gradeup

GATE 2020

Mechanical Engineering

Mega Mock Challenge
(29 Jan -30 Jan)

Questions & Solutions

1. The average marks of each student in a class A is 25% less than the average marks of each students of class B. If the total marks of class A is 30% more than that of class B. Find the number of students in the class B is what percent of the no. of the students of class A?

A. 64.24% B. 57.69%

C. 56.24% D. 73%

Ans. B

Sol. $25\% = \frac{1}{4}$

Let the average marks of the students of the class B = 4x

Then the average marks of the students of the class A = 3x

Let the total no. of students in class B = m

then the total no. of students in class A = n

Total marks of class A $= 3xn$

And total marks of class B $= 4xm$

A.T.Q.

$$\frac{\text{Total marks of A}}{\text{Total marks of B}} = \frac{130}{100} = \frac{3xn}{4xm}$$

⇒ 520m = 300n

$$\Rightarrow \frac{m}{n} = \frac{30}{52}$$

Required percentage $= \frac{30}{52} \times 100$

= 57.69%.

2. A shopkeeper had certain number of gold coins in year 2015. In the year 2016, the number of gold coins increased by 35%. In the year 2017, the number of coins declined to 60%. In the year 2018, the number of coins increased by 25%. In the year 2019, he sold 15% of the total coins, then he had only 54726 coins left. Find the percentage decrease of the no. of coins in this duration.

A. 13.7532% B. 13.9375%

C. 14.28% D. 15.74%

Ans. B

Sol. Let the initial no of coins = 1000

Let the final no. of coins = x

A.T.Q.

$$x = 1000 \times \frac{135}{100} \times \frac{60}{100} \times \frac{125}{100} \times \frac{85}{100}$$

$$x = 1000 \times \frac{27}{20} \times \frac{3}{5} \times \frac{5}{4} \times \frac{17}{20}$$

⇒ x = 860.625

Total decrease in the no. of coins = 1000 – 860.25

= 139.375

% decrease $= \frac{139.375}{1000} \times 100$

= 13.9375%.

3. There are three inlet pipes A, B and C fitted in a tank. If A can fill the tank in 30 hours, B can fill the tank in 35 hours and C can fill the tank in 42 hours. Starting with A, followed by B and C each pipe opens alternatively for one-hour period till the tank gets filled up completely. Find the total time, the tank will be filled completely.

A. $12\frac{3}{2}$ hour B. $11\frac{2}{3}$ hour

C. $13\frac{1}{3}$ hour D. $14\frac{7}{3}$ hour

Ans. B

Sol. Let the capacity of the tank = LCM (30, 35, 42) = 210 unit

Efficiency of pipe A = $\frac{210}{30}$ = 7

Efficiency of pipe B = $\frac{210}{35}$ = 6

Efficiency of pipe C = $\frac{210}{42}$ = 5

Total work done in 3 hours (7 + 6 + 5) = 18 unit

Time taken

$= \frac{210}{18} = 11\frac{12}{18} = 11\frac{2}{3}$ hours.

4. Showing a man on the stage , Rita said, "He is the brother of the daughter of the wife of my hus-band . How is the man on stage related to Rita ?

A. Son
B. Husband
C. Cousin
D. Nephew

Ans. A

Sol. Hence, Correct option is A.

5. **Direction:** Choose the most appropriate option to change the narration (direct/indirect) of the given sentence.

Manali said, "Kindly come on time, dear Vikas."

A. Manali requested Vikas affectionately to come on time.
B. Manali requested to Vikas affectionately to come on time.
C. Manali affectionately requested Vikas to come on time.
D. Manali requested Vikas affectionately to kindly come on time.

Ans. C

Sol. This is an imperative sentence of direct narration. We will change it into the indirect narration accordingly. The inverted commas (" ") used in Direct Narration will be removed in Indirect Narration. 'Said' is changed to 'requested' if sentence starts with please, kindly etc. And adverb affectionately is used for 'dear'. Correct sequence will be 'affectionately requested'. Hence option C is the correct answer.

6. The formula of density of a gas is defined by $\rho = \frac{m}{V}$, where ρ = density, m = mass, V = Volume. Find the percentage change in density if the mass is increased by 35% and volume is decreased by 20%.

A. 48%
B. 35%
C. 58.25%
D. 68.75%

Ans. D

Sol. $\rho_1 = \frac{m}{V}$

A.T.Q.

$$\rho_2 = \frac{135m}{80V} = \frac{27m}{16V}$$

% increase $= \frac{\rho_2 - \rho_1}{\rho_1} \times 100$

$$= \frac{\frac{27m}{16V} - \frac{m}{V}}{\frac{m}{V}} \times 100$$

$$= \frac{1100}{16}\%$$

= 68.75%

7. A, B and C can complete a work in 20, 25 and 45 days respectively. They started the work together and A left 4 days before the completion of the work and B left 3 days before the completion of work. Find the total no. of days for the work to be completed.

A. $33\frac{77}{101}$
B. $11\frac{77}{101}$
C. $14\frac{81}{101}$
D. $13\frac{81}{101}$

Ans. B

Sol. Let the total work = LCM (20, 25, 45) = 900 unit

A's efficiency $= \frac{900}{20} = 45$

B's efficiency $= \frac{900}{25} = 36$

C's efficiency $= \frac{900}{45} = 20$

If A left 4 days before the completion and B left 3 days before the completion,

Now, Total work = 900 + 45×4 + 36×3 = 1188

Required time to complete the whole work $= \frac{1188}{45+36+20} = \frac{1188}{101}$

$= 11\frac{77}{101}$

8. In a family, there are total consumption of 35 kg wheat and 12 kg of sugar every month. If the price of sugar is $33\frac{1}{3}\%$ more than that of wheat. And if he spends total Rs. 765 on the wheat and sugar every month. If the price of sugar in increased by $66\frac{2}{3}\%$. Find the percentage of reduction on the wheat consumption so the expenditure remains the same.

A. 30.47 B. 47.30
C. 30 D. 40

Ans. A

Sol. $33\frac{1}{3}\% = \frac{1}{3}$

Let the price of wheat = 3x
Therefore, the price of sugar = 4x
A.T.Q.
$3x \times 35 + 4x \times 12 = 765$
⇒ 153x = 765
⇒ x = 5
Then price of sugar = 4x = Rs.20
Price of wheat = 3x = Rs.15
When the price of sugar be increased by $66\frac{2}{3}\%$.

$66\frac{2}{3}\% = \frac{2}{3}$

3k = 20 (Given) or $k = \frac{20}{3}$

New price of sugar

$= 3k + 2k = 5k = \frac{100}{3}$

Since the consumption of sugar and price of wheat remain same in both the cases.

Now, $\frac{100}{3} \times 12 + 15 \times y$ (new quantity of wheat) = Rs.765
⇒ 15y = 765 – 400 = 365

$y = \frac{365}{15}$

% change in consumption of

wheat $= \frac{35 - \frac{365}{15}}{35} \times 100$

$= \frac{525 - 365}{35 \times 15} \times 100$

$= \frac{16000}{525} = 30.47\,\%$

9. The ratio of present ages of Vijay and Prashant is 8 : 9. The ratio of their ages before 6 years was 13 : 15. Find the ratio of their ages of 12 years from now.

A. 12 : 13 B. 11 : 12
C. 10 : 11 D. 13 : 14

Ans. B

Sol. Let the age of Vijay and Prashant be 8x and 9x respectively.
A.T.Q.
Ratio of their ages before 6 years,

$\frac{8x - 6}{9x - 6} = \frac{13}{15}$

120x – 90 = 117x - 78
3x = 12
x = 4
Therefore, the present age of Vijay and Prashant is 32 years and 36 years respectively.
Required, Ratio of their ages after 12 years.

$= \frac{32 + 12}{36 + 12}$

$= \frac{44}{48}$

$= \frac{11}{12}$

= 11 : 12.

10. **Direction:** In the following questions, some of the sentences have errors and some have none. Find out which part of a sentence has an error. If there is no error, corresponding to (d) in the answer.
The Party will now seek to stand of its governance record, five years after nearly sweeping the Assembly results in 2015 .

A. The Party will now seek to
B. stand with its governance record,
C. the Assembly results in 2015
D. five years after nearly sweeping

Ans. B

Sol. Option B has the grammatically incorrect part. Here preposition 'of' needs to be replaced with 'on'. **Stand on** means 'to be based on; depend on'.

11. During Morse-key test on 4 cylinder engine, the following observation was made –
When;
all cylinder fired ------- 4000kW
First cylinder not fired ------- 2800kW
Second cylinder not fired ------- 2805kW
Third cylinder not fired ------- 2798kW
Fourth cylinder not fired ------- 2795kW;
Then calculate the mechanical efficiency (in %) of the engine,

Sol. Total BP=4000Kw
I_1=4000-2800=1200Kw
I_2=4000-2805=1195Kw
I_3=4000-2798=1202Kw
I_4=4000-2795=1205 Kw
IP_{total}=4802 Kw
η_m=(BP/IP)=(4000/4802)*100
η_m=83.29 %

12. Match list 1 with list 2 and select the correct answer using the codes given below

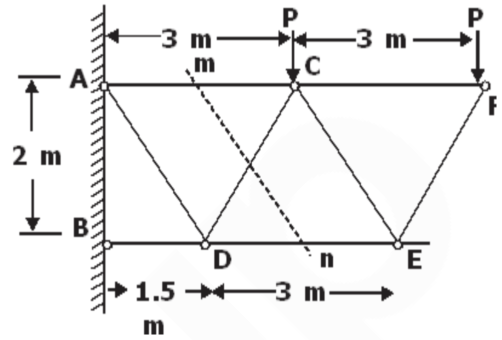
List 1	List 2
a) annealing	1) refined grain structure
b) nitriding	2) improve the hardness of the whole mass
c) martempering	3) increase surface harness
d) normalizing	4) improve ductility

A. A-4 B-3 C-2 D-1
B. A-1 B-3 C-4 D-2
C. A-4 B-2 C-1 D-3
D. A-2 B-3 C-4 D-1

Ans. A

Sol. • annealing improves ductility
• nitriding is used to increase surface hardness
• martempering increase the harness of the whole mass
• normalizing is used to refine the grain structure

13. A cantilever truss is loaded and supported as shown. Find the value of loads P(in kN) which would produce an axial force of magnitude 3 kN in the member AC



Sol. In this case we need not determine the support reactions.
The force in the member AC can be determined using the method of sections.
Pass a section mn cutting the members AC, DC and DE.
Consider the equilibrium of the right hand portion of the truss.

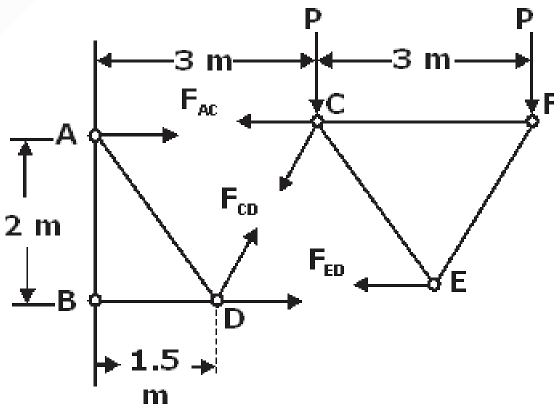


Fig. 9.24

Taking moment about D,

$$\Sigma M_D = 0 : \quad F_{AC} \times 2 - P(1.5) - P(4.5) = 0$$

$$F_{AC} = \frac{6P}{2}$$

$$F_{AC} = 3P$$

As the force in the member is 3 kN,

$$F_{AC} = 3\,kN = 3P$$

$$P = 1\,kN \quad \text{Ans.}$$

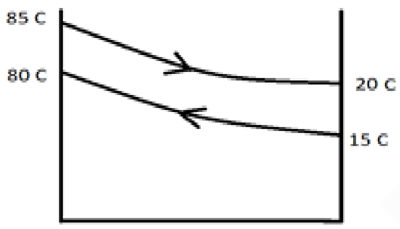
14. Water is flowing at 0.25 kg/s is heated from 15°C to 80°C in a counter flow heat exchanger by a hot water steam flowing at 0.25 kg/s and it enters the heat exchanger at 85 $^\circ C$. The density of water is 1000 kg/m^3 and specific heat is 4.2 kJ/kgK. If overall heat transfer coefficient for the heat exchanger is 1200 W/m^{2}K, the heat exchanger area (in m^2) required is

Sol. 11.375 m^2

By energy balance,

$m_c C_c (T_{c1} - T_{c2}) = m_h C_h (T_{h1} - T_{h2})$

$m_c C_c = m_h C_h$ = 1050 J/s



Counter flow heat exchanger

(80 - 15) = (85 - T_{h2})

T_{h2} = 20 $^\circ C$

LMTD = $\theta_1 = \theta_2$ = 5 $^\circ C$

$m_c C_c (T_{c2} - T_{c1})$ = UA x LMTD

1050 x 65 = 1200 x A x 5

A = 11.375 m^2

15. A single die is rolled six times, the probability that the six outcomes are all different is

A. $\frac{5}{6^6}$ B. $\frac{1}{6^5}$

C. $\frac{5}{324}$ D. $\frac{25}{216}$

Ans. C

Sol. Number of favourable cases = 6!

Total number of outcomes possible = 6^6

Required probability = $\frac{6!}{6^6} = \frac{5}{324}$

16. The velocity field of an incompressible flow is given by V=($a_1x+b_1y+c_1z$)i+($a_2x+b_2y+c_2z$)j, where a_1=2 units, b_1=1 unit and c_2=3 units. The value of b_2 is

Sol. For flow that is incompressible, we have equation for 3D flow given below

$$v = u\hat{i} + v\hat{j} + w\hat{k}$$

$$\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = 0$$

Where u= $a_1x+b_1y+c_1z$, v= $a_2x+b_2y+c_2z$ and w=0

Thus, by solving for the above equation using this result, we get

$a_1+b_2+0=0$

As a_1=2, therefore, b_2=-2

17. In a four-bar mechanism, two adjacent links are rotating at angular velocities of 5 rad/s (clockwise) and 10 rad/s (anti-clockwise). If the radius of the pin joining the links is 3 cm, then what is the value of rubbing velocity:

A. 15 cm/s B. 30 cm/s

C. 40 cm/s D. 45 cm/s

Ans. D

Sol. We know rubbing velocity is given by,

$$v = (\omega_1 \pm \omega_1) \times r$$

Plus (+) sign is used when the links move in opposite direction

Minus (-) sign is used when the links move in same direction

Here

$v = (5 + 10) \times 0.03 = 0.45\ m/s = 45\ cm/s$

18. Consider a hole – shaft interchangeable assembly as 40 $H^{+0.02}_{0.000}$ $j^{+0.01}_{-0.01}$.

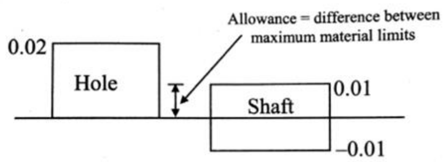
The allowance (in microns) in the assembly is

A. 0.01 B. 0.1

C. 1 D. 10

Ans. D

Sol. As clearly seen in the figure,



Allowance = difference between MML of hole and shaft

= (upper limit)$_{shaft}$ – (lower limit)$_{hole}$

= 0.01 – 0.00 = 0.01 mm = 10 μm

19. At a bank counter, customers arrive according to Poisson's distribution at a rate of 14 customers per hour. The staff at this counter takes 3 minutes per customer on an average with an exponential distribution. The mean waiting time of queue in minutes is.

A. 7 B. 14
C. 5 D. 10

Ans. A

Sol. Given $\lambda = 14$ customer per hour and

1/ μ = 3 mins per customer

Therefore, μ = 20 customers per hour

And the waiting time in the queue is

$t_q = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{14}{20(20-14)} =$ 0.1167 hour

t_q = 7 minutes

20. A spherical shell has a diameter of 1.2 m and thickness 6mm. It is filled with water under pressure until the volume is increased by 400x $10^3\ mm^3$. The pressure exerted by water on the shell in MPa is ________

Take: $E = 204\ GPa\ and\ \mu = 0.3$

Sol. The volumetric strain on a spherical shell is given by :

$$\frac{dV}{V} = \frac{3\sigma}{E}(1-\mu)$$

Volume of the shell is $= \frac{\pi}{6} x1.2^3 = 0.9048\ m^3 = 904.8x10^6\ mm^3$

$$Thus\ \frac{dV}{V} = \frac{400x10^3}{904.8x10^6} = \frac{3\sigma}{204x1000}(1-0.3)$$

$Giving\ \sigma = 42.96\ MPa$

The hoop stress in the shell is given by $\sigma = \frac{pd}{4t}$

Thus:

$$42.96 = \frac{px1.2x1000}{4x6}$$

$giving\ p = 0.86\ MPa$

21. A link AB is 1 m long and rotates about pivot point A. It has a slider at point B. The centripetal acceleration of B with respect to 9 m/s^2. The slider slides with a velocity of 1 m/s relative to B. The magnitude of Coriolis acceleration (in m^2/s) is:

A. 2 B. 3
C. 6 D. 12

Ans. C

Sol. We know centripetal acc. = w^2R

$$w = \sqrt{\frac{a}{R}} = \sqrt{\frac{9}{1}} = 3\frac{rad}{s}$$

Coriolis acc.

$= 2wv = 2 \times 3 \times 1 = 6\ m/s^2$

22. Air at 20°C flows over a flat plate maintained at 75°C . Measurements show that temperature at a distance of 0.5 mm from the surface of plate is 50°C. Presuming thermal conductivity of air as 0.0266 W/m-deg, estimate the value of local heat transfer coefficient.

A. 31.2 W/m^2 – deg
B. 24.18 W/m^2 – deg
C. 21.82 W/m^2 – deg
D. 23.34 W/m^2 – deg

Ans. B

Sol. The heat transfer coefficient is prescribed by the relation

$$h = -\frac{k}{(t_s - t_\infty)}\left(\frac{dt}{dy}\right)_{y=0}$$

Assuming linear variation of temperature,

$$\frac{dt}{dy} = \frac{50-75}{0.0005} = -50 \times 10^3\ {}^\circ C/m$$

$\therefore h = \frac{0.0266}{75-20} \times \left(-50 \times 10^3\right)$

= 24.18 W/m^2 – deg

23. A closed coil helical spring is subjected to a load of 10N made up of a ductile material of radius 10mm & diameter of spring having 10 number of turns is 200mm. If the shear modulus of rigidity of the material is 180GPa and poisson's ratio for the material is 0.22 then the deflection of the spring under the applied load will be

A. 0.22mm B. 0.1mm

C. 0.05mm D. 1mm

Ans. A

Sol. For a spring the deflection is given by,

Modulus of rigidity G = 180MPa

Radius off spring R = 100mm, coil wire diameter d = 20mm

n = 10

Stiffness, K = $\frac{P}{\Delta} = \frac{Gd^4}{64R^3n}$

Deflection, $\Delta = \frac{4PR^3n}{Gr^4}$

Where the symbols have their usual meaning,

$$\Delta = \frac{4 \times 10 \times 0.1^3 \times 10}{180 \times 10^9 \times 0.01^4} = 22 \times 10^{-4} m = 0.222mm$$

24. Two parallel plates kept 0.1 m apart have laminar flow of oil between them with a maximum velocity of 1.5 m/s. The discharge per meter width (in m^3/s) is

Sol. For flow between two parallel plates,

u_{avg}=2/3 times of u_{max}

given,

u_{max}= 1.5m/s

then,

u_{avg}=2/3 x 1.5=1 m/s

area of the flow = l×b=0.1×1=1m^2

Q= A.u_{avg}= 0.1x1=0.1 m^3/s

25. A steel column section has a cross sectional area, 100 cm^2 and second moment of inertia I_x = 12500 cm^4 and I_y = 3200 cm^4 . Yield stress of steel is 250MPa and E = 200 GPa. Considering column to be hinged at both ends, the minimum length(cm) for which Euler's equation may be used for buckling is?

A. 224.7 B. 502.6

C. 485.9 D. 639.5

Ans. B

Sol. Minimum I = 3200 cm^4

$\therefore P_{cr} = \frac{\pi^2 EI}{L^2}$ *for column hinged at both ends*

$$\sigma_{cr} \times A = \frac{\pi^2 EI}{L^2}$$

$$L = \sqrt{\frac{\pi^2 \times 200 \times 1000 \times 3200}{250 \times 100}}$$

= 502.65 cm

26. The system of equation kx + 2y – z = 1, (K – 1) y – 2z = 2 and (k + 2)z = 3 will have unique solution if K =

A. 0 B. 1

C. -2 D. -1

Ans. D

Sol. The given equations can be written as

$$\underset{A}{\begin{bmatrix} k & 2 & -1 \\ 0 & k-1 & -2 \\ 0 & 0 & k+2 \end{bmatrix}} \underset{X}{\begin{bmatrix} x \\ y \\ z \end{bmatrix}} = \underset{B}{\begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}}$$

To get unique solution ρ(A)= ρ(AB) = 3

⇒ |A| ≠ 0

i.e. k (k – 1) (k +2) ≠ 0

∴k≠ 0, 1, -2

27. A U-tube has limbs of internal diameter 6 mm and 16 mm respectively and contains some water. Calculate the difference in water levels (in mm) in the two limbs. Surface tension of water = 0.073 N/m. Take g=9.81 m/s^2

A. 3.1 B. 1.55

C. 6.2 D. 2.9

Ans. A

Sol. Let h = difference in water levels in the two limbs. By assuming the angle of contact θ = 0°.

$$\Delta p = \rho g h = \left(\frac{2\sigma}{R_1} - \frac{2\sigma}{R_2}\right)$$

$$h \times 1000 \times 9.81 = 2 \times 0.073\left(\frac{1}{3\times10^{-3}} - \frac{1}{8\times10^{-3}}\right)$$

$h = 3.1 \times 10^{-3}$ m = 3.1 mm

28. The solution of differential equation

$$\frac{d^2y}{dx^2} + p\frac{dy}{dx} + (q+1)y = 0$$

Where p = 4 and q = 3 is

A. e^{-3x} B. xe^{-x}
C. xe^{-2x} D. x^2e^{-2x}

Ans. C

Sol. Given $\frac{d^2y}{dx^2} + p\frac{dy}{dx} + (q+1)y = 0$

Here P = 4 & q = 3

$$\Rightarrow \left[D^2 + 4D + (3+1)\right]y = 0$$

$$\Rightarrow \left[D^2 + 4D + 4\right]y = 0$$

$$\Rightarrow (D+2)^2 = 0$$

$\Rightarrow D = -2, -2$ [roots are real & equal]

$$\therefore \quad y = (c_1 + c_2x)e^{-2x}$$

$$= c_1e^{-2x} + c_2xe^{-2x}$$

Hence e^{-2x} and xe^{-2x} are independent solution.

29. The dynamic load carrying capacity of a ball bearing is increased to 3 times without any change in the equivalent load then life of the bearing will

A. increase 3 times
B. decrease 9 times
C. increase 27 times
D. decrease 81 times

Ans. C

Sol. Life of a ball bearing is given by, $L_{10} = \left(\frac{C}{P}\right)^3$

Where c = dynamic load carrying capacity

p = equivalent load

When c is change to 3c. Then,

Life becomes 3^3 of original

i.e. It increases to 27 times[Ans]

30. A bar of 75 mm diameter is machined to reduce its diameter by orthogonal cutting. If the length of the cut chip is 73 .5 mm and rake angle is 15°, the shear plane angle is

A. 16° B. 18°
C. 23° D. 29°

Ans. B

Sol. I_c = 73.5 mm

α = 15°

$$r = \frac{\ell_c}{\ell} = \frac{73.5}{\pi d} = \frac{73.5}{\pi \times 75} = 0.31$$

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$$

$$= \tan^{-1}\left(\frac{0.31\cos 15}{1 - 0.31\sin 15}\right)$$

φ = 18.03°

31. A 75 mm diameter shaft is subjected to a pure torsion. The shear stress developed is 150 MPa. The yield strength of the shaft material is 350 MPa. Then the ratio of FOS acc. to von Mises Theory & FOS acc. to Tresca's theory is

Sol. Stress developed = 150 MPa

σ_1 = 150MPa, σ_2 = −150 MPa, Syt = 350MPa

Acc. to von Mises Theory

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

$$(150)^2 + (-150)^2 - (150)(-150) \le \left(\frac{350}{N}\right)^2$$

$$22500 + 22500 + 22500 \le \left(\frac{350}{N}\right)^2$$

$$\sqrt{67500} = \frac{350}{N} \Rightarrow \boxed{N = \frac{350}{259.81} = 1.347}$$

Acc. to Tresca's Theory

$$\text{large of}\left[\left|\frac{\sigma_1 - \sigma_2}{2}\right|, \left|\frac{\sigma_1}{2}\right|, \left|\frac{\sigma_2}{2}\right|\right] \le \frac{Syt}{N}$$

$$\text{large of}\left[\left|\frac{150-(-150)}{2}\right|, \left|\frac{150}{2}\right|, \left|\frac{-150}{2}\right|\right] \le \frac{350}{N}$$

$$\text{large of}\left[\frac{300}{2}, 75, 75\right] \le \frac{350}{N}$$

$$150 \le \frac{350}{N} \Rightarrow \boxed{N = \frac{350}{150} = 2.33}$$

Hence, Ratio $= \frac{1.347}{2.333} = 0.577$

Marks-2

32. A solar collector having an area of 80 m^2 receives solar radiation and transforms it to the internal energy of fluid at an overall efficiency (η) of 50%. Now this high energy fluid is supplied to a heat engine having an efficiency of 40%. If the heat rejected to sink is 30kW. Then power developed by the engine in kW and irradiation to solar collector in kw/m^2 respectively are

A. 50, 1.25 B. 20, 1.25
C. 50, 0.8 D. 20, 0.8

Ans. B

Sol. Given

$\eta_{solar\ collector}$ = 50%, Area of solar collector = 80m^2

$\eta_{Heat\ engine}$ = 40% Heat rejected to sink (Q_R) = 30 kW

$$\eta_{Heat\ engine} = \frac{W_{Net}}{Q_s} \Rightarrow \frac{Q_S - Q_R}{Q_S} = 1 - \frac{Q_R}{Q_S}$$

$$0.4 = 1 - \frac{Q_R}{Q_S} \Rightarrow \frac{Q_R}{Q_S} = 0.6 \Rightarrow \frac{30}{Q_S} = 0.6 \Rightarrow Q_S = 50$$

Q_S = 50 kW

$W_{Net} = Q_S - Q_R$ = 50 – 30 = 20 kW

$$\eta_{solar\ collector} = \frac{\text{energy supplied to engine}}{\text{energy recived at solar collector}} = 50\%$$

$$\Rightarrow \frac{50}{Q_{SC}} = 0.5 \Rightarrow Q_{SC} = \frac{50}{5}$$

Q_{SC} = 100 kW

$$\text{Irradiation} \Rightarrow \frac{Q_{SC}}{\text{Area of plate}} = \frac{100}{80} = \frac{1.25\text{kW}}{m^2}$$

33. A VCRS system uses Refrigerent R-134 and operates b/w 0.15 MPa and 80 kPa, if the values of enthalpy at entry and exit of evaporator are 78 kJ/kg and 178 kJ/Kg and enthalpy at inlet of condenser is 220 kJ/kg . If the power supplied to the compressor is 4.2 kW. What is the refrigeration capacity of the refrigeration plant (kW)?

A. 100 kW B. 10 kW
C. 42 kW D. 4.2kW

Ans. B

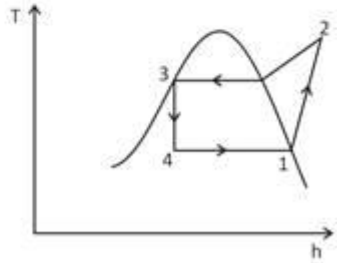
Sol. Given,

Power required by compressor= 4.2kW

h_1 = 178 kJ/kg

h_2 = 220 kJ/kg

$h_3 = h_4$ = 78 kJ/kg



$W_{c/kg}$= (220 – 178) = 42 kJ/kg

Power required by compressor = $m \times W_{c/kg} = m \times 42$

m=0.1 kg/s

RC = $m \times (h_1 - h_4)$ = 0.1(178-78)

RC= 10 kW

34. An NC positioning system uses a leadscrew of 7 .5 mm pitch which drives a worktable. The leadscrew is powered by means of a stepping motor having 200 step angles. The worktable is programmed in a manner to move 120 mm from its present position at a travel speed of 300 mm/min. The number of pulses needed to move the table at the specified distance is __________

Sol. The number of pulses required for table movement of x *is given by*:

$$n_p = \frac{360}{\alpha} X \frac{x}{p}$$

Here $\alpha = \frac{360}{200} = 1.8°$

Putting the values :

$$\frac{\frac{360}{1.8} X120}{7.5} = 3200\ pulses$$

35. The flywheel of a steam engine has a radius of gyration of 1 m and mass 2500 kg. A constant starting torque of 1500Nm is applied on the steam engine to start it from stationary position. The angular Velocity of the flywheel is after 15 sec will be

A. 0.6 rad/s B. 15 rad/s
C. 10 rad/s D. 9rad/s

Ans. A

Sol. Given : k = 1 m

m = 2500 kg

T = 1500 N-m

Let α = Angular acceleration of the flywheel

We know I = m.k^2

= 2500 × 1^2 = 2500 kg-m^2

T= I.α

1500 =2500*α

α =0.6 rad /s^2

$\omega = \omega_0 + \alpha t$

given,

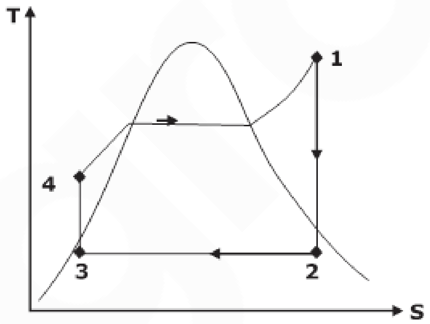
$\omega_0 = 0, \quad t = 15 \text{ sec}$

$\omega = 0 + 0.6 \times 15$

$\omega = 9 rad/s$

36. In a thermal power plant operating on a ranking cycle Seam having enthalpy 2995.1 kJ/kg and entropy 6.5422 kJ/kg° C is produced at 3 MPa and 300° C and is fed to a turbine where it expands to a condenser pressure of 5kPa, where h_f = 137.77 kJ/kg, h_g = 2561.6 kJ/kg, S_f = 0.4763 kJ/kg°C and S_g = 8.3960 kJ/kg° C. At the entrance to the condenser, the enthalpy of steam (in kJ/kg) approximately is …………………

Sol.



h_1 = 2995.1 kJ/kg

S_1 = 6.5422 kJ/kgK

$S_1 = S_2$ = 6.5422 < 8.3960 kJ/kg K, hence entry to condenser will not be saturated vapour.

$S_1 = S_{f2} + x_2 (S_{g2} - S_{f2})$

6.5422 = 0.4763 +x_2 (8.3960 – 0.4763)

X_2 = 0.766

$h_2 = h_{f2} + x_2(h_{g2} - h_{f2})$

= 137.77 + 0.766 (2561.6 – 137.77)

= 1994.4 kJ/kg

37. A closed cycle gas turbine plant, using air as the working medium at pressure 1 bar and temperature 300 K attains the maximum temperature of 1200 K. If final pressure of compressor is 6 bar, then the air-rate of the cycle is ______ kg/kWh.

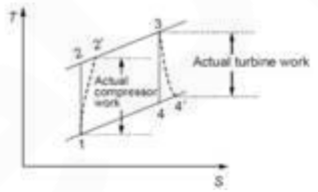
[Given, $\eta_{compressor} = 0.85, \ \eta_{turbine} = 0.8$]

A. 21.10 B. 24.10

C. 28.10 D. 33.10

Ans. B

Sol. $T_2 = T_1 (r_p)^{\frac{1-\gamma}{\gamma}} = 300 \times (6)^{\frac{0.4}{1.4}} = 500.55 \text{ K}$



$\eta_c = \frac{T_2 - T_1}{T'_2 - T_1}$

$\Rightarrow 0.85 = \frac{500.25 - 300}{T'_2 - 300}$

$\Rightarrow T'_2 = 536 \text{ K}$

$T_4 = \frac{T_3}{(r_p)^{\frac{1-\gamma}{\gamma}}} = \frac{1200}{(6)^{\frac{0.4}{1.4}}} = 719.2 \text{ K}$

$\eta_T = \frac{T_3 - T'_4}{T_3 - T_4}$

$\Rightarrow 0.8 = \frac{1200 - T'_4}{1200 - 719.2}$

$\Rightarrow T'_4 = 815.36 \text{ K}$

$W_{net} = W_T - W_C = C_p [T_3 - T'_4 - T'_2 + T_1]$

$= 1.005[1200 - 815.36 - 536 + 300]$

= 149.4 kJ/kg

Air Rate = $\frac{3600}{149.4}$

= 24.1 kg/kWh

38. A hydraulic press has a ram of 150 mm and a plunger of 20 mm diameter. Find the force required on

the plunger to lift a weight of 40kN. If the plunger has a stroke of 0.40 m and makes 30 strokes per minute, determine the power (in W) required by the plunger. Assume no losses whatsoever.

Sol. Let F = force on the plunger. Since the pressure in the fluid is same at the plunger and at the weight.

$$\frac{F}{\left(\frac{\pi}{4}(0.02)^2\right)} = \frac{40}{\left(\frac{\pi}{4}(0.15)^2\right)}$$

F = 0.711 kN

Total length of stroke in one minute = 0.40 × 30 = 12.0 m

Distance travelled by weight / minute

$A_P V_P = A_R V_R$ (By continuity equation)

$$= 12 \times \frac{(0.02)^2}{(0.15)^2} = 0.2133 \text{ m / minute}$$

Power required

$$= \frac{0.2133}{60} \times 40$$

= 0.142 kW = 142 W

39. An EDM process which uses a RC relaxation circuit, a hole of 10 mm diameter is made in a steel plate of 50 mm thickness using a graphite tool and the dielectric is kerosene. The discharge time is negligible. The following parameters are measured:

Resistance= 30 Ω

Capacitance= 25μF

Supply voltage= 220 V

Discharge Voltage= 110 V

Average power input is :

A. 300 W

B. 291 W

C. 450 W

D. 230 W

Ans. B

Sol. The cycle time in an EDM process is given by :

$$t_c = RC \ln \frac{V_s}{V_s - V_D}$$

Where

V_s, V_D *are the supply and discharge voltage*

.

Given, R= 30 Ω , C= 25 μF , $V_s = 220\ V$, $V_D = 110\ V$

So,

$$t_c = 30x25x10^{-6}\ x \ln(\frac{220}{220-110}) = 5.198\ x\ 10^{-4}\ s$$

Thus, power input

$$P = \frac{1}{2}\frac{CV_D^2}{t_c} = \frac{1}{2}\frac{25x10^{-6}x110^2}{5.198\ x\ 10^{-4}} = 290.977\ W$$

40. In a drilling machine 8 spindle speeds are available. The 2nd and 3rd speeds are 200 rpm and 400 rpm respectively. If the sum of all speeds be expressed as N x 10^2 rpm. Calculate the value of N.

Sol. In drilling machine the spindle speeds are in Geometric Progression (G.P).

Writing the speeds as a, ar, ar^2 ,......, ar^7 .

2nd speed = ar and 3rd speed = ar^2.

Where a = 1st spindle speed and r = common ratio of G.P.

r = 3rd speed / 2nd speed = $\frac{ar^2}{ar}$

r = 400 / 200 = 2.

Hence, a = 100 (1st spindle speed)

Therefore the speeds (in rpm) are: 100, 200, 400, 800, 1600, 3200, 6400, 12800.

Sum of spindle speeds = 25500 rpm.

N=255[Ans]

41. The Laplace transform of $e^{4t}\cos(3t)$ is:

A. $\frac{S-3}{(S-3)^2+9}$

B. $\frac{S-3}{(S-3)^2+16}$

C. $\frac{S-4}{(S-4)^2+9}$

D. $\frac{S+4}{(S+4)^2+9}$

Ans. C

Sol. $L\{\cos(3t)\} = \frac{S}{S^2+9}$

By first shift property,

$\therefore L\{e^{4t}\cos t(3t)\} = \frac{S-4}{(S-4)^2+9}$

42. A shaft with circular cross sectional area is subjected to bending moment of 400kNm and turning moment of 300kNm. On the basis of "Maximum principle stress theory" the direct stress is σ and according to "Maximum shear stress theory" the shear stress is τ, then find the ratio of $\frac{\tau}{\sigma}$

A. $\frac{5}{9}$
B. $\frac{9}{5}$
C. $\frac{5}{18}$
D. $\frac{18}{5}$

Ans. A

Sol. M=400kNm T=300kNm d=diameter of shaft

Equivalent Bending moment $M_e = \frac{1}{2}(M + \sqrt{M^2+T^2})$

Equivalent Turning moment $T_e = \sqrt{M^2+T^2}$

According to Maximum principle stress theory;

$M_e = \frac{1}{2}(M + \sqrt{M^2+T^2}) = \frac{\pi}{32}d^3\sigma$

According to Maximum shear stress theory; $T_e = \sqrt{M^2+T^2} = \frac{\pi}{16}d^3\tau$

Dividing both the equations;

$$\frac{\frac{1}{2}(M+\sqrt{M^2+T^2})}{\sqrt{M^2+T^2}} = \frac{\sigma}{\tau\times 2}$$

Putting values of M and T

$$\frac{450}{500} = \frac{\sigma}{\tau\times 2}$$

$$\therefore \frac{\tau}{\sigma} = \frac{5}{9}$$

(Option (a))

43. Find the Solution of the differential equation y``+4y`+13y=0, y (0) = 0; y`(0) =1

A. y= $\frac{e^{-3x}}{3}$ sin(3x)
B. y= $\frac{e^{-2x}}{2}$ sin(2x)
C. y= $\frac{e^{-2x}}{3}$ sin(3x)
D. y= $\frac{e^{-2x}}{3}$ sin(2x)

Ans. C

Sol. y``+4y`+13y=0

$(D^2+4D+13)=0$

D= $\frac{-4\pm\sqrt{16-52}}{2}$ = $\frac{-4\pm i6}{2}$ = -2$\pm i3$

y= e^{-2x} $(c_1\cos3x+c_2\sin3x)$

At x=0, y=0

$0=c_1$

y=e^{-2x} $C_2\sin3x$

y`=$C_2[e^{-2x}$ (3cos3x)+(-2) e^{-2x} sin3x]

At x=0 and y`=1

so $C_2=1/3$

y= $\frac{e^{-2x}}{3}$ sin(3x)

44. A slab milling operation is performed on a mild steel workpiece by a straight slab cutter of 80 mm diameter with 40 teeth. The depth of cut and the rotational speed of cutter are 3 mm and 50 rpm, respectively. If the table feed is 25 mm/min, the value of maximum uncut chip thickness (in microns) will be ________ (Rounded upto two decimals).

Sol. Given,

Cutter diameter, D = 80 mm

Depth of cut, d = 3 mm

Rotational speed, N = 50 rpm

Table feed, f_m = 25 mm/min

Number of teeth, z = 40

Maximum uncut chip-thickness,

$t_1 = 2f_1\sqrt{\frac{d}{D}}$ [where, f_t = feed per tooth]

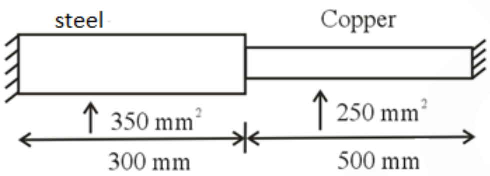
Now, $f_m = f_1 zN$

$\Rightarrow 25 = f_t \times 40 \times 50$

$f_1 \frac{1}{80}$ mm

$\therefore t_1 = 2 \times \frac{1}{80} \times \sqrt{\frac{3}{80}} = 4.84\ \mu m$

45. The composite bar consisting of steel and copper components is connected to two grips at the ends at a temperature of 80°C as shown in figure. If the temperature of this system falls to 30°C and the ends are allowed to yield by 0.3 mm then the stresses induced in steel (in MPa) is
(take E_s = 200 GPa and E_c = 100 GPa, $\alpha_s = 2 \times 10^{-5}$/°C , $\alpha_c = 2.5 \times 10^{-5}$/°C,
where, s and c abbreviation refers to steel and copper respectively)



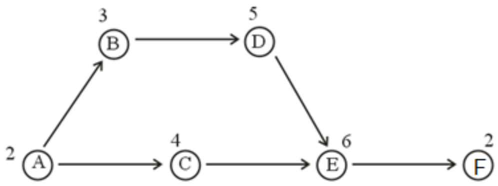
A. 73.5 B. 103
C. 147 D. 206

Ans. A

Sol. Given,
A_s = 350 mm², A_c = 250 mm²,
l_s = 300 mm, l_c = 500 mm,
permissible yielding = 0.3 mm
Total contraction prevented =
Contraction prevented in steel +
Contraction prevented in copper......(i)
Total contraction prevented = free contraction – yielding ....(ii)
Free contraction of composite bar =
Contraction in steel + Contraction in copper
$= \alpha_s \times \Delta T \times l_s + \alpha_c \times \Delta T \times l_c$
$= 2 \times 10^{-5} \times (80-30) \times 300 + 2.5 \times 10^{-5} \times (80-30) \times 500$
ΔL_{max} = 0.925 mm

From (ii),
Total contraction prevented = 0.925 − 0.3 = 0.625 mm ....(iii)
Tensile stress will induce when the contraction is prevented.
Let σ_s and σ_c are stresses induced in steel and copper rods.
Also, $\sigma_s A_s = \sigma_c A_c$ (∵ same force exists in both the rods)
$\sigma_s \times 350 = \sigma_c \times 250$
$\sigma_c = 1.4\sigma_s$
Also from (i),
Total contraction prevented =
$\frac{\sigma_s l_s}{E_s} + \frac{\sigma_c l_c}{E_c}$
$= \frac{\sigma_s \times 300}{200 \times 10^3} + \frac{\sigma_c \times 500}{100 \times 10^3}$
$= (1.5\sigma_s + 5\sigma_c) \times 10^{-3}$
$= (1.5\sigma_s + 5 \times 1.4\,\sigma_c) \times 10^{-3}$
$= 8.5 \times 10^{-3}\,\sigma_s$ ....(v)
From (iii) and (v)
$8.5 \times 10^{-3}\,\sigma_s = 0.625$
σ_s = 73.53 MPa

46. Consider the following problem of assembly line balancing. The tasks and their time duration in minutes are mentioned:



If the cycle time is 8 min, then the line efficiency (in %) based on shortest processing time (SPT) is

Sol. Assigned task on a station in such a way that total task time of that station should not be exceed the cycle time.

Work station	Tasks	Time
1	A, B	2 + 3 = 5
2	C	4
3	D	5
4	E,F	6 + 2 = 8

So, the minimum no. of work stations required based on SPT = 4
Line efficiency

$= \frac{\sum t}{NT_c}$

$\sum t$ = Sum of all task time

= 2+3+4+5+6+2 =22 min.

N = no. of work stations required = 4

T_c = cycle time

= 8 min

Line efficiency $= \frac{22}{4 \times 8}$ = 0.6875 = 68.75 %

47. An electronic semiconductor device generates 0.16 kJ/hr of heat. To keep the surface temperature at the upper safe limit of 75°C, it is desired that the generated heat should be dissipated to the surrounding environment which is at 30°C. The task is accomplished by attaching aluminium fins, 0.5 mm^2 square and 10 mm to the surface. Work out the number of fins if thermal conductivity of fin material is 690 kJ/m-hr-deg and the heat transfer coefficient is 45 kJ/m^2-hr-deg. Neglect the heat loss from the tip of the fin.

A. 3 B. 6

C. 7 D. 4

Ans. D

Sol. For a fin of rectangular cross-section,

$P = 2(b + \delta) = 2\ (0.5 + 0.5)$

$= 2\ mm = 2 \times 10^{-3}\ m$

$A_c = b \times \delta = 0.5 \times 0.5$

$= 0.25\ mm^2$

$= 0.25 \times 10^{-6}\ m^2$

$$m = \sqrt{\frac{hP}{kA_c}} = \sqrt{\frac{45 \times 2 \times 10^{-3}}{690 \times 0.25 \times 10^{-6}}} = 22.84 m^{-1}$$

For a fin with insulated tip,

$Q_{fin} = kA_c\ m(t_0 - t_a)\ \tanh ml$

$= 690 \times (0.25 \times 10^{-6}) \times 22.84 \times (75 - 30)\ \tanh\ (22.84 \times 0.01)$

$= 39.77 \times 10^{-3}$ kJ/hr per fin

∴ Number of fins

$$= \frac{0.16}{39.77 \times 10^{-3}} = 4.02$$

Thus, 4 fins are needed to dissipate the required amount of heat.

48. If is given that the solution of the differential equation $\frac{dy}{dt} = t(1+y)$ passes through origin. The value of y(2) will be______

Sol. $\frac{dy}{dt} = t(1+y)$

$$\frac{dy}{1+y} = tdt$$

By taking integration on both sides, we get

$$\ln(1+y) = \frac{t^2}{2} + c$$

Given, that above equation passes through given

So for t = 0, y = 0.

ln(1) = 0 + c

$$\ln(1+y) = \frac{t^2}{2}$$

$$y = -1 + e^{t^2/2}$$

$$y(2) = -1 + e^2 = 6.40$$

49. If a root of the equation $3x^3 - 4x^2 - 4x + 7 = 0$ is found out using Newton Raphson's method. If the first assumption for the root is 2.5, then the root after two iterations will be________.

Sol. $f(x) = 3x^3 - 4x^2 - 4x + 7$

$$f'(x) = 9x^2 - 8x - 4$$

$$x_1 = x_0 - \left.\frac{f(x)}{f'(x)}\right|_{x=2.5}$$

$$= 2.5 - \frac{3x(2.5)^3 - 4x(2.5)^2 - 4 \times 2.5 + 7}{9x(2.5)^2 - 8 \times 2.5 - 4} = 1.9147$$

Similarly by doing second iteration by taking x_1=1.9147

we get x_2=1.495

50. In a casting of a toy, sprue hight is 200mm & cross section area of sprue at beginning is 580mm^2 & the discharge rate of liquid is

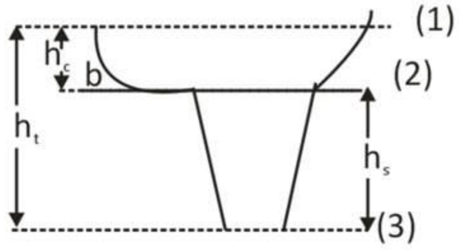
$5.8*10^5 mm^3/s$ calculate cross section area at the bottom(in mm^2)?

Sol. H_s =200mm

A_2 =580mm^2

Q=$5.8*10^5 mm^3/s$

A_3=?



$Q_3=A_3V_3$

$V_3=\sqrt{(2gh_t)}$ $\{h_t=h_c+h_t\}$

$V_2=\sqrt{(2gh_c)}$

$Q_2=A_2V_2 \rightarrow V_2=Q/A_2$

$V_2 =(5.8*10^5)/580 =1000$ mm/s

$V_2=\sqrt{(2gh_c)}$ g=9810 mm/s^2

$1000=\sqrt{(2*9810*h_c)}$

h_c=50.96mm

$h_t=h_s+h_c$ =200+50.96=250.96mm

$h_t/h_c =(A_2/A_3)^2$

A_3=261.36mm^2

51. A concrete column used in bridge construction is cylindrical in shape with a diameter of 1 metre. The column is completely poured in a short interval of time and the hydration of concrete results in the equivalent of a uniform source strength of 0.7 W/kg. Determine the temperature (in ^{0}C) at the centre of the cylinder at a time when the outside surface temperature is 75°C. The column is sufficiently long so that temperature variation along its length may be neglected.

For concrete :

Average thermal conductivity = 0.95 W/mk

Average density = 2300 kg/m^3

Sol. Since the hydration of concrete results in uniform internal heat generation, the maximum temperature occurs at the centre of the cylindrical column and is described by the equation,

$$t_{max} = t_w + \frac{q_g}{4k}R^2$$

q_g = 0.7 W/kg = 0.7 × 2300 W/m^3

Substituting the given values

$$t_{max} = 75 + \frac{0.7\times2300}{4\times0.95}(0.5)^2$$

t_{max} =180.92 ^{0}C

52. The minimum diameter of hole which can be produced on the sheet of thickness 4 mm, having shear strength of 400 MPa, crushing yield strength of punch as 1600 MPa and a factor of safety of 2 is

A. 16 mm B. 8 mm

C. 4 mm D. 2 mm

Ans. B

Sol. d_{min}= ?

t = 4 mm

σs = 400 MPa

σ_c = 1600 MPa

Fos = 2

$$Fos = \frac{\sigma_c}{\sigma_{allowable}}$$

$$\Rightarrow \sigma_{allowable} = \frac{1600}{2} = 800 \text{ MPa}$$

$$d_{min.} = \frac{4t\sigma_s}{\sigma_{allowable}}$$

$$= \frac{4\times4\times400}{800}$$

$$= 8\ mm$$

53. A disc of weight 200 N is mounted on a shaft of length 5m rotating at a speed of 1000 rpm. The plane of the mounted disc is not perfectly at right angle but having mismatch of 1.5° from the vertical axis. If the reaction on each bearing due to gyroscopic couple is 200 N-m. Then diameter of the mounted disc will be

A. 56 cm B. 62 cm

C. 68 cm D. 74 cm

Ans. D

Sol. given,

N = 1000rpm,

weight of the rotor = 200N
reaction at the end of bearing is 200Nm
plane of the disc is inclined from the vertical by 1.5° thus angle between the axis of the shaft and the rotor is 1.5°

$\omega = 2\pi N/60 = 104.719$ rad/s
mass,
m = 200/9.81 = 20.39 kg

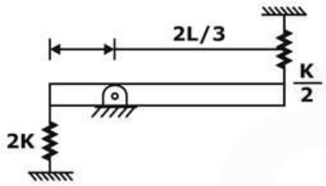
$$\text{Gyroscopic Couple for disc} = \frac{mr^2\omega^2\sin(2\theta)}{8}$$

$$200 = \frac{20.39 \times r^2 \times 104.719^2 \sin(2 \times 1.5^\circ)}{8}$$

r = 0.3697m

Diameter, d = 2r = 0.7395 m
d = 74 cm

54. A slender bar of mass 'M' and length L is pivoted at L/3 from one end and constrained to rotate in the horizontal plane with the help of springs as shown. What will be the frequency of vibration in (rad/sec)



A. $\sqrt{\frac{K}{m}}$

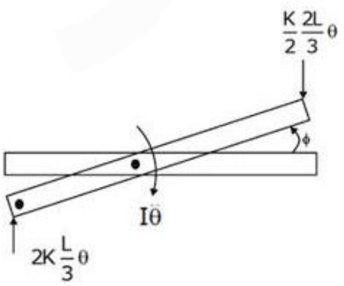
B. $2\sqrt{\frac{K}{m}}$

C. $\frac{1}{2}\sqrt{\frac{K}{m}}$

D. None of the above

Ans. B

Sol.



Moment about the Hinge

$$= I\ddot{\theta} + \frac{K}{2}\frac{2L}{3}\cdot\frac{2L\theta}{3} + 2K\frac{L}{3}\cdot\frac{L\theta}{3} = 0$$

$$I = \frac{mL^2}{9} \text{ about the point @ L/3}$$

$$\Rightarrow \frac{mL^2}{9}\ddot{\theta} + 4\frac{KL^2}{9}\theta = 0$$

$$\omega_n = \sqrt{\frac{4KL^2/9}{mL^2/9}} = 2\sqrt{\frac{K}{m}}$$

55. A new multiple plate clutch disc having inner and outer diameters 100 mm and 200 mm respectively transmits power through contact surface.If the friction coefficient and permissible intensity of pressure is 0.2 and 1 MPa. Then the no. of pair of contacting surfaces if the torque carrying capacity of clutch at 750 rpm is 1.1 KN-m.

A. 1 B. 2
C. 3 D. 4

Ans. C

Sol. The torque carrying capacity of multiple clutches is given by

$T = n\mu WR_m$

Where,

n = No. of pair of contacting surfaces

μ = 0.2, P = 1 MPa

T= 1.1kNm N = 750rpm

W = Operating force

$r = \frac{100}{2} = 50$ mm

$R = \frac{200}{2} = 100$ mm

R_m = mean radius

$R_m = \frac{2}{3}\frac{(R^3 - r^3)}{(R^2 - r^2)}$ For uniform pressure theory

$= \frac{R+r}{2}$ For uniform wear theory

$R_m = \frac{2}{3}\frac{(100^3 - 50^3)}{(100^2 - 50^2)} = 77.77$ mm

W = pressure × Area

W= $\pi[R^2 - r^2] \times p$ = $\pi[100^2 - 50^2] \times 1$

P = 23561.95 N

T= n×0.2 × 23561.95×77.77 N-mm

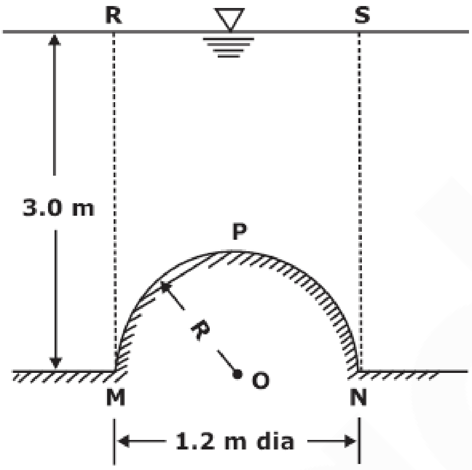
= 0.366×Z KN-m

1.1 = 0.366×n

n = 3

56. A hemispherical bulge of diameter 1.2 m is provided in the bottom of a tank. If the depth of water above the horizontal floor of the tank is 3.0m. The magnitude (in KN) of net hydrostatic force on bulge is

Sol. By symmetry the net horizontal force = 0



Vertical force

Fv = weight of fluid above the hemisphere

$$= \gamma\left[\pi R^2 H - \frac{1}{2}\cdot\frac{4}{3}\pi R^3\right]$$

$$= 9.81\left[\pi \times (0.6)^2 \times 3.0 - \frac{2}{3}\pi(0.6)^3\right]$$

= 28.84 kN

Resultant force is the same as the vertical force Fv = 28.84 kN acting vertically at the centre of the hemisphere.

57. A pelton turbine is to operate under a net head of 500 m at 420 rpm. If a single jet with diameter 18 cm is used, find the specific speed of the machine. Take C_v = 0.98, φ = 0.45 and overall efficiency $\eta_0 = 0.85$.

Sol. H = 500 m

$V_1 = C_v\sqrt{2gH}$

$= 0.98\sqrt{2 \times 9.81 \times 500}$

= 97.06 m/s

Discharge

$Q = \frac{\pi}{4} d_2 V_1 = \frac{\pi}{4} \times (0.18)^2 \times 97.06$

= 2.47 m^3/s

Power developed

$P = \eta_0 \gamma Q H$

= 0.85 × 9.81 × 2.47 × 500

= 10,298 kW

Specific speed

$$N_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{420\sqrt{10,277}}{(500)^{5/4}} = 18$$

58. A manufacturing plant has a capacity to produce 15000 units of a product per year. It average monthly demand of product increases from 1000 units in 2018 to 1100 units in 2019, the percentage change in production factor is equal to

A. 29.1 B. 24.2

C. 32.2 D. 22.4

Ans. A

Sol. Given capacitor p = 15000 units/year

d_1 = 1000 × 12 = 12000 unit/year

d_2 = 1100 × 2 = 13200 unit/year

Production factor $X = \sqrt{\frac{P}{P-d}}$

$$X_1 = \sqrt{\frac{15000}{15000-12000}} = \sqrt{5} = 2.236$$

$$X_2 = \sqrt{\frac{15000}{15000-13200}} = \frac{5}{\sqrt{3}} = 2.887$$

% charge =

$$\frac{X_2 - X_1}{X_1} \times 100$$

=

$$\frac{(2.887 - 2.236)}{2.236} \times 100$$

= 29.1%

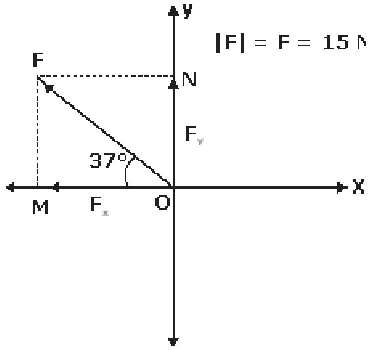
59. A force F has magnitude of 15 N. Direction of F is at 37° from negative x-axis towards positive y-axis. Represent F in terms of $\hat{i}$ and $\hat{j}$?

A. $(-12\hat{i}-9\hat{j})$ B. $(-12\hat{i}+9\hat{j})$

C. $(12\hat{i}+9\hat{j})$ D. $(+12\hat{i}-9\hat{j})$

Ans. B

Sol.



The given force is an shown in figure. Let us find its x and y components.

$F_x = F\cos 37°$

$= 15 \times \frac{4}{5}$

$= 12\,N$ (along negative x – axis)

$F_y = F\sin 37°$

$= 15 \times \frac{3}{5}$

$= 9\,N$ (along positive y – axis)

From parallelogram law of vector addition, we can see that

$F = OM + ON$

$= F_x(-\hat{i}) + F_y(\hat{j})$

$= (-12\hat{i}+9\hat{j})N$

60. A carnot cycle refrigerator 'A' operates between 500K and 900K, whereas a carnot cycle refrigerator 'B' operates between 300K and 500K. Find out the ratio of coefficient of performance of A to B

A. 1 B. 0.34

C. 0.83 D. 0.54

Ans. C

Sol. We know that, coefficient of performance (C.O.P) = $\frac{T_2}{T_1-T_2}$

C.O.P of A = $\frac{500}{900-500} = 1.25$

C.O.P of B = $\frac{300}{500-300} = 1.50$

So, ratio of C.O.P's

$= \frac{COP_A}{COP_B} = \frac{1.25}{1.50} = 0.83$

61. An anti-aircraft gun can take a maximum of four shots at an enemy plane moving away from it. The probabilities of hitting the plane destroyed at first, second, third and the fourth shot are 0.4, 0.3, 0.2 and 0.1 respectively. What is the probability that the gum hits the plane?

A. 0.6024 B. 0.0024

C. 0.8976 D. 0.6976

Ans. D

Sol. Let P(i^{st} shot) = 0.4, P(2^{nd} shot) = 0.3

P(3^{rd} shot) = 0.2, P(4^{th} shot) = 0.1

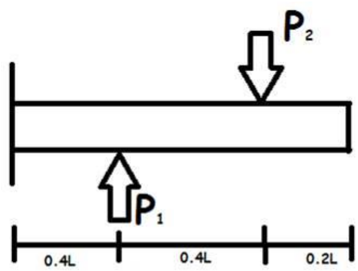
∴ Requires probability

= P(1^{st}) + (1-P(1^{st})) P(2^{nd}) + (1-P (1^{st}))(1-P(2^{nd})) P(3^{rd}) + (1-P (1^{st}))(1-P(2^{nd})(1-P(3^{rd})(P (4^{th})

= 0.4 + 0.6 × 0.3 + 0.6 × 0.7 × 0.2 + 0.6 × 0.7 × 0.8 × 0.1

=0.4 + 0.18 + 0.084 + 0.0336 = 0.6976

62. A cantilever beam as shown is acted upon by two loads P_1 and P_2. If the net deflection at the end is zero then the ratio of P_1/P_2 is_______.



Sol. Net deflection at the free end due to combination of two point load is

$$\delta=\frac{P_1(0.4L)^3}{3EI}+\frac{P_1(0.4L)^2}{2EI}\times0.6L-\frac{P_2(0.8L)^3}{3EI}-\frac{P_2(0.8L)^2}{2EI}\times0.2L$$

since net defection is given is zero thus,

$$0=\frac{P_1(0.4L)^3}{3EI}+\frac{P_1(0.4L)^2}{2EI}\times0.6L-\frac{P_2(0.8L)^3}{3EI}-\frac{P_2(0.8L)^2}{2EI}\times0.2L$$

After solving the above equation we get,

$$\frac{P_1}{P_2}=3.384$$

63. Air (c_p = 1.005 kJ/kg-°C) enters the heat exchanger at 95 kPa and 20°C with a rate of 1.6m³/s. The combustion gases (c_p = 1.10kJ/kg-°C) enters at 180°C with a rate of 2.2 kg/s and leave at 95°C. What will be the rate of entropy generation?

A. 0.455 kW/K B. 0.91 kW/K
C. 0.091 kW/K D. 9.1 kW/K

Ans. C

Sol. We take the exhaust pipes as the system, which is a control volume. The energy balance for the steady-flow system can be expressed in the rate form as

$$\dot{E}_{in}-\dot{E}_{out}=\Delta\dot{E}_{system}=0$$

$$\dot{E}_{in}=\dot{E}_{out}$$

$$\dot{m}h_1=\dot{Q}_{out}+\dot{m}h_2$$

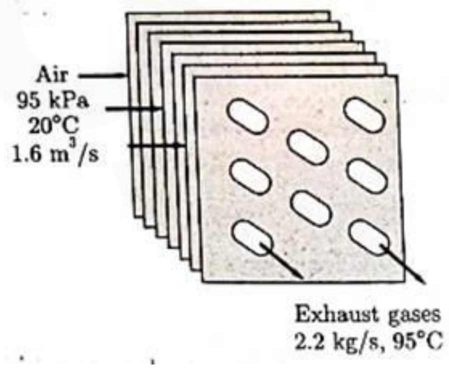
(since ΔK.E. ≅ Δ P.E. ≅ 0)

Then, the rate of heat transfer from the exhaust gases becomes

$$\dot{Q}=\left[\dot{m}c_p(T_{in}-T_{out})\right]_{gas}=2.2\times1.10\times(180-95)$$
$$=205.7\text{kW}$$

The mass flow rate of air is

$$\dot{m}=\frac{p\dot{v}}{RT}=\frac{95\times1.6}{0.287\times293}=1.808\text{ kg/s}$$



The heat loss by the exhaust gases is equal to the heat gain by the air, then the outlet temperature of the air becomes

$$\dot{Q}=\left[\dot{m}c_p(T_{out}-T_{in})\right]_{air}$$

$$T_{out}=T_{in}+\frac{\dot{Q}}{\dot{m}c_p}=20+\frac{205.7}{1.808\times1.005}$$
$$=133.2°\text{C}$$

The rate of entropy generation within the heat exchanger is determined by applying the rate form of the entropy balance on the entire heat exchanger

$$\dot{S}_{in}-\dot{S}_{out}+\dot{S}_{gen}=\Delta\dot{S}_{system}=0$$

$$\dot{m}_1s_1+\dot{m}_3s_3-\dot{m}_2s_2-\dot{m}_3s_4+\dot{s}_{gen}=0$$

(since Q = 0)

$$\dot{m}_{exhaust}s_1+\dot{m}_{air}s_3-\dot{m}_{exhaust}s_2+\dot{m}_{air}s_4+\dot{s}_{gen}=0$$

$$\dot{m}_{exhaust}(s_2-s_1)+\dot{m}_{air}(s_4-s_3)=\dot{s}_{gen}$$

Then, the rate of entropy generation is determined to be

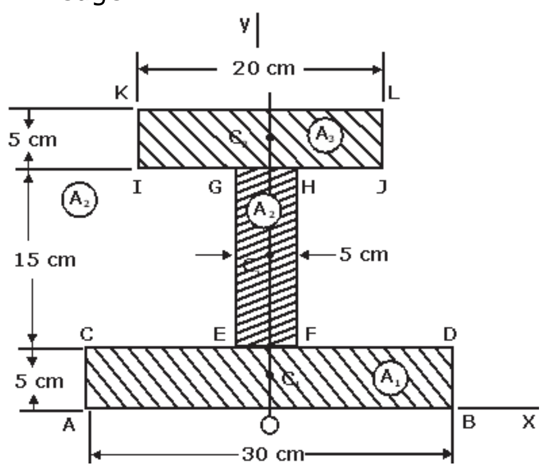
$$\dot{s}_{gen}=\dot{m}_{exhaust}c_p\ln\frac{T_2}{T_1}+\dot{m}_{air}c_p\ln\frac{T_4}{T_3}$$

(Since heat exchanger works at constant pressure)

$$=(2.2\times1.1)\ln\frac{368}{453}+(1.808\times1.005)\ln\frac{406.2}{293}$$

= 0.091 kW/K

64. Determine the distance of the centroid of the cross-sectional area of an unequal I-section from bottom edge.



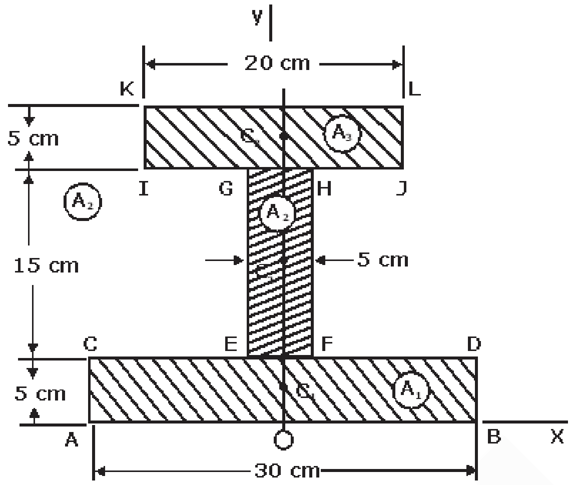
A. 10.96 cm B. 9.96 cm
C. 8.96 cm D. 11.96 cm

Ans. A

Sol. The figure is symmetrical about the vertical line which is also chosen as the y-axis.

x-axis is chosen to coincide with the bottom edge AB

The figure can be considered to be made up of three rectangles, ABCD EFGH and IJKL.



From symmetry, centroid of the total figure lies on y-axis.

Therefore,

Figure	Area (cm^2)	x-coordinate of the centroid (cm)	y-coordinate of the centroid (cm)
Rectangle ABCD	$A_1 = 5 \times 30 = 150$	0	$Y_1 = 5/2 = 2.5$ cm
Rectangle EFGH	$A_2 = 5 \times 15 = 75$	0	$Y_2 = 5 + 15/2 = 12.5$ cm
Rectangle IJKL	$A_3 = 20 \times 5 = 100$	0	$5 + 15 + 5/2 = 22.5$ cm

$$y_e = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1 + A_2 + A_3}$$

$$= \frac{(150 \times 2.5) + (75 \times 12.5) + (100 \times 22.5)}{150 + 75 + 100}$$

$$y_e = \frac{3562.5}{325}$$

$y_e = 10.96$ cm Ans

65. The power source characteristic is given by $I^2 = 300(100 - V)$ and the voltage length characteristics is given by V = 25 + 5L (L is length in mm, V is voltage in Volts, I is in Ampere). Change in power for a change in arc length from 5mm to 7mm is ______________ kW (Upto 2 decimals)

Sol. 1. When length is 5mm.

V= 25+ 25= 50V

$I^2 = 300 * 50 \rightarrow$ I = 122.4745 Amp

Power, P = VI = 50*122.4745 = 6123.725 W ...... (1)

2. When length is 7mm.

V = 25 + 35= 60V

$I^2 = 300 * 40 \rightarrow$ I = 109.5445 Amp

Power, P = VI = 60*109.5445 = 6572.670 W...... (2)

Change in Power = 6572.670 – 6123.725 = 448.945 W

= 0.448kW

****


OUR TOP GRADIANS
IN GATE 2019
Anshul Goel
AIR-2
Mechanical Engg.
Nipun Mittal
AIR-3
Computer Science Engg.
Chetan
AIR-4
Electronics Engg.
Pradeep Kumar
AIR-5
Electrical Engg.
Shreyans Mehta
AIR-7
Civil Engg.
Mahesh Singh
AIR-10
Mechanical Engg.
Raja Keshri
AIR-11
Electrical Engg.
Sairam
AIR-13
Raghvendra Sharma
AIR-16
Computer Science Engg.
Ghanendra Singh
AIR-21
Electronic Engg.
Manthan Sharma
AIR-22
Electrical Engg.
Swastik Samantaray
AIR-23
Electronics Engg.
Arghya Kamal Dey
AIR-23
Electronics Engg.
Rohan Kumar Biswal
AIR-27
Mechanical Engg.
Boda Devilal
AIR-29
Civil Engg.
Kartavya Kothari
AIR-45
Computer Science Engg.
Umang Jaggi
AIR-46
Civil Engg.
Guda Sai Rohin
AIR-30
Mechanical Engg.
Sethu Raj R
AIR-33
Civil Engg.
Ajay Kumar Sharma
AIR-37
Civil Engg.
Nishant Pahuja
AIR-48
Electrical Engg.
Mohd Kashif
AIR-60
Computer Science Engg.
Nikhil Kote
AIR-63
Mechanical Engg.
Ankur Agrawal
AIR-65
Mechanical Engg.
Syed Hashim
AIR-70
Mechanical Engg.
Rohit Gaur
AIR-71
Civil Engg.
Abhinav Sridhar
AIR-80
Electronics Engg.
Akhil Sharma
AIR-100
Civil Engg.
And Many More.......
Vision 2021
Start Free Trial
A Course for ESE & GATE Aspirants (Mechanical)