^3}{12}$



$h^* = \frac{\frac{h^3}{12}}{h \times 1 \times \frac{h}{2}} + \frac{h}{2} = \frac{2h}{3}$

Now this centre of pressure is from top

from bottom distance of centre of pressure = $\frac{h}{3}$

So, Net moment around A

$$= \frac{1}{2}\rho g h_1^2 \times \frac{h_1}{3} - \frac{1}{2}\rho g h_2^2 \times \frac{h_2}{3}$$

$$= \frac{1}{2}\rho g\left[\frac{h_1^3}{3} - \frac{h_2^3}{3}\right]$$

$$= \frac{1000 \times 10}{2 \times 3}\left[4^3 - 1^3\right]$$

= 105 KNm

65.

Ans. (5.3%)

Sol. Case 1

D = 1000 year

T = 2 hrs.

CP = Rs. 10

$$Ch = \frac{10}{100} \times 10$$

= Rs. 1

T.C.1 = 10 × 1000 + 480

$$= 10 \times 1000 + 400 + \frac{1000}{2} \times 1$$

= 10000 + 400 + 500

= 10900

Case II

T = 6 mins

Cp = Rs. 5

Ch = Rs. 5

$$T.C.2 = 800 \times 10 + 2 \times 200 + \frac{800}{2} \times 1 + 200 \times 5 + \frac{6}{60} \times 200 + \frac{200}{2} \times 5$$

= Rs. 10320

% reduction

$$= 1 - \frac{10320}{10900}$$

= 0.053

= 5.3%

****

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