MADE EASY

India's Best Institute for IES, GATE & PSUs

GATE 2020
Mechanical Engineering

Click here for
Questions and Solutions

Date of Exam : 01/02/2020 (Forenoon)

Scroll down to view

www.madeeasy.in

Corporate Office: 44-A/1, Kalu Sarai, New Delhi - 110016 | **Ph:** 011-45124612, 9958995830

Delhi | Hyderabad | Noida | Bhopal | Jaipur | Lucknow | Indore | Pune | Bhubaneswar | Kolkata | Patna

SECTION A : GENERAL APTITUDE

Q.1 He is known for his unscrupulous ways. He always sheds _____ tears to deceive people.

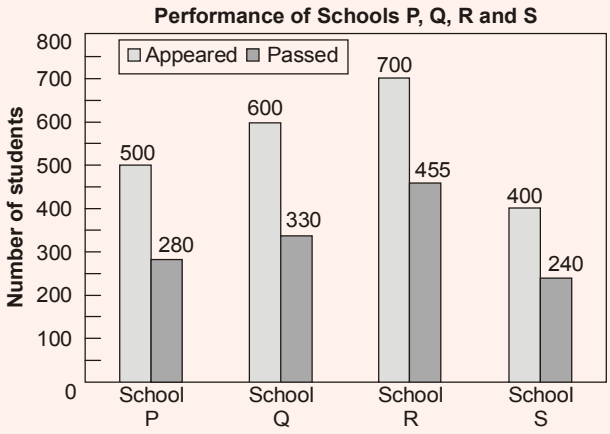
(a) crocodile's
(b) fox's
(c) crocodile
(d) fox

Ans. **(c)**

The term crocodile tears refers to hyporite crying. It is a false or insincere display of grief.

End of Solution

Q.2 The bar graph shows the data of the students who appeared and passed in an examination for four schools P, Q, R and S. The average of success rates (in percentage) of these four schools is _____.



(a) 58.8
(b) 59.0
(c) 58.5
(d) 59.3

Ans. **(b)**

$$\text{Average percentage of passing students} = \frac{\frac{\text{Total no. of passed students}}{\text{Total no. of students}}}{4} \times 100$$

$$= \frac{\frac{280}{500} + \frac{330}{600} + \frac{455}{700} + \frac{240}{400}}{4} \times 100$$

$$= \frac{0.56 + 0.55 + 0.65 + 0.60}{4} \times 100 = 59\%$$

End of Solution

UPPSC
Combined State Engineering Services Exam, 2019

MADE EASY
India's Best Institute for IES, GATE & PSUs

Assistant Engineer | Total Posts : 692

Classroom Course
Streams: CE, ME, EE

Commencing from 10th Feb, 2020 | Classes at Delhi and Lucknow
- 650 Hrs of comprehensive course.
- General Studies and Hindi covered.
- Exclusive study materials will be provided as per requirement of UPPSC.

Admission open

Postal Course
Streams: CE, ME, EE

Enrollment open
- Technical theory books with practice questions.
- Previous years' solved papers.
- Practice books (MCQ) for technical subjects.
- General Studies theory book with practice questions.
- Hindi book with practice questions.

Admission open

Live/Online Classes
Streams: CE, ME, EE

Commencing from 10th Feb, 2020
- Useful for those candidates who are not able to join classroom programme.
- 650 Hrs of quality classes at your doorstep.
- Flexibility to learn at your own pace.
- Physical study materials will be dispatched at your address.

Admission open

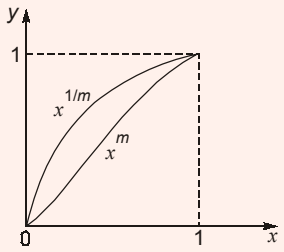
Test Series (Online/Offline)
Streams: CE, ME, EE

20 Tests | Commencing from 23rd Feb, 2020
- Quality questions with detailed solutions.
- Comprehensive performance analysis.
- Tests on standard and pattern as per UPPSC examination.

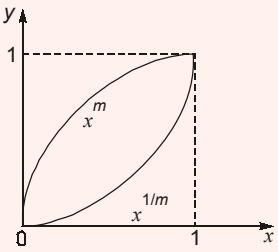
Admission open

Q.3 Select the graph that schematically represents BOTH $y = x^m$ and $y = x^{1/m}$ properly in the interval $0 \le x \le 1$. For integer values of m, where $m > 1$.

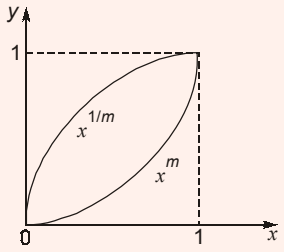
(a)



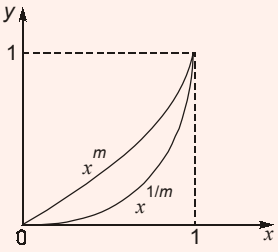
(b)



(c)



(d)



Ans. **(c)**

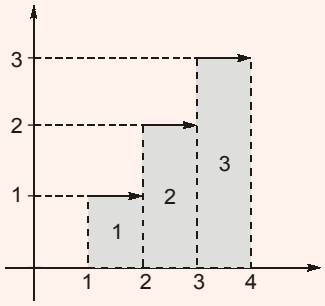
End of Solution

Q.4 Define $[x]$ as the greatest integer less than or equal to x, for each $x \in (-\infty, \infty)$. If $y = [x]$, then area under y for $x \in [1, 4]$ is _____.

(a) 3 (b) 1

(c) 6 (d) 4

Ans. **(c)**



Area = $1 \times 1 + 1 \times 2 + 1 \times 3$

$= 1 + 2 + 3 = 6$

End of Solution

Q.5 P, Q, R and S are to be uniquely coded using α and β. If P is coded as $\alpha\alpha$ and Q as $\alpha\beta$, then R and S, respectively, can be coded as _____.

(a) $\beta\alpha$ and $\beta\beta$ (b) $\alpha\beta$ and $\beta\beta$

(c) $\beta\alpha$ and $\alpha\beta$ (d) $\beta\beta$ and $\alpha\alpha$

Ans. **(a)**

$\beta\alpha$ and $\beta\beta$

Given, code of $P = \alpha\alpha$

code of $Q = \alpha\beta$

these code of $R = \beta\alpha$

and code of $S = \beta\beta$

End of Solution

Q.6 Crowd funding deals with mobilisation of funds for a project from a large number of people, who would be willing to invest smaller amounts through web-based platforms in the project.

Based on the above paragraph, which of the following is correct about crowd funding?

(a) Funds raised through unwilling contributions on web-based platforms.

(b) Funds raised through coerced contributions on web-based platforms.

(c) Funds raised through large contributions on web-based platforms.

(d) Funds raised through voluntary contributions on web-based platforms.

Ans. **(d)**

Crowd funding has been defined as a large number of people making small cantribution for a project. Only option and is implied.

End of Solution

Q.7 Jofra Archer, the England fast bowler, is _____ than accurate.

(a) faster (b) more faster

(c) more fast (d) less fast

Ans. **(c)**

When two qualities of the same noun are compared, more + positive degree adjective is used. Use more fast and not 'faster'.

End of Solution

Q.8 Select the word that fits the analogy:

Build : Building : : Grow : _____

(a) Grew (b) Growed

(c) Grown (d) Growth

Ans. **(d)**

Build : Building

(verb) *(noun)*

Grow : Growth

(verb) *(noun)*

End of Solution

Q.9 I do not think you know the case well enough to have opinions. Having said that, I agree with your other point. What does the phrase "having said that" mean in the given text?

(a) in addition to what I have said
(b) despite what I have said
(c) contrary to what I have said
(d) as opposed to what I have said

Ans. **(b)**

End of Solution

Q.10 The sum of the first n terms in the sequence 8, 88, 888, 8888, ... is _____.

(a) $\frac{81}{80}(10^n-1)+\frac{9}{8}n$

(b) $\frac{80}{81}(10^n-1)+\frac{8}{9}n$

(c) $\frac{81}{80}(10^n-1)+\frac{9}{8}n$

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

Ans. **(d)**

Using throw options put $n = 1$ and $n = 2$

Actual method:

$8 + 88 + 888 + ...$

$8[1 + 11 + 111 + ...]$

$\frac{8}{9}[9+99+999+.....]$

$\frac{8}{9}[(10-1)+(10^2-1)+(10^3-1)+.....]$

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

$\frac{8}{9}[(10+10^2+10^3+.....)-n]$

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

End of Solution

SECTION B : TECHNICAL

Q.1 For three vectors $\vec{A} = 2\hat{j} - 3\hat{k}, \vec{B} = -2\hat{i} + \hat{k}$ and $\vec{C} = 3\hat{i} - \hat{j}$, where $\hat{i}, \hat{j}$ and $\hat{k}$ are unit vectors along the axes of a right-handed rectangular/Cartesian coordinate system, the value of $\left(\vec{A}\cdot(\vec{B}\times\vec{C}) + 6\right)$ is _____.

Ans. **(6)**

$$\vec{A}\cdot(\vec{B}\times\vec{C}) = \begin{vmatrix} 0 & 2 & -3 \\ -2 & 0 & 1 \\ 3 & -1 & 0 \end{vmatrix} = 0 - 2\,[0 - 3] - 3\,[2 - 0] = 0$$

$$\vec{A}\cdot(\vec{B}\times\vec{C}) + 6 = 0 + 6 = 6$$

End of Solution

Q.2 The compressor of a gas turbine plant, operating on an ideal intercooled Brayton cycle, accomplishes an overall compression ratio of 6 in a two-stage compression process, Intercooling is used to cool the air coming out from the first stage to the inlet temperature of the first stage, before its entry to the second stage. Air enters the compressor at 300 K and 100 kPa. If the properties of gas are constant, the intercooling pressure for minimum compressor work is_____ kPa (round off to 2 decimal places).

Ans. **(244.95)**

$$\frac{P_3}{P_1} = 6 \qquad \Rightarrow P_3 = 600 \text{ kPa}$$

$$\text{Intermediate pressure} = \sqrt{P_3 P_1} = \sqrt{600 \times 100} = 244.94 \text{ kPa}$$

End of Solution

Q.3 The Laplace transform of a function $f(t)$ is $L(f) = \dfrac{1}{(s^2 + \omega^2)}$. Then, $f(t)$ is

(a) $f(t) = \dfrac{1}{\omega^2}(1 - \sin\omega t)$

(b) $f(t) = \dfrac{1}{\omega^2}(1 - \cos\omega t)$

(c) $f(t) = \dfrac{1}{\omega}\cos\omega t$

(d) $f(t) = \dfrac{1}{\omega}\sin\omega t$

Ans. **(d)**

$$L\{f\} = \frac{1}{s^2 + \omega^2}$$

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

End of Solution

Q.4 Match the following.

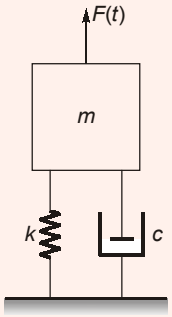
	Heat treatment process		Effect
P.	Tempering	1.	Strengthening
Q.	Quenching	2.	Toughening
R.	Annealing	3.	Hardening
S.	Normalizing	4.	Softening

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

Ans. **(d)**

End of Solution

Q.5 A single-degree-of-freedom oscillator is subjected to harmonic excitation $F(t) = F_0\cos(\omega t)$ as shown in the figure.



The non-zero value of ω, for which the amplitude of the force transmitted to the ground will be F_0, is

(a) $\sqrt{\frac{k}{2m}}$
(b) $\sqrt{\frac{2k}{m}}$
(c) $\sqrt{\frac{k}{m}}$
(d) $2\sqrt{\frac{k}{m}}$

Ans. **(b)**

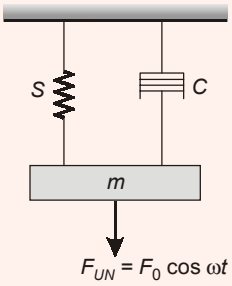
Given,

$$F_T = F_0$$

Then transmissibility

$$\epsilon = \frac{F_T}{F_0} = \frac{F_0}{F_0} = 1$$

$$\frac{\sqrt{1+\left(\frac{2\xi\omega}{\omega_n}\right)^2}}{\sqrt{\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right)^2+\left(\frac{2\xi\omega}{\omega_n}\right)^2}} = 1$$



$$1+\left(\frac{2\xi\omega}{\omega_n}\right)^2 = \left(1-\left(\frac{\omega}{\omega_n}\right)^2\right)^2 + \left(\frac{2\xi\omega}{\omega_n}\right)^2$$

$$1-\left(\frac{\omega}{\omega_n}\right)^2 = \pm 1$$

Taking (–ve) sign

$$\Rightarrow \quad 1-\left(\frac{\omega}{\omega_n}\right)^2 = -1$$

$$\Rightarrow \quad \left(\frac{\omega}{\omega_n}\right)^2 = \sqrt{2}$$

$$\Rightarrow \quad \frac{\omega}{\omega_n} = \sqrt{2} = \sqrt{2}\omega_n = \sqrt{\frac{2k}{m}}$$

End of Solution

Q.6 For an ideal gas, the value of the Joule-Thomson coefficient is

(a) positive (b) zero

(c) negative (d) indeterminate

Ans. **(b)**

Value of Joule Thomson coefficient for ideal gas $\mu = \left(\frac{\partial T}{\partial P}\right)_h = 0$.

End of Solution

Q.7 The stress state at a point in a material under plane stress condition is equi-biaxial tension with a magnitude of 10 MPa. If one unit on the $\sigma - \tau$ plane is 1 MPa, the Mohr's circle representation of the state-of-stress is given by

(a) a circle with a radius of 10 units on the $\alpha - \tau$ plane

(b) a circle with a radius equal to principal stress and its center at the origin of the $\sigma - \tau$ plane

(c) a point on the τ axis at a distance of 10 units from the origin

(d) a point on the σ axis at a distance of 10 units from the origin

Ans. **(d)**

End of Solution

ESE 2020 Main Exam

Streams: CE ME EE E&T

MADE EASY
India's Best Institute for IES, GATE & PSUs

Classroom Course

Batches from
18th Feb, 2020

Conventional Questions Practice Programme

Location : Delhi Centre

- 300-350 Hrs of comprehensive classes.
- Dynamic test series in synchronization with classes.
- Well designed comprehensive Mains workbooks.
- Special sessions to improve writing skills, time management & presentation skills.

Admission open

Online Classes

Batches from
25th Feb, 2020

Conventional Questions Practice Programme

- 300-350 Hrs of comprehensive recorded sessions.
- Convenience of learning at your own pace.
- Physical study materials will be provided at your address.

Admission open

Mains Test Series

Batches from
15th Mar, 2020

15 Tests | Mode : Offline/Online

- Test series will be conducted in synchronisation with subjects taught in the classes.
- Exactly on the UPSC pattern and standard.
- Contains **Repeat Topics** and **New Topics** to maintain continuity in study.
- Facility to cross check the evaluated answer sheet & access to the top scorer copy.
- Time bound evaluation of answer sheets with feedback.

Admission open

Q.8 The base of a brass bracket needs rough grinding. For this purpose, the most suitable grinding wheel grade specification is

(a) A50G8V (b) C30Q12V

(c) A30D12V (d) C90J4B

Ans. **(b)**

For brass 'Silicon carbide' is the abrasive. As brass is soft material, we need hard wheel. Therefore 'Q' is the best choice.

$$\underset{\text{soft}}{A} \rightarrow \underset{\text{hard}}{Z}$$

So, 'J' is in the softer side. So best option is (b).

End of Solution

Q.9 Which of the following function $f(z)$, of the complex variable z, is NOT analytic at all the points of the complex plane?

(a) $f(z) = z^2$ (b) $f(z) = \log z$

(c) $f(z) = e^z$ (d) $f(z) = \sin z$

Ans. **(b)**

$\log z$ is not analytic at all points.

End of Solution

Q.10 Multiplication of real valued square matrices of same dimension is

(a) not always possible to compute

(b) associative

(c) always positive definite

(d) commutative

Ans. **(b)**

Matrix multiplication is associative.

End of Solution

Q.11 A company is hiring to fill four managerial vacancies. The candidates are five men and three women. If every candidate is equally likely to be chosen then the probability that at least one women will be selected is _____ (round off to 2 decimal places).

Ans. **(0.93)**

5 men, 3 women

P[atleast one women selected for 4 vacancies]

$$= 1 - P[\text{none}]$$

$$= 1 - \frac{{}^{5}C_{4}\,{}^{3}C_{0}}{{}^{8}C_{4}} = 1 - \frac{5}{70} = 1 - \frac{1}{14} = \frac{13}{14} = 0.93$$

End of Solution

Q.12 In a concentric tube counter-flow heat exchanger, hot oil enters at 102°C and leaves at 65°C. Cold water enters at 25°C and leaves at 42°C. The log mean temperature difference (LMTD) is _____°C (round off to one decimal place).

Ans. **(49.3)**

$$T_{hi} = 102°C, \quad T_{he} = 65°C$$
$$T_{c,i} = 25°C, \quad T_{ce} = 42°C$$

$$\text{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)};$$

$$\Delta T_1 = 102°C - 42°C = 60°C; \Delta T_2 = 65°C - 25°C = 40°C;$$

$$= \frac{60 - 40}{\ln\left(\frac{60}{40}\right)} = \frac{20}{0.4054} = 49.3°C$$

End of Solution

Q.13 A flywheel is attached to an engine to keep its rotational speed between 100 rad/s and 110 rad/s. If the energy fluctuation in the flywheel between these two speeds is 1.05 kJ then the moment of inertia of the flywheel is _____kg.m^2 (round off to 2 decimal places).

Ans. **(1)**

$$\Delta E_{max} = \frac{1}{2} I \left(\omega_{max}^2 - \omega_{min}^2\right)$$

$$\therefore \quad 1.05 \times 10^3 \times 2 = I\left(110^2 - 100^2\right)$$

$$I = 1 \text{ kg.m}^2$$

End of Solution

Q.14 In the Critical Path Method (CPM), the cost-time slope of an activity is given by

(a) $\frac{\text{Crash Cost} - \text{Normal Cost}}{\text{CrashTime}}$

(b) $\frac{\text{Normal Cost}}{\text{Crash Time} - \text{Normal Time}}$

(c) $\frac{\text{Crash Cost} - \text{Normal Cost}}{\text{Crash Time} - \text{Normal Time}}$

(d) $\frac{\text{Crash Cost}}{\text{Crash Time} - \text{Normal Time}}$

Ans. **(c)**

End of Solution

Q.15 A sheet metal with a stock hardness of 250 HRC has to be sheared using a punch and a die having a clearance of 1 mm between them. If the stock hardness of the sheet metal increases to 400 HRC, the clearance between the punch and the die should be_____ mm.

Ans. **(1.26)**

Tensile strength $\propto$ Hardness number

$\therefore$ Shear strength = 0.5 tensile strength (Tresca theory)

= 0.577 tensile strength (Von mises theory)

Shear strength $\propto$ Hardness number

and clearance, $C = 0.0032t\sqrt{\tau}$

$$C \propto \sqrt{\text{Hardness number}}$$

$$\frac{C_2}{C_1} = \sqrt{\frac{(\text{Hardness number})_2}{(\text{Hardness number})_1}}$$

or $$C_2 = 1 \times \sqrt{\frac{400}{250}} = 1.265 \text{ mm}$$

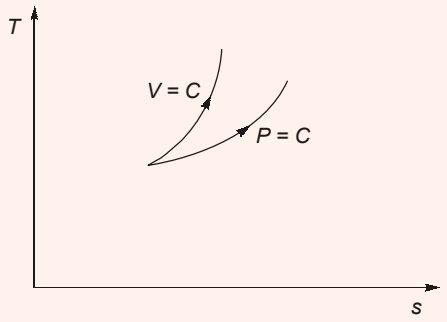
End of Solution

Q.16 For an ideal gas, a constant pressure line and a constant volume line intersect at a point, in the Temperature (T) versus specific entropy (s) diagram. C_P is the specific heat at constant pressure and C_V is the specific heat at constant volume. The ratio of the slopes of the constant pressure and constant volume lines at the point of intersection is

(a) $\frac{C_P - C_V}{C_P}$ (b) $\frac{C_P - C_V}{C_V}$

(c) $\frac{C_P}{C_V}$ (d) $\frac{C_V}{C_P}$

Ans. **(d)**



If $v = C$

$Tds = du + pdv$

$Tds = du$

$$du = C_V dT \qquad [\because V = C]$$
$$Tds = C_V dT$$
$$\left(\frac{dT}{ds}\right)_V = \frac{T}{C_v}$$

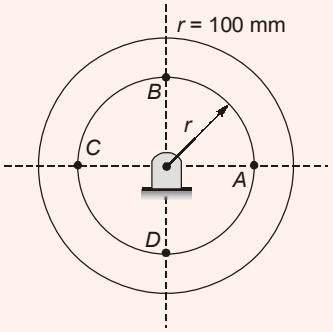
If $P = C$

$$Tds = dh - vdP$$
$$dh = C_P dT \qquad [\because P = C]$$
$$Tds = C_P dT$$
$$\left(\frac{dT}{ds}\right)_P = \frac{T}{C_P}$$

Ratio, $\dfrac{(dT/ds)_P}{(dT/ds)_V} = \dfrac{(T/C_P)_P}{(T/C_V)_V} = \dfrac{C_V}{C_P}$

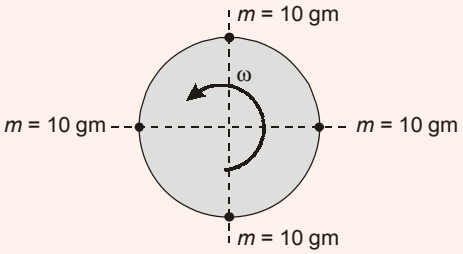
End of Solution

Q.17 A balanced rigid disc mounted on a rigid rotor has four identical point masses, each of 10 grams, attached to four points on the 100 mm radius circle shown in the figure



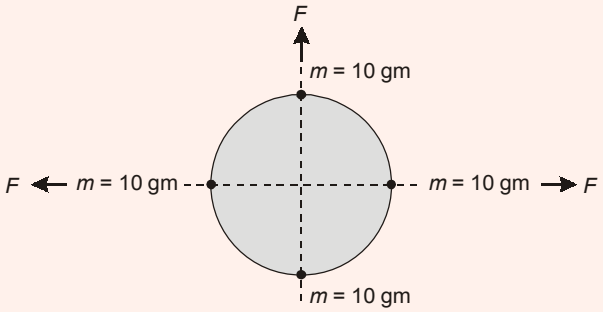
The rotor is driven by a motor at uniform angular speed of 10 rad/s. If one of the masses gets detached then the magnitude of the resultant unbalance force on the rotor is _____ N. (round off to 2 decimal places).

Ans. **(0.1)**



$\omega = 10$ rad/s, $r = 100$ mm $= 0.1$ m

If one mass is detached then



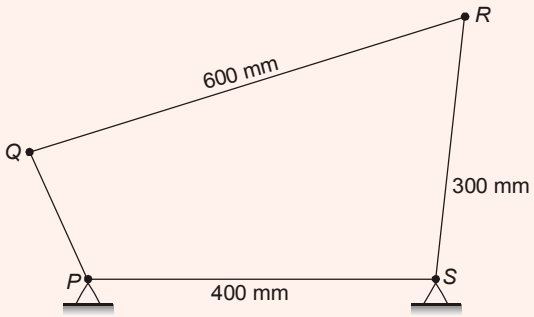
Now, unbalance tone, $F = mr\omega^2$

$$= \frac{10}{1000} \times 0.1 \times (10)^2 = \frac{10 \times 0.1 \times 100}{1000}$$

$$= 0.1 \text{ N}$$

End of Solution

Q.18 A four bar mechanism is shown below.

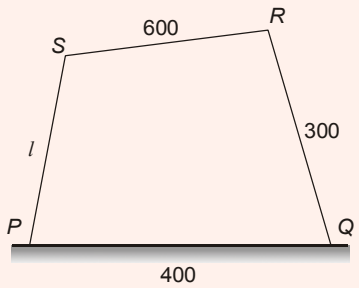


For the mechanism to be a crank-rocker mechanism, the length of the link *PQ* can be

(a) 350 mm (b) 200 mm

(c) 300 mm (d) 80 mm

Ans. **(d)**



For Crank-Rocker mechanism, shortest link must be crank and adjacent to fixed as well as Grashoff's law must be satisfied.

If $l = 80$ mm

then shortest will be = 80 mm

as well as $(80 + 600) < (400 + 300)$

$680 < 700$

Therefore law is satisfied.

$\Rightarrow \quad l = 80$ mm

End of Solution

Q.19 The value of $\lim_{x\to 1}\left(\frac{1-e^{-c(1-x)}}{1-xe^{-c(1-x)}}\right)$

(a) $c + 1$ (b) $\frac{c+1}{c}$

(c) c (d) $\frac{c}{c+1}$

Ans. **(d)**

$\lim_{x\to 1}\frac{1-e^{-c(1-x)}}{1-xe^{-c(1-x)}} = \frac{0}{0}$ form

Applying 'L' Hospital rule

$$= \lim_{x\to 1}\frac{-ce^{-c(1-x)}}{-e^{-c(1-x)} - x(e)^{-c(1-x)}}$$

$$= \lim_{x\to 1}\frac{-c}{-1-cx} = \frac{-c}{-1-c} = \frac{c}{1+c}$$

End of Solution

Q.20 A helical gear with 20° pressure angle and 30° helix angle mounted at the mid-span of a shaft that is supported between two bearings at the ends. The nature of the stresses induced in the shaft is

(a) normal stress due to bending in one plane and axial loading; shear stress due to torsion

(b) normal stress due to bending in two planes; shear stress due to torsion

(c) normal stress due to bending only

(d) normal stress due to bending in two planes and axial loading; shear stress due to torsion

Ans. **(d)**

End of Solution

Q.21 The crystal structure of γ iron (austenite phase) is

(a) BCC (b) BCT

(c) HCP (d) FCC

Ans. **(d)**

End of Solution

Q.22 The velocity field of an incompressible flow in a Cartesian system is represented by

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

Which one of the following expressions for v is valid?

(a) $-4xy - 4xz$ (b) $4xy - 6xz$

(c) $4xy + 4xz$ (d) $-4xz + 6xz$

Ans. **(a)**

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

For Incompressible flow

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

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

$$\frac{\partial v}{\partial y} = -4x$$

$$v = -4xy + f(x, z)$$

End of Solution

Q.23 Match the following non-dimensional numbers with the corresponding definitions:

	Non-dimensional number		Definition
P.	Reynolds number	1.	$\frac{\text{Buoyancy force}}{\text{Viscous force}}$
Q.	Grashof number	2.	$\frac{\text{Momentum diffusivity}}{\text{Thermal diffusivity}}$
R.	Nusselt number	3.	$\frac{\text{Inertia force}}{\text{Viscous force}}$
S.	Prandtl number	4.	$\frac{\text{Convective heat transfer}}{\text{Conduction heat transfer}}$

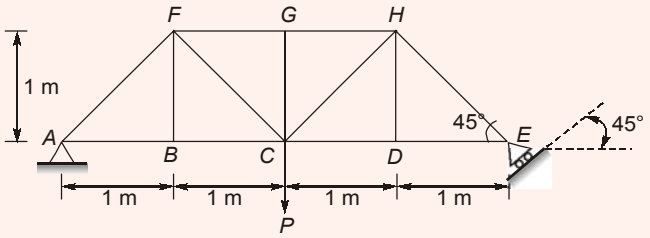
(a) P-3, Q-1, R-2, S-4 (b) P-3, Q-1, R-4, S-2

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

Ans. **(b)**

End of Solution

Q.24 The members carrying zero force (i.e. zero-force members) in the truss shown in the figure, for any load P > 0 with no appreciable deformation of the truss (i.e. with no appreciable change in angles between the members), are



(a) BF, DH and GC only
(b) BF, DH, GC, CD and DE only
(c) BF and DH only
(d) BF, DH, GC, FG and GH only

Ans. **(b)**

End of Solution

Q.25 Froude number is the ratio of
(a) inertia forces to viscous forces
(b) buoyancy forces to viscous forces
(c) buoyancy forces to inertia forces
(d) inertia forces to gravity forces

Ans. **(d)**

End of Solution

Q.26 A vector field is defined as

$$\vec{F}(x,y,z)=\frac{x}{\left[x^2+y^2+z^2\right]^{3/2}}i+\frac{y}{\left[x^2+y^2+z^2\right]^{3/2}}\hat{j}+\frac{z}{\left[x^2+y^2+z^2\right]^{3/2}}\hat{k}$$

where, $\hat{i},\hat{j},\hat{k}$ are unit vectors along the axes of a right-handed rectangular/Cartesian coordinate system. The surface integral $\iint\vec{F}d\vec{S}$ (where $d\vec{S}$ is an elemental surface area vector) evaluated over the inner and outer surfaces of a spherical shell formed by two concentric spheres with origin as the center, and internal and external radii of 1 and 2, respectively, is

(a) 0
(b) 2π
(c) 8π
(d) 4π

Ans. **(a)**

$$\vec{F} = \frac{\vec{r}}{r^3}$$

$$\nabla \cdot \vec{F} = \nabla \cdot \frac{\vec{r}}{r^3} = 0$$

By divergence theorem

$$\iint_s \vec{f} \cdot \vec{dS} = \iiint_R \nabla \vec{F} dx\, dy\, dz = 0$$

End of Solution

Q.27 Two business owners Shveta and Ashok run their businesses in two different states. Each of them, independent of the other, produces two products A and B, sells them at Rs. 2,000 per kg and Rs, 3,000 per kg, respectively, and uses Linear Programming to determine the optimal quantity of A and B to maximize their respective daily revenue. Their constraints are as follows: i) for each business owner, the production process is such that the daily production of A has to be at least as much as B, and the upper limit for production of B is 10 kg per day, and ii) the respective state regulations restrict Shveta's production of A to less than 20 kg per day and Ashok's production of A to less than 15 kg per day. The demand of both A and B in both the states is very high and everything produced is sold.
The absolute value of the difference in daily (optimal) revenue of Shveta and Ashok is _____ thousand Rupees (round off to 2 decimal places)

Ans. **(10)**

Maximum $z = 2000x_1 + 3000x_2$

$A \rightarrow x_1$ units $\quad x_1 \geq x_2$

$B \rightarrow x_2$ units $\quad x_2 \geq 10$

$x_1 < 20$

$x_1 < 15$

Shveta's Profit = Rs. 70000 at (20, 10)

Ashok's Profit = Rs. 60000 at (15, 10)

Difference Rs. 10000

End of Solution

Q.28 In a disc-type axial clutch, the frictional contact takes place within an annular region with outer and inner diameters 250 mm and 50 mm, respectively. An axial force F_1 is needed to transmit a torque by a new clutch. However, to transmit the same torque, one needs an axial force F_2 when the clutch wears out. If contact pressure remains uniform during operation of a new clutch while the wear is assumed to be uniform for an old clutch and the coefficient of friction does not change, then the ratio F_1/F_2 is_____ (round off to 2 decimal places).

Ans. (0.871)

$$T = \mu W \times R_m$$
$$T_{new} = \mu \times W \times R_{new}$$
$$T_{new} = \mu \times W_{new} \times \frac{2}{3}\frac{\left(R_0^3 - R_i^3\right)}{R_0^2 - R_i^2}$$
$$T_{old} = \mu \times W \times R_{old}$$
$$T_{new} = T_{old}$$
$$W_{new} \times \frac{2}{3}\frac{\left(R_0^3 - R_i^3\right)}{R_0^2 - R_i^2} = W_{old} \times \frac{\left(R_0 + R_i\right)}{2}$$
$$\frac{W_{new}}{W_{old}} = 0.871$$

End of Solution

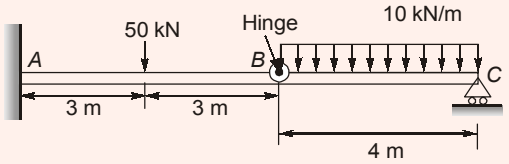
Q.29 In a turning process using orthogonal tool geometry, a chip length of 100 mm is obtained for an uncut chip length of 250 mm.
The cutting conditions are cutting speed = 30 m/min. rake angle = 20°.
The shear plane angle is _____ degrees (round off to one decimal place).

Ans. (23.5)

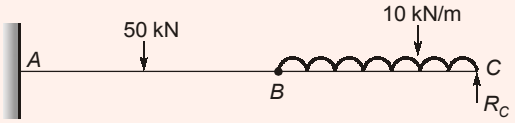
$$r = \frac{l_c}{l} = \frac{100}{250} = 0.4$$
$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} = \frac{0.4\cos 20°}{1 - 0.4 \times \sin 20°} = 0.4354$$
$$\phi = \tan^{-1}(0.4354) = 23.5°$$

End of Solution

Q.30 The magnitude of reaction force at joint C of the hinge-beam shown in the figure is _____ kN (round off to 2 decimal places).



Ans. (20)



$$\Sigma M_{B_{Right}} = 0$$
$$4R_C = 10 \times 4 \times 2$$
$$R_C = 20 \text{ kN}$$

End of Solution

New Batches

MADE EASY
India's Best Institute for IES, GATE & PSUs

ESE 2021
GATE 2021

1 Year/2Years
Classroom Courses

Regular	Weekend

Early Start... • Extra Edge...

BATCH COMMENCEMENT DATES

Delhi and Noida

REGULAR BATCHES

DELHI

Evening :

ME : 16th Jan, 2020
25th Feb, 2020
CE : 30th Jan, 2020
20th Feb, 2020
EE, EC : 20th Jan, 2020

Morning :

CE, ME : 12th Feb, 2020 (Batch Closed)
EE : 18th Feb, 2020
EC : 6th Apr, 2020
CS : 18th May, 2020

WEEKEND BATCHES

DELHI

CE : 1st Feb, 2020
ME : 9th Feb, 2020
EE : 22nd Feb, 2020
EC : 22nd Feb, 2020

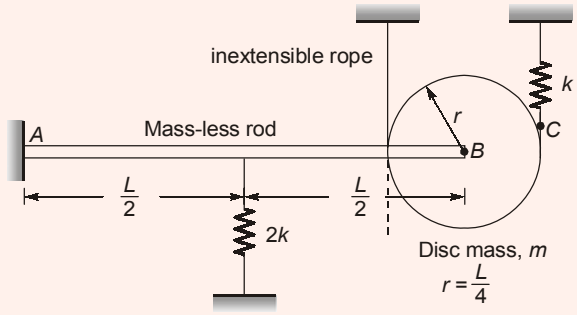
NOIDA

CE & ME : 8th Feb, 2020
EC & EE : 18th Jan, 2020
16th Feb, 2020

Rest of India

Patna : 24-02-2020
Lucknow : 20-02-2020
Bhopal : 16-01-2020
Indore : 20-02-2020
Pune : 10-02-2020
Hyderabad : 16-03-2020
Bhubaneswar : 23-01-2020
Kolkata : 25-01-2020
Jaipur : 16-02-2020

Q.31 A rigid mass-less rod of length L is connected to a disc (pulley) of mass m and radius $r = L/4$ through a friction-less revolute joint. The other end of that rod is attached to a wall through a friction-less hinge. A spring of stiffness $2k$ is attached to the rod at its mid-span. An inextensible rope passes over half the disc periphery and is securely tied to a spring of stiffness k at point C as shown in the figure. There is no slip between the rope and the pulley. The system is in static equilibrium in the configuration shown in the figure and the rope is always taut.



Neglecting the influence of gravity, the natural frequency of the system for small amplitude vibration is

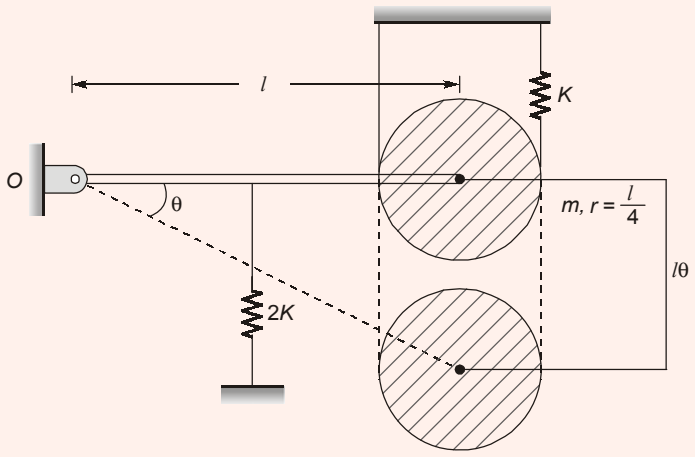
(a) $\sqrt{\frac{k}{m}}$

(b) $\frac{3}{\sqrt{2}}\sqrt{\frac{k}{m}}$

(c) $\sqrt{3}\sqrt{\frac{k}{m}}$

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

Ans. **(c)**



MI about point O:

$$I = \frac{mr^2}{2} + ml^2 = \frac{m}{2}\left(\frac{l}{4}\right)^2 + ml^2 = \frac{33ml^2}{32}$$

MI about disc centre:

$$I_{disc} = \frac{mr^2}{2}$$

When rod rotates by β,

$$\beta \cdot r = l \cdot \theta$$

$$\beta = \frac{l \cdot \theta}{r}$$

(If disc is also rotating about its own centre due to static friction).

Energy Method:

E = (Rotational KE)$_{\text{system about } O}$ + (Rotational KE)$_{\text{disc about its own centre}}$ + (PE of spring of 2K) + (PE of spring of K)

$$E = \frac{1}{2}I(\dot{\theta})^2 + \frac{1}{2}I_{disc}(\dot{\beta})^2 + \frac{1}{2}(2K)\times\left(\frac{l}{2}\cdot\theta\right)^2 + \frac{1}{2}K(2l\cdot\theta)^2$$

$$= \frac{1}{2}\cdot\frac{33ml^2}{32}\dot{\theta}^2 + \frac{1}{2}\cdot\frac{mr^2}{2}\left(\frac{l^2}{r^2}\right)\dot{\theta}^2 + \frac{1}{2}\cdot 2K\cdot\frac{l^2}{4}\cdot\theta^2 + \frac{1}{2}K\cdot 4l^2\theta^2$$

$$E = \frac{1}{2}\left(\frac{33ml^2}{32} + \frac{ml^2}{2}\right)\dot{\theta}^2 + \frac{1}{2}\left(\frac{Kl^2}{2} + 4Kl^2\right)\theta^2$$

$$= \frac{1}{2}\left(\frac{49ml^2}{32}\right)\dot{\theta}^2 + \frac{1}{2}\left(\frac{9Kl^2}{2}\right)\theta^2$$

$$\frac{dE}{dt} = 0$$

$$\frac{1}{2}\left[\frac{49ml^2}{32}\cdot 2\dot{\theta}\ddot{\theta} + \frac{9Kl^2}{2}2\cdot\theta\cdot\dot{\theta}\right] = 0$$

$$\frac{49ml^2}{16}\ddot{\theta} + 9Kl^2\theta = 0$$

$$\frac{49m}{16}\ddot{\theta} + 9K\cdot\theta = 0$$

$$\ddot{\theta} + \frac{9K\times 16}{49m}\cdot\theta = 0$$

$$\omega_n = \frac{12}{7}\sqrt{\frac{k}{m}}$$ This is exact solution.

But this solution is very close to $\sqrt{3}\sqrt{\frac{k}{m}}$

Because, $\frac{12}{7}\sqrt{\frac{k}{m}} = (1.714)\sqrt{\frac{k}{m}}$

$$\sqrt{3}\sqrt{\frac{k}{m}} = (1.732)\sqrt{\frac{k}{m}}$$

Therefore, $\omega_n = \frac{12}{7}\sqrt{\frac{k}{m}} = \sqrt{3}\sqrt{\frac{k}{m}}$

Note: If we take an approximation in moment of inertia about hinge axis.

That, $I = \frac{mr^2}{2} + ml^2 \qquad (r = l/4)$

$$= \left(\frac{ml^2}{32} + ml^2\right)$$

If we neglect $\frac{ml^2}{32}$ because $\frac{ml^2}{32} <<<< ml^2$

If we take, $I = ml^2$

Then we get, $\omega_n = \sqrt{3}\sqrt{\frac{k}{m}}$

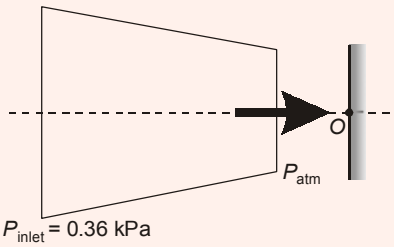
But if we take exact inertia,

$$I = \left(\frac{ml^2}{32} + ml^2\right) = \frac{33ml^2}{32}$$

Then exact answer is $\omega_n = \frac{12}{7}\sqrt{\frac{k}{m}}$.

End of Solution

Q.32 Air discharges steadily through a horizontal nozzle and impinges on a stationay vertical plate as shown in figure.



The inlet and outlet areas of the nozzle are 0.1 m^2 and 0.02 m^2, respectively. Take air density as constant and equal to 1.2 kg/m^3. If the inlet gauge pressure of air is 0.36 kPa, the gauge pressure at point O on the plate is _____ kPa (round off to two decimal places).

Ans. **(0.375)**

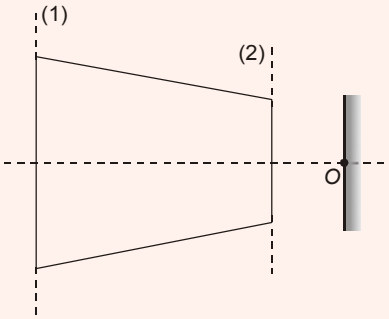
On applying continuity equation,

$$\dot{m} = \rho_1 \cdot A_1 \cdot v_1 = \rho_2 \cdot A_2 \cdot v_2$$

$$\Rightarrow \quad 0.1\,V_1 = 0.02\,V_2$$

$$\Rightarrow \quad V_2 = \frac{10}{2}V_1 = 5V_1$$

Now on applying Bernoulli between 1 and 2 section



$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+z_1=\frac{P_2}{\rho g}^{0}+\frac{V_2^2}{2g}+z_2$$

$$\Rightarrow \quad \frac{0.36\times10^3}{1.21\times9.81}+\frac{V_1^2}{2g}=\frac{25V_1^2}{2g}$$

$$\Rightarrow \quad V_1 = 4.98 \text{ m/s}$$

$$\Rightarrow \quad V_2 = 24.89 \text{ m/s}$$

On applying Bernoulli between 2 and 3 sections

$$\frac{P_2}{\rho g}^{0}+\frac{V_2^2}{2g}+z_2=\frac{P_3}{\rho g}+\frac{V_3}{2g}^{2\,0}+z_3$$

$$P_3=\frac{\rho g\cdot V_2^2}{2g}=\frac{1.21\times(24.89)^2}{2}=375 \text{ Pa}$$

$$= 0.375 \text{ kPa (gauge)}$$

End of Solution

Q.33 For an ideal Rankine cycle operating between pressures of 30 bar and 0.04 bar, the work output from the turbine is 903 kJ/kg and the work input to the feed pump is 3 kJ/kg. The specific steam consumption is _____ kg/kW.h (round off to 2 decimal places).

Ans. **(4)**

$$(WD)_{\text{turbine}} = 903 \text{ kJ/kg}$$

$$(WD)_{\text{pump}} = 3 \text{ kJ/kg}$$

Specific steam consumption = ? (kg/kW-hr)

$$\text{SSC} = \frac{3600}{W_T - W_C}$$

$$= \frac{3600}{903-3} = 4 \text{ kg/kW-hr}$$

End of Solution

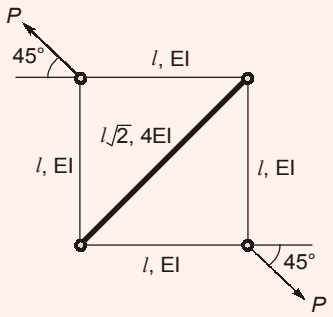
Q.34 For an assembly line, the production rate was 4 pieces per hour and the average processing time was 60 minutes. The WIP inventory was calculated. Now, the production rate is kept the same, and the average processing time is brought down by 30 percent. As a result of this change in the processing time, the WIP inventory

(a) increases by 25%
(b) increases by 30%
(c) decreases by 25%
(d) decreases by 30%

Ans. (d)

End of Solution

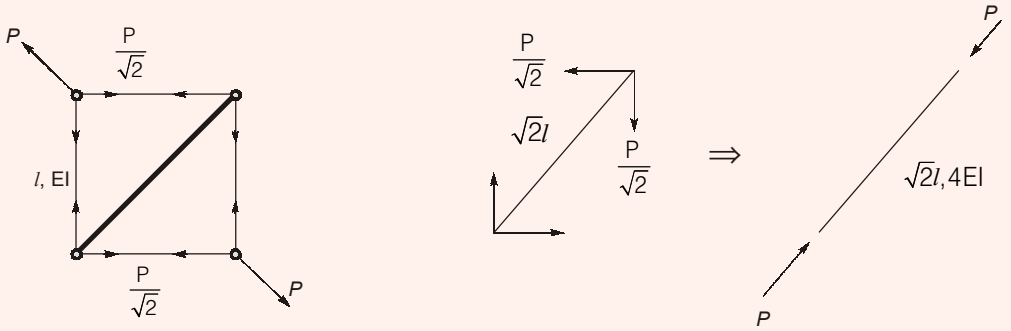
Q.35 The truss shown in the figure has four members of length l and flexural rigidity EI, and one member of length $l\sqrt{2}$ and flexural rigidity 4EI. The truss is loaded by a pair of forces of magnitude P, as shown in the figure.



The smallest value of P, at which any of the truss members will buckle is

(a) $\frac{\pi^2 EI}{l^2}$
(b) $\frac{\sqrt{2}\pi^2 EI}{l^2}$
(c) $\frac{\pi^2 EI}{2l^2}$
(d) $\frac{2\pi^2 EI}{l^2}$

Ans. (d)



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

End of Solution

Q.36 A steel part with surface area of 125 cm^2 is to be chrome coaled through an electroplating process using chromium acid sulphate as an electrolyte. An increasing current is applied to the part according to the following current time relation:

$$I = 12 + 0.2t$$

where, I = current (A) and t = time (minutes). The part is submerged in the plating solution for a duration of 20 minutes for plating purpose. Assuming the cathode efficiency of chromium to be 15% and the plating constant of chromium acid sulphate to be 2.50×10^{-2} mm^3/A·s, the resulting coating thickness on the part surface is _____ µm (round off to one decimal place).

Ans. **(5.0)**

$$I = 12 + 0.2t$$

After time, 't', Next infinitly small time 'dt' let heat deposited 'dQ'.

$$\therefore \quad dQ = 2.50 \times 10^{-2}\ (mm^3/A.s) \times 12 + 0.2t \times dt$$

As we have to convert this 's' to 'min'

$$\therefore \quad dQ = 2.50 \times 10^{-2}\ (mm^3/A \times min) \times 12 + 0.2t \times dt$$

Considering cathode efficiency of 15%

$$dQ = 2.50 \times 10^{-2} \times 60 \times (12 + 0.2t)dt \times 0.15\ mm^3$$

$\therefore$ In 20 min, $$Q = \int dQ = \int_0^{20} 2.50\times10^{-2}\times60\times(12+0.2t)dt\times0.15$$

$$= 0.225\left[12+0.1t^2\right]_0^{20} = 0.225\left[12\times20+0.1\times20^2\right] mm^3$$

$$= 63\ mm^3$$

As area os 125 cm^2

Plating thickness, $$t = \frac{63}{125\times(100)} = 0.00504\ mm = 5.04\ \mu m$$

(As 1 cm^2 = 100 mm^2)

End of Solution

Q.37 An analytic function of a complex variable $z = x + iy\,(i = \sqrt{-1})$ is defined as

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

where $\psi(x, y)$ is a real function. The value of the imaginary part of $f(z)$ at $z = (1 + i)$ is _____ (round off to 2 decimal places).

Ans. **(2)**

$f(z) = \phi + i\psi$ is analytic

$C-R$ equations

$\phi_x = \psi_y$

$\phi_y = -\psi_x$

$$\phi = x^2 - y^2$$

$$\phi_x = 2x = \psi_y$$
$$\phi_y = -2y = -\psi_x$$
$$\psi_x = 2y \Rightarrow \psi = 2xy + C_1$$
$$\psi_y = 2x \Rightarrow \psi = 2xy + C_2$$

Comparing $\psi = 2xy + C$ valid for all C put $C = 0$

$\psi(1 + i) \Rightarrow (x = 1 \quad y = 1)$

$\therefore \quad \psi = 2$

End of Solution

Q.38 A strip of thickness 40 mm is to be rolled to a thickness of 20 mm using a two-high mill having rolls of diameter 200 mm. Coefficient of friction and arc length in mm, respectively are

(a) 0.45 and 44.72 (b) 0.45 and 38.84

(c) 0.39 and 38.84 (d) 0.39 and 44.72

Ans. **(a)**

$h_0 = 40$ mm, $h_f = 20$ mm, $\Delta h = 40 - 20 = 20$ mm, $D = 200$ mm, $R = 100$ mm

Projected length, $L = \sqrt{R\Delta h} = \sqrt{100 \times 20} = \sqrt{2000} = 44.7213\,\text{mm}$

$\Delta h = \mu^2 R$

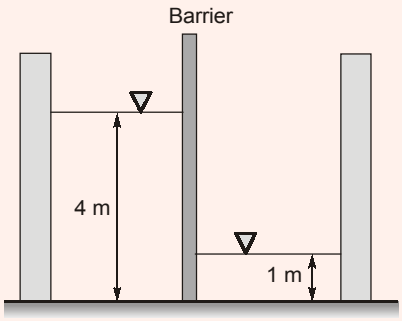
$\therefore \quad 20 = \mu^2 \cdot 100$

$\therefore \quad 0.2 = \mu^2$

$\mu = 0.4472$

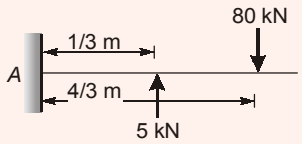
End of Solution

Q.39 The barrier shown between two water tanks of unit width (1 m) into the plane of the screen is modeled as a cantilever.



Taking the density of water as 1000 kg/m^3, and the acceleration due to gravity as 10 m/s^2, the maximum absolute bending moment developed in the cantilever is _____ kNm (round off to the nearest integer).

Ans. **(105)**



$F_1 = \rho g A \cdot \bar{x}_1$

$= 1000 \times 10 \times (1 \times 4) \times 2 = 80$ kN

$$F_2 = \rho g A \cdot \bar{x}_2$$
$$= 1000 \times 10 \times (1 \times 1) \times 0.5 = 5 \text{ kN}$$
$$CP_1 = 4 \times \frac{1}{3} = \frac{4}{3} \text{ m}$$
$$CP_2 = 1 \times \frac{1}{3} = \frac{1}{3} \text{ m}$$

So, $$M_A = 80 \times \frac{4}{3} - 5 \times \frac{1}{3} = 105 \text{ kN-m}$$

End of Solution

Q.40 Consider two exponentially distributed random variables X and Y, both having a mean of 0.50. Let $Z = X + Y$ and r be the correlation coefficient between X and Y. If the variance of Z equals 0, then the value of r is _____ (round off to 2 decimal places).

Ans. **(–1)**

$X \sim E(\lambda_1)$; $\quad \text{mean} = \frac{1}{\lambda_1} = 0.5$

$\Rightarrow \quad \lambda_1 = 2$

$$\text{Variance, } x = \frac{1}{\lambda_1^2} = \frac{1}{4} = 0.25$$

$Y \sim E(\lambda_2)$; $\quad \text{Mean} = \frac{1}{\lambda_2} = 0.5$

$\Rightarrow \quad \lambda_2 = 2$

$$\text{Variance, } y = 0.25$$

Given $\text{Var}(Z) = \text{Var}(x) + \text{Var}(y) + 2\,\text{COV}(x, y)$

$$0 = 0.25 + 0.25 + 2\,\text{COV}(x, y)$$

$$\text{COV}(x, y) = -\frac{0.5}{2} = -0.25$$

Correlation, $$\rho = \frac{COV(x,y)}{\sigma_x \sigma_y} = \frac{-0.25}{\sqrt{(0.25)}\sqrt{(0.25)}} = -1$$

End of Solution

Q.41 The thickness of a steel plate with material strength coefficient of 210 MPa, has to be reduced from 20 mm to 15 mm in a single pass in a two-high rolling mill with a roll radius of 450 mm and rolling velocity of 28 m/min. If the plate has a width of 200 mm and its strain hardening exponent, n is 0.25, the rolling force required for the operation is_____kN (round off to 2 decimal places).

Note: Average Flow Stress = Material Strength Coefficient $\times \frac{(\text{True strain})^n}{(1+n)}$

Ans. **(1167.26)**

$$\text{True strain, } (\epsilon_T) = \ln\left(\frac{h_f}{h_o}\right) = \ln\left(\frac{15}{20}\right) = -0.28768$$

$$\bar{\sigma}_o = k\left(\frac{\epsilon_T^n}{1+n}\right) = 210 \times \frac{(0.28768)^{0.25}}{1+0.25} = 123.04 \text{ MPa}$$

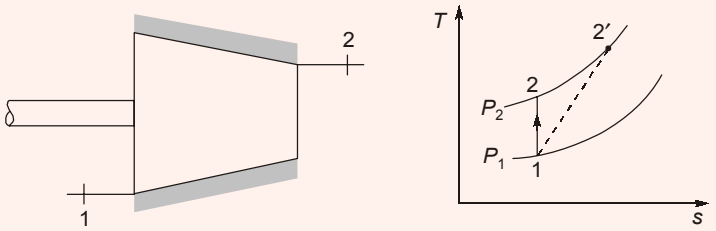
$$F = \bar{\sigma}_o \times \sqrt{R\Delta h} \times b = 123.04 \times \sqrt{450 \times (20-15)} \times 200$$

$$= 1167259.9 \text{ N} = 1167.26 \text{ kN}$$

End of Solution

Q.42 Air (ideal gas) enters a perfectly insulated compressor at a temperature of 310 K. The pressure ratio of the compressor is 6. Specific heat at constant pressure for air is 1005 J/kg.K and ratio of specific heats at constant pressure and constant volume is 1.4. Assume that specific heats of air are constant. If the isentropic efficiency of the compressor is 85 percent, the difference in enthalpies of air between the exit and the inlet of the compressor is _____ kJ/kg (round off to nearest integer).

Ans. **(245)**



$$T_1 = 310\text{K}$$

$$r_p = \frac{P_2}{P_1} = 6 \qquad \eta_s = 0.85$$

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

$$\gamma = 1.4$$

$$\therefore \quad \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\Rightarrow \quad \frac{T_2}{310} = (6)^{1.4-1/1.4}$$

$$\Rightarrow \quad T_2 = 517.225 \text{ K}$$

Now,
$$\eta_{isen} = \frac{W_{isen}}{W_{actual}} = \frac{h_2 - h_1}{h_{2'} - h_1}$$

$$0.85 = \frac{C_p(T_2 - T_1)}{h_{2'} - h_1}$$

$$\Rightarrow \quad h_{2'} - h_1 = \frac{1.005(517.22 - 310)}{0.85} = 245 \text{ kJ/kg}$$

End of Solution

NEXT IAS

BIG LEARNINGS MADE EASY

An initiative of MADE EASY Group

AVAIL UPTO

100% Scholarship

in tuition fee

Civil Services Scholarship Test

Test Date : 1st Mar, 2020 cst.nextias.com

Applicable on

GENERAL STUDIES FOUNDATION COURSE

Live/Online classes also available

Students may opt <u>any one</u> of the following paper:

- **GS Based Paper :** CSAT Paper II Syllabus
- **Aptitude Based Paper :** CSAT Paper I Syllabus

- 80 Questions;
- 200 Marks;
- 2 Hours duration

---

cst@nextias.com 8800338066 www.nextias.com

Q.43 Consider two cases as below.

Case 1: A company buys 1000 pieces per year of a certain part from vendor 'X'. The changeover time is 2 hours and the price is Rs. 10 per piece. The holding cost rate per part is 10% per year.

Case 2: For the same part, another vendor 'Y" offers a design where the changeover time is 6 minutes, with a price of Rs. 5 per piece, and a holding cost rate per part of 100% per year. The order size is 800 pieces per year from 'X' and 200 pieces per year from 'Y'.

Assume the cost of downtime as Rs. 200 per hour. The percentage reduction in the annual cost for Case 2, as compared to Case 1 is_____ (round off to 2 decimal places).

Ans. **(5.32)**

Given Data : 1000 pieces/year from '*X*'.

Changeover time = 2 hrs.

Cost of downtime = Rs. 200/hour

So, Total cost of downtime

2×200 = Rs. 400/downtime

C = Rs. 10/piece

Holding cost, C_h = 10% of Rs. 10

C_h = Rs. 1/unit/year

So, total cost for Case I :

= Material Cost + Downtime Cost + Inventory Holding Cost

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

Total cost for case I = Rs. 10,900/-

Case II : Order quantity 800 units from *X* and 200 units from *Y*.

For *Y* : Change overtime = 6 min. = 0.1 hour

Downtime cost = 0.1×200 = Rs. 20/-

Unit cost, C = Rs. 5/piece

Holding cost, C_h = 100% of unit cost = Rs. 5/-

So, total cost for case II :

= Cost for '*X*' + Cost for '*Y*'

$$= \left(800 \times 10 + 400 + \frac{800}{2} \times 1\right) + \left(200 \times 5 + 20 + \frac{200}{2} \times 5\right)$$

= 8000 + 800 + 1000 + 520

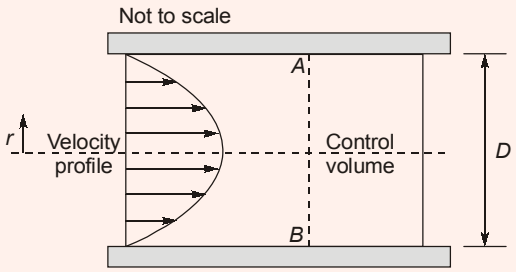
Total cost for case II = Rs. 10,320/-

So, percentage reduction in total cost of case II :

$$= \frac{10900 - 10320}{10900} \times 100 = \frac{580}{10900} \times 100 = 5.32\%$$

End of Solution

Q.44 Consider steady, viscous, fully developed flow of a fluid through a circular pipe of internal diameter *D*. We know that the velocity profile forms a paraboloid about the pipe centre line, given by: $V = -C\left(r^2 - \frac{D^2}{4}\right)$ m/s, where C is a constant. The rate of kinetic energy (in J/s) at the control surface *A*-*B*, as shown in the figure, is proportional to D^n. The value of *n* is_____.



Ans. (8)

$$v = -C\left[r^2 - \frac{D^2}{4}\right] = -C\left[r^2 - R^2\right]$$

$$v = C\left[R^2 - r^2\right] = CR^2\left[1 - \frac{r^2}{R^2}\right]$$

$$\left(K\dot{E}\right) = \frac{1}{2}\int_0^R \rho v^3 dA = \rho\int_0^R C^3R^6\left[1 - \frac{r^2}{R^2}\right]^3 \cdot 2\pi r \cdot dr$$

$$= \rho C^3R^6 2\pi\int_0^R\left[1 - \frac{r^2}{R^2}\right]^3 \cdot r \cdot dr$$

$$= \rho C^3R^6 2\pi\int_0^R\left[1 - \frac{r^6}{R^6} - \frac{3r^2}{R^2}\left[1 - \frac{r^2}{R^2}\right]\right] \cdot r \cdot dr$$

$$= \rho C^3R^6 2\pi\int_0^R\left[1 - \frac{r^6}{R^6} - \frac{3r^2}{R^2} + \frac{3r^4}{R^4}\right] \cdot r \cdot dr$$

$$= \rho C^3 2\pi R^6\left[\frac{R^2}{2} - \frac{R^2}{8} - \frac{3R^2}{4} + \frac{R^2}{2}\right]$$

$$= \rho C^3 2\pi R^6\left[R^2 - \frac{R^2}{8} - \frac{3R^2}{4}\right] = \rho C^3 2\pi R^6\left[\frac{R^2}{8}\right]$$

$$= \frac{\rho C^3 2\pi}{8}R^8 = \frac{\rho C^3 2\pi}{8 \times (2)^8} \times D^8$$

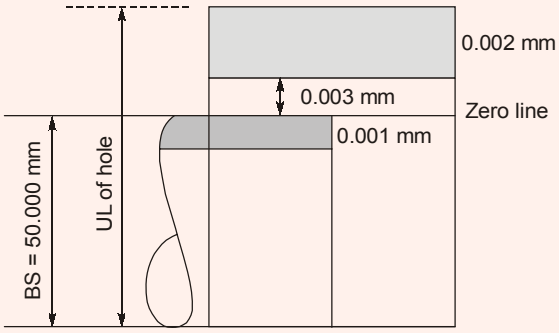
n = 8

End of Solution

Q.45 The following data applies to basic shaft system:
tolerance for hole = 0.002 mm,
tolerance for shaft = 0.001 mm,
allowance = 0.003 mm, basic size = 50 mm
The maximum hole size is _____ mm (round off to 3 decimal places).

Ans. **(50.005)**

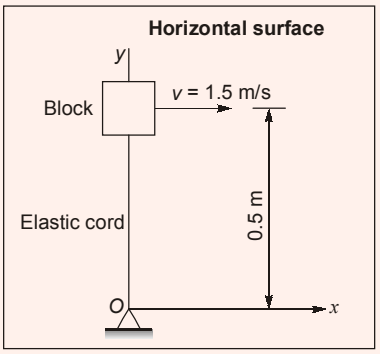
Using diagram method



UL of hole = BS + 0.003 + 0.002 mm = 50.005 mm

End of Solution

Q.46 The 2 kg block shown in figure (top view) rests on a smooth horizontal surface and is attached to a massless elastic cord that has a stiffness 5 N/m.



The cord hinged at O is initially unstretched and always remains elastic. The block is given a velocity v of 1.5 m/s perpendicular to the cord. The magnitude of velocity in m/s of the block at the instant the cord is stretched by 0.4 m is

(a) 1.36 (b) 1.07
(c) 0.83 (d) 1.50

Ans. **(a)**

Energy conservation,

$$\frac{1}{2}mV_1^2 = \frac{1}{2}mV_0^2 + \frac{1}{2}kx^2$$

$$\Rightarrow \quad 2 \times 1.5^2 = 2 \times V_0^2 + 5 \times 0.4^2$$

$$V_0 = 1.360 \text{ m/s}$$

End of Solution

MADE EASY

India's Best Institute for IES, GATE & PSUs

Avail upto

100% Scholarship

Through

National Scholarship Test

For ESE & GATE 2021

Date of Test : 1st Mar, 2020

Scholarship applicable on Long Term Classroom Courses for ESE & GATE

Valid on batches commencing from **Apr-June, 2020**

Students may opt any one of the following paper:

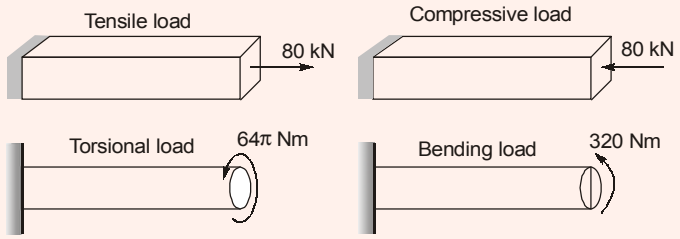
- **Technical Paper :** CE, ME, EE, EC, CS, IN
- **Aptitude Based Paper :** Maths + Reasoning + English

- 50 Questions;
- 100 Marks;
- 1 Hour duration

09599946203, 09599946204 **nst@madeeasy.in**

For registration, visit: www.madeeasy.in

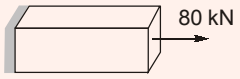
Q.47 Bars of square and circular cross-section with 0.5 m length are made of a material with shear strength of 20 MPa. The square bar cross-section dimension is 4 cm x 4 cm and the cylindrical bar cross-section diameter is 4 cm. The specimens are loaded as shown in the figure.



Which specimen(s) will fail due to the applied load as per maximum shear stress theory?

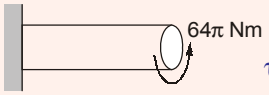
(a) Torsional load specimen
(b) Bending load specimen
(c) None of the specimens
(d) Tensile and compressive load specimens

Ans. **(d)**



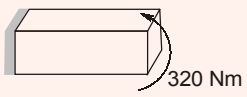
$$\sigma = \frac{80\times10^3}{40^2} = 50\ \text{N/mm}^2$$

$$\tau_{max} = \frac{\sigma}{2} = 25\,\text{N/mm}^2 > 20\ \text{MPa}$$



$$\tau_{max} = \frac{16T}{\pi d^3} = \frac{16\times64\pi\times10^3}{\pi(40)^3}$$

$$= 16\ \text{N/mm}^2 < 20\ \text{MPa}$$

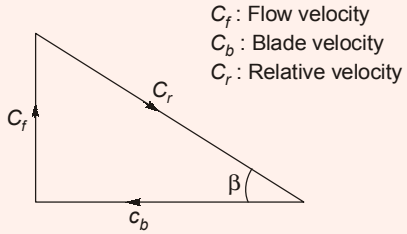


$$\sigma = \frac{320\times10^3}{\frac{40^3}{6}} = 30\ \text{N/mm}^2$$

$$\tau_{max} = \frac{\sigma}{2} = 15\ \text{N/mm}^2 < 20\ \text{MPa}$$

End of Solution

Q.48 For a Kaplan (axial flow) turbine, the outlet blade velocity diagram at a section is shown in figure.



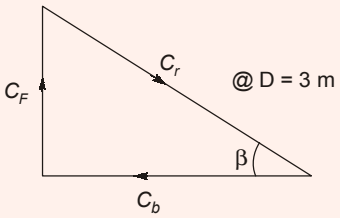
The diameter at this section is 3 m. The hub and tip diameters of the blade are 2 m and 4 m, respectively. The water volume flow rate is 100 m^3/s. The rotational speed of the turbine is 300 rpm. The blade outlet angle β is _____ degrees (round off to one decimal place).

Ans. (12.7)

$D_b = 2$ m $Q = 100\ m^3/sec$

$D_o = 4$ m $N = 300$ rpm

$$\tan\beta = \frac{C_F}{C_b} = \frac{V_{F2}}{u_2}$$



$$u_2 = C_b = \frac{\pi DN}{60} = \frac{\pi \times 3 \times 300}{60}$$

$$u_2 = C_b = 47.12 \text{ m/s}$$

$$Q = \frac{\pi}{4}(4^2 - 2^2) \times V_{F2}$$

$$V_{F2} = C_F = 10.61 \text{ m/s}$$

$$\tan\beta = \frac{10.61}{47.12}$$

$$\Rightarrow \quad \beta = 12.69° \simeq 12.7°$$

End of Solution

Q.49 A slot of 25 mm x 25 mm Is lo be milled in a workpiece of 300 mm length using a side and face milling cutter of diameter 100 mm, width 25 mm and having 20 teeth. For a depth of cut 5 mm, feed per tooth 0.1 mm, cutting speed 35 m/min and approach and over travel distance of 5 mm each, the time required for milling the slot is_____ minutes (round off to one decimal place).

Ans. (8.1)

$$V = \pi DN$$

$$35 = \pi \times 0.100 \times N$$

$$N = \pi \times 111.408 \text{ rpm}$$

$$t = \frac{L + \frac{D}{2} + A + O}{fzN} = \frac{300 + \frac{100}{2} + 5 + 5}{0.1 \times 20 \times 111.408}$$

$$= 1.6157 \text{ min per pass}$$

For 25 mm cuts min 5 mm depth of cut 5 pass needed.

Total machining time = 8.078 min $\simeq$ 8.1 min

End of Solution

Q.50 A small metal bead (radius 0.5 mm), initially at 100°C, when placed in a stream of fluid at 20°C, attains a temperature of 28°C in 4.35 seconds. The density and specific heat of the metal are 8500 kg/m^3 and 400 J/kgK, respectively. If the bead is considered as lumped system, the convective heat transfer coefficient (in W/m^2K) between the metal bead and the fluid stream is

(a) 149.9 (b) 449.7

(c) 283.3 (d) 299.8

Ans. **(d)**

r = 0.5 mm; c_p = 400 J/kgk; ρ = 8500 kg/m^3; t = 4.35 sec

$$\because \quad \frac{V}{A} = \frac{\frac{4}{3}\pi R^3}{4\pi R^2} = \frac{R}{3}$$

$$\because \quad \frac{T - T_\infty}{T_i - T_\infty} = e^{\frac{-hA\tau}{\rho C_p V}}$$

$$\Rightarrow \quad \frac{28 - 20}{100 - 20} = e^{-\left(\frac{h\cdot 3000}{0.5\times 8500\times 400}\right)\times 4.35}$$

$$\Rightarrow \quad h = 299.95 \text{ W/m}^2\text{K}$$

End of Solution

Q.51 The evaluation of the definite integral $\int_{-1}^{1.4} x|x|dx$ by using Simpson's 1/3rd (one-third) rule with step size h = 0.6 yields

(a) 0.592 (b) 0.581

(c) 0.914 (d) 1.248

Ans. **(a)**

$\int_{-1}^{1.4} x|x|dx$ step size h = 0.6

x	−1	−0.4	0.2	0.8	1.4
y	−1	−0.16	0.04	0.64	1.96

Simpson's 1/3rd rule

$$\int_{-1}^{1.4} x|x|dx = \frac{0.6}{3}\left[(-1+1.96)+4(-0.16+0.64)+2(0.04)\right]$$

$$= 0.2[0.96+1.92+0.08] = 0.592$$

End of Solution

Q.52 A cam with a translating flat-face follower is desired to have the follower motion

$$y(\theta) = 4[2\pi\theta - \theta^2], \qquad 0 \le \theta \le 2\pi$$

Contact stress considerations dictate that the radius of curvature of the cam profile should not be less than 40 mm anywhere. The minimum permissible base circle radius is _____ mm (round off to one decimal place).

Ans. **(48)**

Flat face follower

Displacement equation:

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

$$\frac{dy}{d\theta} = V = 4(2\pi - 2\theta)$$

$$= 8(\pi - \theta)$$ (For y to be max $\frac{dy}{d\theta} = 0 \Rightarrow \theta = \pi$)

$$a = \frac{dv}{d\theta} = -8$$

$$(R_{curvature})_{Min} = R_{Base} + (y + a)_{min}$$ (y_{min} is 0 at $\theta = 0, 2\pi$)

$$40 = R_{Base} + [0 - 8]_{Min}$$

$$40 = R_{Base} + [-8]$$

$$R_{Base} = 40 - (-8) = 40 + 8 = 48 \text{ mm}$$

End of Solution

Q.53 One kg of air, initially at a temperature of 127°C, expands reversibly at a constant pressure until the volume is doubled. If the gas constant of air is 287 J/kg.K, the magnitude of work transfer is _____ kJ (round off to 2 decimal places).

Ans. **(114.8)**

$m = 1$ kg; $T_1 = 127°C = 400$ K

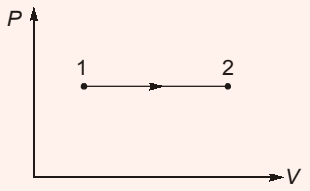
$P = C$; $V_2 = 2V_1$; $R = 0.287$ kJ/kgK

$$W = P_1(V_2 - V_1)$$

$$= P_1(2V_1 - V_1)$$

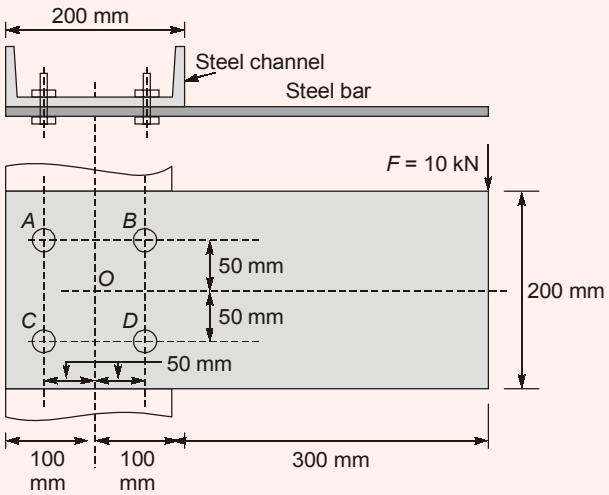
$$= P_1 \cdot V_1 = mRT_1$$

$$= 114.8 \text{ kJ}$$



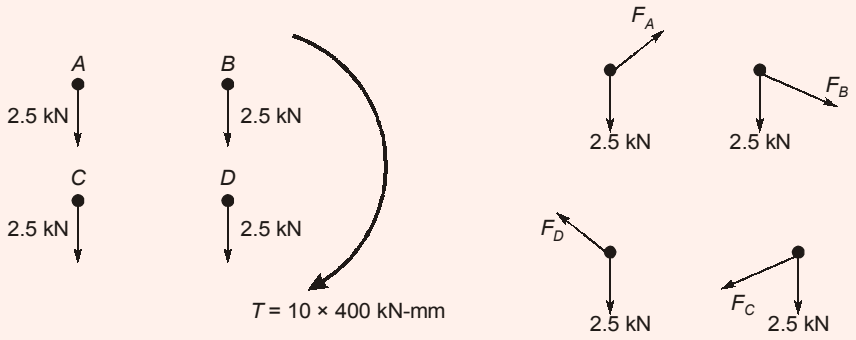
End of Solution

Q.54 A rectangular steel bar of length 500 mm, width 100 mm, and thickness 15 mm is cantilevered to a 200 mm steel channel using 4 bolts, as shown.



For an external load of 10 kN applied at the tip of the steel bar, the resultant shear load on the bolt at B, is _____ kN (round off to one decimal place).

Ans. (16.0)



$$F_A = F_B = F_C = F_D = \frac{10\times 400}{4\times 50\sqrt{2}} = 14.14 \text{ kN}$$

$$\text{Res}_B = \sqrt{14.14^2 + 2.5^2 + 2(14.14)(2.5)\cos 45}$$

$$\text{Res}_B = 16.005 \text{ kN}$$

End of Solution

Q.55 The indicated power developed by an engine with compression ratio of 8, is calculated using an air-standard Otto cycle {constant properties). The rate of heat addition is 10 kW. The ratio of specific heats at constant pressure and constant volume is 1.4. The mechanical efficiency of the engine is 80 percent. The brake power output of the engine is _____ kW (round off to one decimal place).

Ans. (4.5)

$$\eta = 1 - \frac{1}{r_c^{\gamma-1}} = 1 - \frac{1}{8^{0.4}} = 0.5647$$

$$\frac{W}{Q_1} = 0.5647$$

$$W = \frac{10\times 5647}{1000} = 5.647 \text{ kW}$$

$$\text{BP} = \eta_m \times W = 0.8 \times 5.647$$
$$= 4.5175 \text{ kW}$$

End of Solution

■■■■