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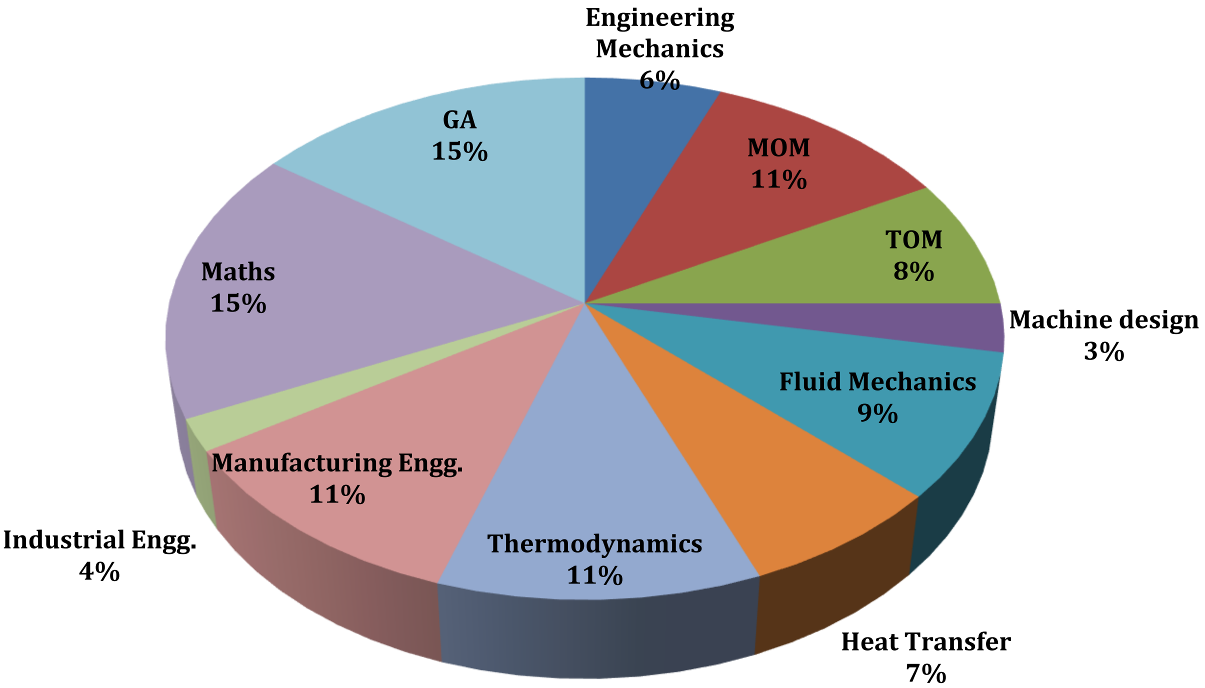
ANALYSIS OF GATE 2016
Mechanical Engineering



GATE-2016- ME 30/01/2016 9 AM-12 PM

SUBJECT	NO OF QUESTION	Topics Asked in Paper	Level of Toughness	Total Marks
Engineering Mechanics	1 M: 2 2 M: 2	Free body diagram ; Dynamics;Kinamatics	Moderate	6
Mechanics of Materials	1 M: 3 2 M: 4	deflection of beam;Tress & Strain;Moment of inertia;Statically indeterminate beams; Mohr's Circle,Torsions; Plain Stress & Strain; Bending stress, Helical spring,	Tough	11
Theory of Machine	1 M: 2 2 M: 3	Degree of freedom; Velocity Analysis; Vibrations; Balancing*. Gear train; Gyroscope*; Rotating masses*	Easy	8
Machine Design	1 M: 1 2 M: 1	Bearing; Bolted joint; failure theory	Easy	3
Fluid Mechanics	1 M: 3 2 M: 3	Continuty ; Pipe flow Impact of Jet ; Fluid Kinamatics; boundary layer;turbulent flow, stability of floating bodies; turbine.	Moderate	9
Heat Transfer	1 M: 1 2 M: 3	Convections; Heat Exchanger; Radiations; Lumped model	Easy	7
Thermodynamics	1 M: 3 2 M: 4	Power Engg; Properties of pure sustances; Study Flow energy; Psychromaetry; Compressor; Refregaration	Tough	11
Manufacturing Engg.	1 M: 5 2 M: 3	Unconventional Machining; Gear Menufecturing; Casting; Tool Life; Resistance welding; Shear Angle	Tough	11
Industrial Engg	1 M: 0 2 M: 2	CPM –PERT; Linear Programming; Forcosting; Inventory.	Moderate	4
Mathematics	1 M: 5 2 M: 5	Numerical Method ;Complex Variable Probability & Joint Distributions;Limit & Continuty ; Liner algebra.	Moderate	15
GA	1 M: 5 2 M: 5	Time & Work ; Mixtures,Directions ; Venn Diagram ; Mensuration& Area, clock.	Easy	15
Total	**65**		Moderate	**100**

* Indicates Questions from New Syllabus

Faculty Feedback: Few questions came from New Syllabus; General Ability was pretty easy; many question from MOM& TD& Manufacturing, qualifying is easy but scoring is tough. Practice previous question papers will be beneficial.

GATE-2016

Question Paper

&

Answer Keys

GATE 2016 Examination

Mechanical Engineering

Test Date: 30/01/2016

Test Time: 9:00 AM to 12:00 PM

Subject Name: ME MECHANICAL ENGINEERING

Section: General Aptitude

Q.1 - Q.5 Carry One Mark each.

1. Which of the following is **CORRECT** with respect to grammar and usage? Mount Everest is __________.

(A) the highest peak in the world
(B) highest peak in the world
(C) one of highest peak in the world
(D) one of the highest peak in the world

[Ans. A]

The sentence is stating the highest peak in the world. Since it is a specific thing, we need to use the definite article 'the' before it. Also the sentence is using the superlative degree and so we say 'the highest peak in the world' making option 1 the correct answer. There cannot be many highest peaks in the world and so options 3 and 4 are incorrect.

2. The policeman asked the victim of a theft, "What did you________?"

(A) loose
(B) lose
(C) loss
(D) louse

[Ans. B]

The context of the sentence is asking a person who has been deprived of something because of a theft. The word to be used to fill the blank is 'lose' which means to be deprived of something. 'Loose' means something that is not fitted. 'Louse' is the singular form of the word 'lice' that is a parasite that lives in the skin of mammals and birds. 'Loss' is a noun that means the process of losing someone or something. Eg: He suffered tremendous loss in his business.

3. Despite the new medicine's________ in treating diabetes, it is not________widely.

(A) effectiveness --- prescribed
(B) availability --- used
(C) prescription --- available
(D) acceptance --- proscribed

[Ans. A]

The sentence is looking for a contrast as it is joined by the conjunction 'despite'. The best pair of words that can fit the context of the sentence is 'effectiveness…prescribed'. Though the medicine is 'effective' in treating diabetes, it is not being 'prescribed' widely. A new medicine cannot have a 'prescription' or 'availability' for treating a disease. 'Proscribed' means forbidden by law. In case we use 'acceptance…proscribed' the sentence will not make any sense because it will mean that though the medicine is accepted widely, it is not forbidden by law.

4. In a huge pile of apples and oranges, both ripe and unripe mixed together, 15% are unripe fruits. Of the unripe fruits, 45% are apples. Of the ripe ones, 66% are oranges. If the pile contains a total of 5692000 fruits, how many of them are apples?

(A) 2029198
(B) 2467482
(C) 2789080
(D) 3577422

[Ans. A]

Let T = total no of fruits = 5692000
R = Ripe fruits
U = Unripe fruits
A = Apple
O = Oranges

Given U = 15% of T : $\frac{15}{100} \times 5692000 = 853800$

R = T – U= 4838200

A(U) = 45% of U: $\frac{45}{100} \times 853800 = 384210$

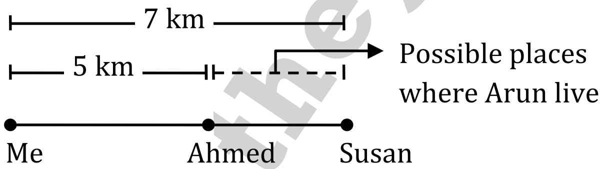
A(R) = (100 − 66)% of R: $\frac{34}{100} \times 4838200 = 1644988$

∴ A(U) + A(R) = 2029198

5. Michael lives 10 km away from where I live. Ahmed lives 5 km away and Susan lives 7 km away from where I live. Arun is farther away than Ahmed but closer than Susan from where I live. From the information provided here, what is one possible distance (in km) at which I live from Arun's place?

(A) 3.00
(B) 4.99
(C) 6.02
(D) 7.01
(E)

[Ans. C]



In question it is given that Ahmed is 5 km away and Susan is 7 km away from where I live. Further it is given that Arun is farther away than Ahmed from where I live and not as far as Susan. That means Arun must be living at distance more than 5 km but less than 7 km from my house which is according to given options can be 6.02 km.

Note: Information about Michal is unnecessary and just given to confuse.

Q.6 - Q.10 Carry Tne Marks each.

6. A person moving through a tuberculosis prone zone has a 50% probability of becoming infected. However, only 30% of infected people develop the disease. What percentage of people moving through a tuberculosis prone zone remains infected but does not show symptoms of disease?

(A) 15
(B) 33
(C) 35
(D) 37

[Ans. C]

Percentage probability of being infected = P(A) = 50%

Percentage probability of infected person developing disease is having system,

= P(B) = 30%

∴ Percentage probability of infected person not showing symptoms = $P(\overline{B})$=70%

∴ Percentage probability of person moving though a TB prone zone remaining infected but not showing symptoms

$$= P(A).P(\overline{B}) = \frac{50}{100} \times \frac{70}{100} = 35\%$$

7. In a world filled with uncertainty, he was glad to have many good friends. He had always assisted them in times of need and was confident that they would reciprocate. However, the events of the last week proved him wrong. Which of the following inference(s) is/are logically valid and can be inferred from the above passage?

(i) His friends were always asking him to help them.

(ii) He felt that when in need of help, his friends would let him down.

(iii)He was sure that his friends would help him when in need.

(iv) His friends did not help him last week.

(A) (i) and (ii)
(C) (iii) only
(B) (iii) and (iv)
(D) (iv) only

[Ans. B]

The paragraph states that the subject was very confident about his good friends helping him in his times of need because he had always helped them before in their time. Thus, inference iii follows.

Since the events of the last week proved him wrong, this means that his confidence was broken and his friends had not helped him. Thus inference iv also follows.

8. Leela is older than her cousin Pavithra. Pavithra's brother Shiva is older than Leela. When Pavithra and Shiva are visiting Leela, all three like to play chess. Pavithra wins more often than Leela does. Which one of the following statements must be **TRUE** based on the above?

(A) When Shiva plays chess with Leela and Pavithra, he often loses.

(B) Leela is the oldest of the three.

(C) Shiva is a better chess player than Pavithra.

(D) Pavithra is the youngest of the three.

[Ans. D]

According to given information the points we got are

(A) Shiva is brother of Pavithra

(B) Shiva and Pavithra are cousins of Leela

(C) According to their ages Shiva > Leela > Pavithra

(D) They all live play chess

(E) Pavithra wins more often than Leela but information about winning cases of Shiva is not given.

So from the given options statement which is clearly true is that Pavithra is the youngest of all.

9. If $q^{-a} = \frac{1}{r}$, $r^{-b} = \frac{1}{s}$ and $S^{-c} = \frac{1}{q}$, then the value of abc is

(A) $(rqs)^{-1}$
(B) 0
(C) 1
(D) $r + q + s$

[Ans. C]

$q^{-a} = \frac{1}{r}$; $r^{-b} = \frac{1}{s}$ and $s^{-c} = \frac{1}{q}$

$\therefore q^a = r;\ r^b = s$ and $s^c = q$

$\therefore$ alogq = log r ... . (1)

And b log r = log s ... . (2)

And c log s = log q ... . (3)

Multiplying equations (1), (2) and (3)

abc (log q)(log r)(log s) = (log r)(log s)(log q)

$\therefore$ abc = 1

10. P, Q, R and S are working on a project. Q can finish the task in 25 days, working alone for 12 hours a day. R can finish the task in 50 days, working alone for 12 hours per day. Q worked 12 hours a day but took sick leave in the beginning for two days. R worked 18 hours a day on all days. What is the ratio of work done by Q and R after 7 days from the start of the project?

(A) 10:11
(B) 11:10
(C) 20:21
(D) 21:20

[Ans. C]

Person	Days	Hours	Man hours/piece of work	Work done per hour
P				
Q	25	12	25×12	$\frac{1}{25\times 12}$
R	50	12	50×12	$\frac{1}{25\times 12}$
S				

After 7 days from start of project:

Q took sick leave on first 2 days

$\therefore$ Man hours by Q = 5×12

$\therefore$ Work done by Q $= 5\times 12\times\frac{1}{25\times 12} = \frac{1}{5}$ Man hours by R $= 7\times 18$

$\therefore$ Work done by R $= \frac{1}{50\times 12}\times 7\times 18 = \frac{21}{100}$

$\therefore$ Ratio of work done by Q to work done by R $= \frac{1}{5}:\frac{21}{100} = \frac{100}{5\times 21} = \frac{20}{21}$

Section: Technical

Q.1 - Q.25 Carry One Mark each.

1. The solution to the system of equations

$\begin{bmatrix} 2 & 5 \\ -4 & 3 \end{bmatrix} \begin{Bmatrix} x \\ y \end{Bmatrix} = \begin{Bmatrix} 2 \\ -30 \end{Bmatrix}$ is

(A) 6, 2
(B) −6, 2
(C) −6, −2
(D) 6, −2

[Ans. D]

$$\begin{bmatrix} 2 & 5 \\ -4 & 3 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 2 \\ -30 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} 2x + 5y \\ -4x + 3y \end{bmatrix} = \begin{bmatrix} 2 \\ -30 \end{bmatrix}$$

On comparing the matrix, we get

$2x + 5y = 2 \ldots\ldots\ldots ①$

$-4x + 3y = -30 \ldots\ldots\ldots ②$

By solving the equation (1) and (2)

We get $x = 6, y = -2$

2. If f(t) is a function defined for all $t \geq 0$, its Laplace transform F(s) is defined as

(A) $\int_0^\infty e^{st} f(t)dt$
(B) $\int_0^\infty e^{-st} f(t)dt$
(C) $\int_0^\infty e^{-st} f(t)dt$
(D) $\int_0^\infty e^{-ist} f(t)dt$

[Ans. B]

As we know that, the Laplace transform of the function f(t) is given by,

$$L\{f(t)\} = \int_{-\infty}^{\infty} e^{-st} f(t)dt = F(s)$$

But the function f(t) is destined only for $t \geq 0$

$$\text{So, } L\{f(t)\} = \int_0^\infty e^{-st} f(t)$$

3. $f(z) = u(x, y) + iv(x, y)$ is an analytic function of complex variable $z = x + iy$ where $i = \sqrt{-1}$. If $u(x, y) = 2\,xy$, then $v(x, y)$ may be expressed as

[Ans. A]

Given that $f(z) = u(x, y) + iv(x, y)$ is analytic function of complex variable $z = x + iy$. Then the function derivatives can be given as,

$$u_x = v_y \text{ or } \frac{\partial u}{\partial x} = \frac{\partial v}{\partial y} = 2y$$

$$\text{And } v_x = -u_y \text{ or } \frac{\partial_v}{\partial_x} = \frac{-\partial v}{\partial y} = -2x$$

Now, check by option

Alternate

$$\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y} = 2y \Rightarrow \partial v = 2y dy$$

On $\frac{\partial v}{\partial x} = \frac{-\partial v}{\partial y} = -2x \Rightarrow \partial v = -2x dx$

Integrate the above equations.

$V = y^2 + c$ and $V = -x^2 + c$

So the value of $v = -x^2 + y^2 + c$

4. Consider a Poisson distribution for the tossing of a biased coin. The mean for this distribution is μ. The standard deviation for this distribution is given by

(A) $\sqrt{\mu}$
(B) μ^2
(C) μ
(D) $1/\mu$

[Ans. A]

As we know that, for the poisson distribution, mean = variance = μ

And also, we know that, Standard deviation = $\sqrt{\text{variance}}$

$\Rightarrow$ Standard deviation= $\sqrt{\mu}$

5. Solve the equation $x = 10\cos(x)$ using the Newton-Raphson method. The initial guess is $x = \pi/4$. The value of the predicted root after the first iteration, up to second decimal, is _______

[Ans. *] Range: 1.53 to 1.59

Given that, $f(x) = x - 10\cos x$

and $x_0 = \pi/4$

$f(x) = 1 + 10\sin x$

From the Newton's Rap son method,

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

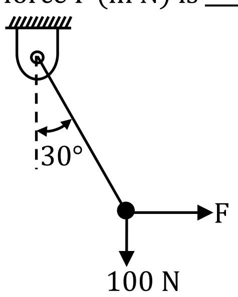
$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}$$

$$\Rightarrow x_1 = \frac{\pi}{4} - \left(\frac{\frac{\pi}{4} - 10\cos\left(\frac{\pi}{4}\right)}{1 + 10\sin\left(\frac{\pi}{4}\right)}\right)$$

$$\Rightarrow x_1 = \frac{\pi}{4} - \left\{\frac{\frac{\pi}{4} - 10\cos 45}{1 + 10\sin 45}\right\}$$

$$\Rightarrow x_1 = 1.564$$

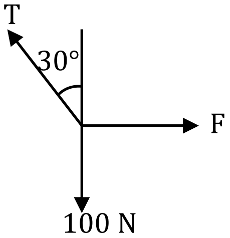
6. A rigid ball of weight 100 N is suspended with the help of a string. The ball is pulled by a horizontal force F such that the string makes an angle of 30° with the vertical. The magnitude of force F (in N) is _________



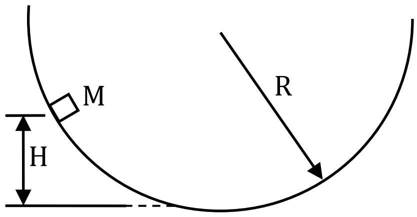
[Ans. *] Range: 55 to 60

$$\frac{T}{\text{Sin } x} = \frac{F}{\text{Sin } (180-30)} = \frac{100}{\sin(90+30)}$$

$\Rightarrow F = 57.735$ N



7. A point mass M is released from rest and slides down a spherical bowl (of radius R) from a height H as shown in the figure below. The surface of the bowl is smooth (no friction). The velocity of the mass at the bottom of the bowl is



(A) $\sqrt{gH}$

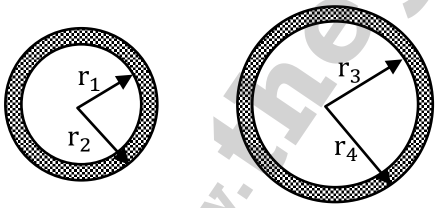
(B) $\sqrt{2gR}$

(C) $\sqrt{2gH}$

(D) 0

[Ans. C]

8. The cross sections of two hollow bars made of the same material are concentric circles as shown in the figure. It is given that $r_3 > r_1$ and $r_4 > r_2$, and that the areas of the cross-sections are the same. J_1 and J_2 are the torsional rigidities of the bars on the left and right, respectively. The ratio J_2/J_1 is



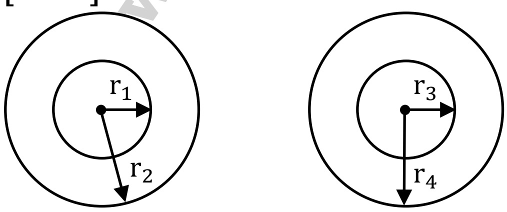
(A) > 1

(B) < 0.5

(C) $=1$

(D) between 0.5 and 1

[Ans. A]



$r_3 > r_1$ & $r_4 > r_2$

Given areas are same hence

$(r_2^2 - r_1^2) = (4_4^2 - r_3^2)$ ………. ①

torsion rigidity = G3

Here both are same material hence $G_1 = G_2$

$$\left(\frac{J_2}{J_1}\right) = \frac{\pi(r_4^4 - r_3^4)/2}{\pi(r_2^4 - r_1^4)/2} = \left(\frac{r_4^4 - r_3^4}{r_2^4 - r_1^4}\right)$$

$$= \frac{(r_4^2 + r_3^2)\,(r_4^2 - r_3^2)}{(r_2^4 + r_1^2)\,(r_2^2 + r_1^2)} \text{ from } \textcircled{1}$$

$$= \left(\frac{r_4^2 + r_3^2}{r_2^2 + r_1^2}\right) > 1$$

9. A cantilever beam having square cross-section of side a is subjected to an end load. If a is increased by 19%, the tip deflection decreases approximately by

(A) 19%
(B) 29%
(C) 41%
(D) 50%

[Ans. D]

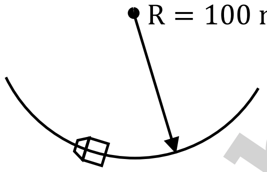
$$\delta_1 = \frac{Pl^3}{3EI}$$

$$\frac{\delta_2}{\delta_1} = \frac{(a^4/12)}{\left(\frac{(1.19a)^4}{12}\right)} = \frac{1}{(1.19)^4} = 0.5$$

$\delta_2 = 0.5(\delta_1)$; δ_2 reduced by 50%

10. A car is moving on a curved horizontal road of radius 100 m with a speed of 20 m/s. The rotating masses of the engine have an angular speed of 100 rad/s in clockwise direction when viewed from the front of the car. The combined moment of inertia of the rotating masses is 10 kg-m^2. The magnitude of the gyroscopic moment (in N-m) is _________

[Ans. *] Range: 199 to 201



Given that, $I = 10\text{ kg} - m^2$, $R = 100$ m

Angular velocity $\omega = 100$ rad/s, $V = 20$ m/s

Angular velocity of precision, $\omega_p = \frac{V}{R} = \frac{20}{100} = 0.2$

Magnitude of Gyroscopic moment is given by,

$C = I\omega\omega_p = 10 \times 100 \times 0.2 = 200$ N-m

11. A single degree of freedom spring mass system with viscous damping has a spring constant of 10 kN/m. The system is excited by a sinusoidal force of amplitude 100 N. If the damping factor (ratio) is 0.25, the amplitude of steady state oscillation at resonance is _______mm.

[Ans. *] Range: 19.9 to 20.1

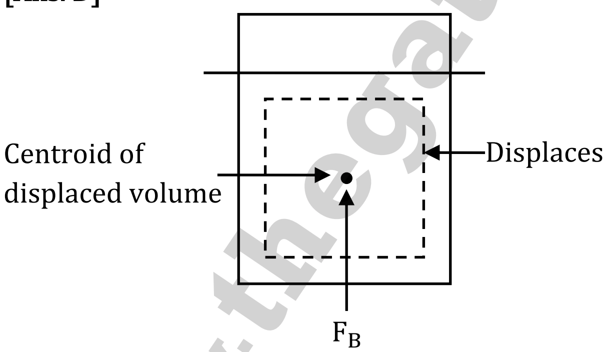
$$M.F = \frac{A}{F_o/k} = \frac{L}{\sqrt{\left[1 - \left(\frac{\omega}{\omega_n}\right)^2\right]^2 + \left(2\xi\frac{\omega}{\omega_n}\right)^2}}$$

$$\Rightarrow A = \frac{100}{10 \times 10^3 (2 \times 0.25)} = \frac{100}{5000} = 20 \text{ mm}$$

12. The spring constant of a helical compression spring DOES NOT depend on
(A) coil diameter
(B) material strength
(C) number of active turns
(D) wire diamete
[Ans. B]

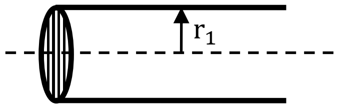
13. The instantaneous stream-wise velocity of a turbulent flow is given as follows:
$u(x, y, z, t) = \bar{u}(x, y, z) + u'S(x, y, z, t)$
The time-average of the fluctuating velocity $u'S(x, y, z, t)$is
(A) $u'/2$
(B) $-\bar{u}/2$
(C) zero
(D) $\bar{u}/2$
[Ans. C]
Given that, instantaneous velocity,
$u(x, y, z, t) = \bar{u}(x, y, z) + u'(x, y, z, t)$
Then, the time average for fluctuating velocity $u'(x, y, z, t) = 0$

14. For a floating body, buoyant force acts at the
(A) centroid of the floating body
(B) center of gravity of the body
(C) centroid of the fluid vertically below the body
(D) centroid of the displaced fluid
[Ans. D]



Buoyancy force is the force due to displaced volume of water. Hence, buoyancy force always acts on the centroid of displaced volume.

15. A plastic sleeve of outer radius $r_0 = 1$ mm covers a wire (radius $r = 0.5$ mm) carrying electric current. Thermal conductivity of the plastic is 0.15 W/m-K. The heat transfer coefficient on the outer surface of the sleeve exposed to air is 25 W/m^2-K. Due to the addition of the plastic cover, the heat transfer from the wire to the ambient will
(A) increase
(B) remain the same
(C) decrease
(D) be zero
[Ans. A]



Given that, $K_{inx} = 0.15 \frac{w}{m-k}$

$r = 0.5$ mm, $r_o = 1$ mm

And $h_o = 25 \frac{w}{m^2 - k}$

Given, the wire is like a cylinder. Hence, critical radius of insulation is

$rc = \frac{K_{ins}}{h_o} = \frac{0.15}{25} = 6 \times 10^{-3}$m

Or, $r_c = 6 \text{ mm} > r_o$

Now if we add insulation (plastic cover), the heat transfer will increase.

16. Which of the following statements are TRUE with respect to heat and work?
(i) They are boundary phenomena
(ii) They are exact differentials
(iii) They are path functions
(A) both (i) and(ii)
(B) both (i) and (iii)
(C) both (ii) and (iii)
(D) only (iii)

[Ans. B]

Since, Heat and work are the path function and these are not the property of system. Hence exact different of Heat and work will not be zero. So, Heat and Work are the inexact differential.

Also, heat and work are the energy in transit or boundary phenomena.

17. Propane (C_3H_8) is burned in an oxygen atmosphere with 10% deficit oxygen with respect to the stoichiometric requirement. Assuming no hydrocarbons in the products, the volume percentage of CO in the products is ________

[Ans. *] Range: 13.7 to 14.9

18. Consider two hydraulic turbines having identical specific speed and effective head at the inlet. If the speed ratio (N_1/N_2) of the two turbines is 2, then the respective power ratio (P_1/P_2) is _______

[Ans. *] Range: 0.24 to 0.26

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

$$N_{s1} = \frac{N_1\sqrt{P_1}}{H_1^{5/4}}$$

$$N_{s2} = \frac{N_2\sqrt{P_2}}{H_2^{5/4}}$$

$\because N_{s1} = N_{s2}$

$H_1 = H_2$

$$\frac{N_{s1}}{N_{s2}} = \frac{N_1\sqrt{P_1}}{N_2\sqrt{P_2}}$$

$$\Rightarrow \frac{\sqrt{P_2}}{\sqrt{P_1}} = \frac{N_1}{N_2} = 2$$

$$\therefore \frac{\sqrt{P_2}}{\sqrt{P_1}} = 2$$

$$\frac{P_2}{P_1} = 4$$

$$\therefore \frac{P_1}{P_2} = \frac{1}{4} = 0.25$$

19. The INCORRECT statement about regeneration in vapor power cycle is that
   (A) it increases the irreversibility by adding the liquid with higher energy content to the steam generator
   (B) heat is exchanged between the expanding fluid in the turbine and the compressed fluid before heat addition
   (C) the principle is similar to the principle of Stirling gas cycle
   (D) it is practically implemented by providing feed water heaters

   [Ans. A]

20. The "Jominy test" is used to find
   (A) Young's modulus
   (B) hardenability
   (C) yield strength
   (D) thermal conductivity

   [Ans. B]

   Jominy Test measures the hardenability of the steels

21. Under optimal conditions of the process the temperatures experienced by a copper work piece in fusion welding, brazing and soldering are such that
   (A) $T_{welding} > T_{soldering} > T_{brazing}$
   (B) $T_{soldering} > T_{welding} > T_{brazing}$
   (C) $T_{brazing} > T_{welding} > T_{soldering}$
   (D) $T_{welding} > T_{brazing} > T_{soldering}$

   [Ans. D]

   Under the optimal conditions temperature of different processes experienced by a copper work piece is given by

   $T_{welding} > T_{brazing} > T_{soldering}$

22. The part of a gating system which regulates the rate of pouring of molten metal is
   (A) pouring basin
   (B) runner
   (C) choke
   (D) ingate

   [Ans. C]

   Rate of poring molten metal is regulated by choke. As, the choke area is the minimum area of the gating system, which decide the gating will be pressurized and unpressurised [Or turbulence will occur or not]. Hence, choke is the part which regulates the rate of pouring.

23. The non-traditional machining process that essentially requires vacuum is
(A) electron beam machining
(B) electro chemical machining
(C) electro chemical discharge machining
(D) electro discharge machining
[Ans. A]
In electron- beam machining, vacuum conditions are created/required for material removal, because electrons move efficiently in vacuum.

24. In an orthogonal cutting process the tool used has rake angle of zero degree. The measured cutting force and thrust force are 500 N and 250 N, respectively. The coefficient of friction between the tool and the chip is ________
[Ans. *] Range 0.49 to 0.51
Coefficient of friction $= \frac{F}{N} = \frac{250}{500} = 0.5$

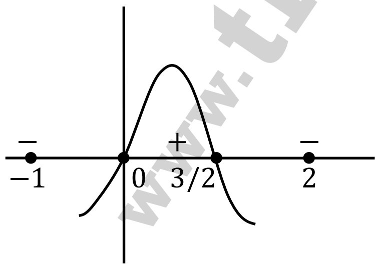
25. Match the following:

P. Feeler gauge	I. Radius of an object
Q. Fillet gauge	II. Diameter within limits by comparison
R. Snap gauge	III. Clearance or gap between components
S. Cylindrical plug gauge	IV. Inside diameter of straight hole

(A) P–III, Q–I, R–II, S–IV
(B) P–III, Q–II, R–I, S–IV
(C) P–IV, Q–II, R–I, S–III
(D) P–IV, Q–I, R–II, S–III
[Ans. A]

Q.26 - Q.55 Carry Two Marks each.

26. Consider the function $f(x) = 2x^3 - 3x^2$ in the domain $[-1, 2]$. The global minimum of f(x)is ________
[Ans. *] Range: -5.1 to -4.9
$f(x) = 2x^3 - 3x^2$
$= x^2(2x - 3)$



From the curve, the minimum value of function will lie at -1 or 2.
Then,
$f(-1) = 2(-1)^3 - 3(-1)^2 = -5$
$f(2) = 2(2)^3 - 3(2)^2 = 4$
Hence, global minimum value of f(x) is -5

27. If $y = f(x)$ satisfies the boundary value problem $y'' + 9y = 0, y\,0 = 0, y\,(\pi/2) = \sqrt{2}$, then $y\,(\pi/4)$ is ________

[Ans. *] Range: -1.05 to -0.95

Given that, $y(0) = 0, y\left(\frac{\pi}{2}\right) = \sqrt{2}$

And $y'' + 9y = 0$

The auxiliary equation of the given problem is

$m^2 + 9 = 0 \Rightarrow m = \pm 3i$

Hence, the General solution of the problem is,

$y = C_1 \cos 3x + C_2 \sin 3x$ ……… . ①

Now, applying boundary conditions on the above equations,

At $x = 0, y = 0$ (1)

Then, $0 = C_1 \cos(0) + C_2 \sin(0)$

$\Rightarrow C_1 = 0$

So, $y = C_2 \sin 3x$

Now applying another boundary condition,

$y = \sqrt{2}$ at $x = \pi$

$\Rightarrow \sqrt{2} = C_2 \sin\left(\frac{3\pi}{2}\right) \Rightarrow C_2 = -\sqrt{2}$

Hence, the solution of the problem is

$Y = \sqrt{-2} \sin 3x$

Now at $x = \frac{\pi}{4}$

$\Rightarrow y = -\sqrt{2} \sin\left(3 \times \frac{\pi}{4}\right) - \sqrt{2} \times \frac{1}{\sqrt{2}}$

$\Rightarrow y = -1$

28. The value of the integral

$$\int_{-\infty}^{\infty} \frac{\sin x}{x^2 + 2x + 2} dx$$

Evaluated using contour integration and the residue theorem is

(A) $-\pi \sin(1)/e$

(B) $-\pi \cos(1)/e$

(C) $\sin(1)/e$

(D) $\cos(1)/e$

[Ans. A]

29. Gauss-Seidel method is used to solve the following equations (as per the given order):

$x_1 + 2x_2 + 3x_3 = 5$

$2x_1 + 3x_2 + x_3 = 1$

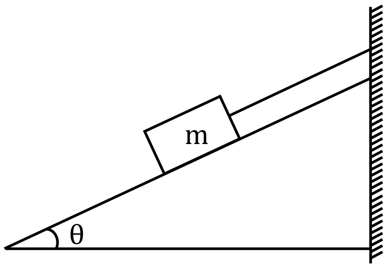
$3x_1 + 2x_2 + x_3 = 3$

Assuming initial guess as $x_1 = x_2 = x_3 = 0$, the value of x_3 after the first iteration is ________

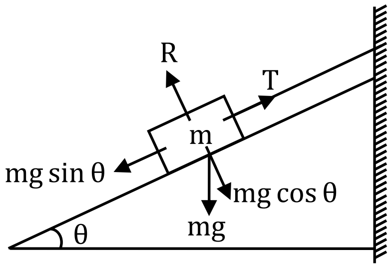
[Ans. *] Range: -6 to -6

30. A block of mass m rests on an inclined plane and is attached by a string to the wall as shown in the figure. The coefficient of static friction between the plane and the block is 0.25. The string

can withstand a maximum force of 20 N. The maximum value of the mass (m) for which the string will not break and the block will be in static equilibrium is ___________ kg.
Take $\cos\theta = 0.8$ and $\sin\theta = 0.6$.
Acceleration due to gravity $g = 10 \text{ m/s}^2$



[Ans. *] Range: 4.95 to 5.05



$T + \mu R = mg\sin\theta \ldots\ldots\ldots (1)$

$R = mg\cos\theta \ldots\ldots\ldots (2)$

$\therefore T + \mu(mg\cos\theta) = mg\sin\theta$

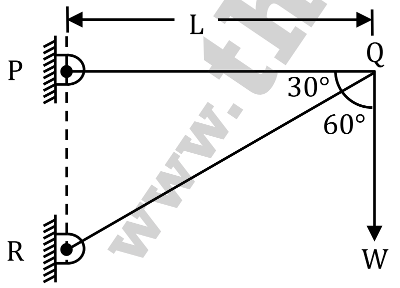
$T + 0.25 \times m \times 10 \times 0.8 = m \times 10 \times 0.6$

$T = 6\text{ m} - 2\text{ m} = 4\text{ m}$

$T = 20\text{ N} \Rightarrow 20 = 4\text{ m}$

$\therefore m = \frac{20}{4} = 5\text{ kg}$

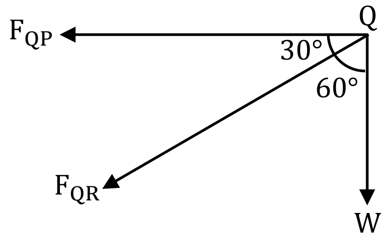
31. A two-member truss PQR is supporting a load W. The axial forces in members PQ and QR are respectively



(A) 2W tensile and 3W compressive
(B) 3W tensile and 2W compressive
(C) 3W compressive and 2W tensile
(D) 2W compressive and 3W tensile

[Ans. B]

FBD for the point Q is given by,

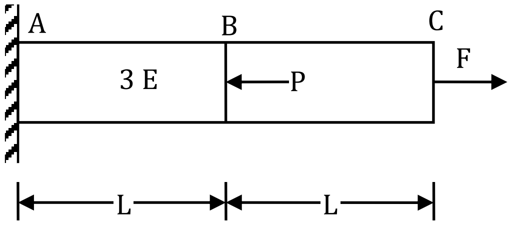


From the diagram, $F_{QR}\cos 60 + W = 0$; $F_{QR} = -2W$

$\Rightarrow F_{QP} = 2W$ (compressive); $\Rightarrow F_{QP} = -2W\cos 30° = -\sqrt{3}\,W$

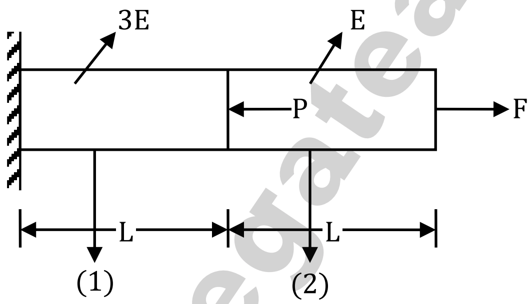
Then FPQ $= \sqrt{3}W$ (Tensile)

32. A horizontal bar with a constant cross-section is subjected to loading as shown in the figure. The Young's moduli for the sections AB and BC are 3E and E, respectively.



For the deflection at C to be zero, the ratio P/F is ________

[Ans. *] Range 3.9 to 4.1



$b - a = P$

$b = F$

$\Rightarrow a = b - P = F - P$

Deflection at 'c' $\dfrac{aL^3}{(3E)\times I} + \dfrac{bL^3}{EI} = 0$

$\Rightarrow \dfrac{(F-P)L^3}{3EI} + \dfrac{FL^3}{EI} = 0$

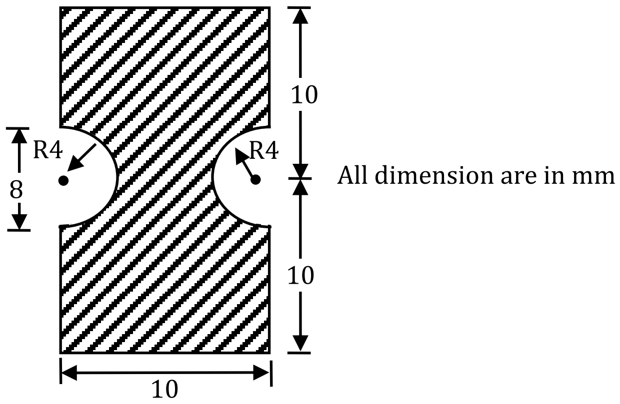
$\Rightarrow \left(\dfrac{F-P}{3}\right) + F = 0$

$\Rightarrow F - P + 3F = 0$

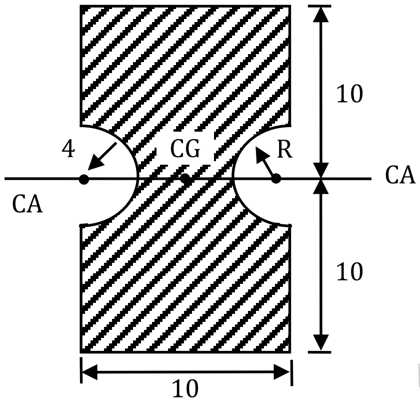
$\Rightarrow 4F - P = 0$

$\Rightarrow \left(\dfrac{P}{F}\right) = 4$

33. The figure shows cross-section of a beam subjected to bending. The area moment of inertia (in mm^4) of this cross-section about its base is ________



[Ans. *] Range: 1873 to 1879



Area moment of inertia @ centroidal axis is given by

$I_{CA} = [\text{I of rectangle @CA} - \text{I of circle of radius 4 @CA}]$

$$I_{CA} = \frac{10 \times 10^3}{12} - \left(\frac{\pi}{64} \times 8^4\right)$$

and are moment of inertial about base

$I_{base} = [I_{rect}@CA + A_1 r_1^2] - [I_{circle}@\,CA + A_2 r_2^2]$

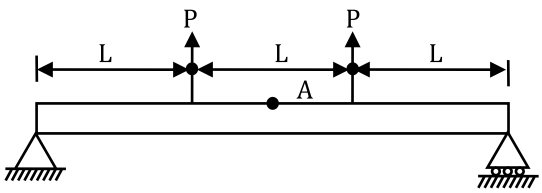
$A_1, A_2 \Rightarrow$ Area of rectangle and circle

$r_1, r_2 \Rightarrow$ distance from base of rectangle to centroid of rectangle and circle

$$\text{Then, } I_{base} = \frac{10 \times 10^3}{12} + (10 \times 10 \times 5^2) - \left[\frac{\pi}{64} \times 8^4 + \frac{\pi}{4} \times 8^2 \times 5^2\right]$$

$I_{base} = 1875.634\ mm^4$

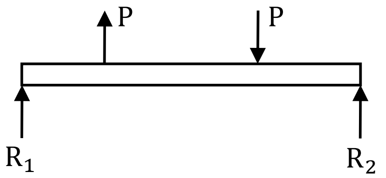
34. A simply-supported beam of length 3L is subjected to the loading shown in the figure.



It is given that P = 1 N, L = 1 m and Young's modulus E = 200 GPa. The cross-section is a square with dimension 10 mm × 10 mm. The bending stress (in Pa) at the point A located at the top surface of the beam at a distance of 1.5L from the left end is __________

(Indicate compressive stress by a negative sign and tensile stress by a positive sign.)

[Ans. *] Range −1 to 1



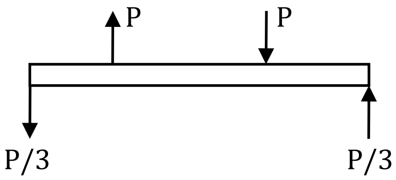
$R_1 + R_2 + P = P \Rightarrow R_1 + R_2 = 0$

$PL - P(2L) + R_2(3L) = 0$

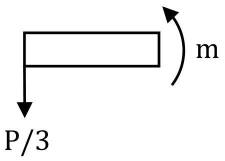
$-PL + R_2(3L) = 0$

$\Rightarrow R_2 = \frac{P}{3}$

$\Rightarrow R_1 = -\frac{P}{3}$

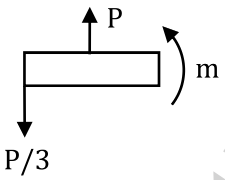


For $x \in [0, L)$



$m + \frac{P}{3}x = 0;\ m = -\frac{P}{3}x$

For $x \in [L, 2L)$



$m + \frac{P}{3}x - P(x - L) = 0$

$m - \frac{2Px}{3} + PL = 0$

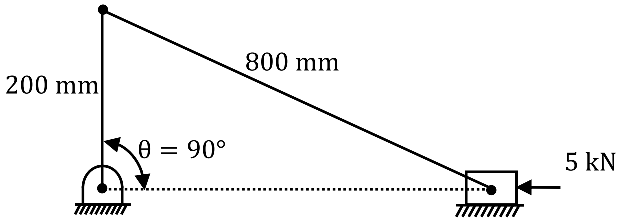
$m = \frac{2Px}{3} - PL$

$\text{at } x = \frac{3L}{2}, m = \frac{2P}{3} \times \frac{3L}{2} - PL$

$m = 0$

35. A slider crank mechanism with crank radius 200 mm and connecting rod length 800 mm is shown. The crank is rotating at 600 rpm in the counterclockwise direction. In the configuration shown, the crank makes an angle of 90° with the sliding direction of the slider,

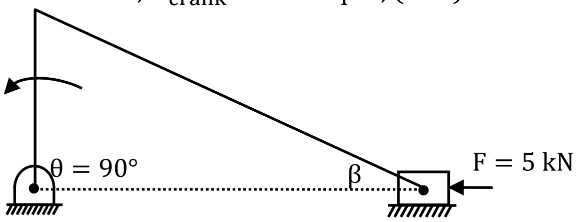
and a force of 5 kN is acting on the slider. Neglecting the inertia forces, the turning moment on the crank (in kN-m) is ________



[Ans. *] Range: 0.9 to 1.1

Given that, $r = 200$ mm

$l = 80$ mm, $N_{crank} = 600$ rpm, (ccw)



Obliquity ratio, $n = \frac{l}{r} = \frac{800}{200} = 4$

And, $\sin\beta = \frac{\sin\theta}{n} = \frac{1}{4}$

$\Rightarrow \beta = \sin^{-1}\left(\frac{1}{3}\right) = 19.4775$

Thrust force F_t

$F_t = \frac{F}{\cos\beta}\sin(\theta + \beta)$

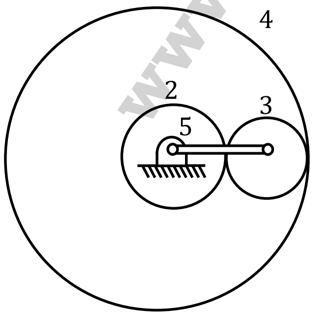
$\Rightarrow F_t = \frac{5}{\cos(19.4775)} \times \sin(90 + 19.4775)$

$= F_t = 5$ kN

Now, turning moment. $T = F_t \times r = 5 \times 200 \times 10^{-3}$

$\Rightarrow T = 1$kN- m.

36. In the gear train shown, gear 3 is carried on arm 5. Gear 3 meshes with gear 2 and gear 4. The number of teeth on gear 2, 3, and 4 are 60, 20, and 100, respectively. If gear 2 is fixed and gear 4 rotates with an angular velocity of 100 rpm in the counterclockwise direction, the angular speed of arm 5 (in rpm) is



(A) 166.7 counterclockwise
(B) 166.7 clockwise
(C) 62.5 counterclockwise
(D) 62.5 clockwise

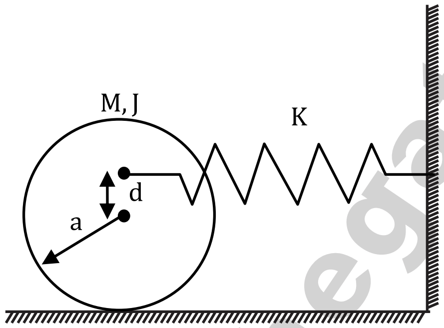
[Ans. C]

Given (taking CW as positive)
$T_2 = 60, T_3 = 20, T_4 = 100$
$N_2 = 0, N_4 = -100, N_5 = ?$

Condition	Arm or 5	Gear 2	Gear 3	Gear 4
If Arm-fixed and gear 2 is given + x rev.	0	x	$-x\frac{T_2}{T_3}$	$-x\frac{T_2}{T_4}$
Total motion if Arm is given +y rev.	y	x+y	$-x\frac{T_2}{T_3}+y$	$-x\frac{T_2}{T_4}+y$

Given $N_2 = 0 = x + y$ ……(1)
And $N_4 = -100 = -x\frac{T_2}{T_4} + y$
$\Rightarrow -x\left(\frac{60}{100}\right) + y = -100$
$\Rightarrow -3x + 5y = -500$ …..(2)
From equation 1 and 2, we get
$y = -62.5$ and $x = 62.5$
then, $N_{arm} = y = -62.5$
or $N_{arm} = 62.5$ ccw.

37. A solid disc with radius a is connected to a spring at a point d above the center of the disc. The other end of the spring is fixed to the vertical wall. The disc is free to roll without slipping on the ground. The mass of the disc is M and the spring constant is K. The polar moment of inertia for the disc about its centre is $J = Ma^2/2$.



The natural frequency of this system in rad/s is given by

(A) $\sqrt{\frac{2K(a+d)^2}{3Ma^2}}$

(B) $\sqrt{\frac{2K}{3M}}$

(C) $\sqrt{\frac{2K(a+d)^2}{Ma^2}}$

(D) $\sqrt{\frac{K(a+d)^2}{Ma^2}}$

[Ans. A]

38. The principal stresses at a point inside a solid object are $\sigma_1 = 100$ MPa, $\sigma_2 = 100$ MPa and $\sigma_3 = 0$ MPa. The yield strength of the material is 200 MPa. The factor of safety calculated using Tresca (maximum shear stress) theory is n_T and the factor of safety calculated using von Mises (maximum distortional energy) theory is n_V. Which one of the following relations is TRUE?

(A) $n_T = (\sqrt{3}/2)n_V$

(B) $n_T = (\sqrt{3})n_V$

(C) $n_T = n_V$

(D) $n_V = (\sqrt{3})n_T$

[Ans. C]

Given $\sigma_1 = 100$ MPa

$\sigma_2 = 100$ MPa

$\sigma_3 = 0$

$s_{yt} = 200$ MPa

FOS by Tresca $= h_T$

FOS by Von mises $= n_y$

Tresca:

$$\left(\frac{s_{yt}}{h_T}\right) = \text{max. of}[(\sigma_1 - \sigma_2), (\sigma_2 - \sigma_3), (\sigma_1 - \sigma_3)]$$

$$\frac{s_{yt}}{h_T} = 100$$

$$\Rightarrow h_T = \frac{200}{100} = 2$$

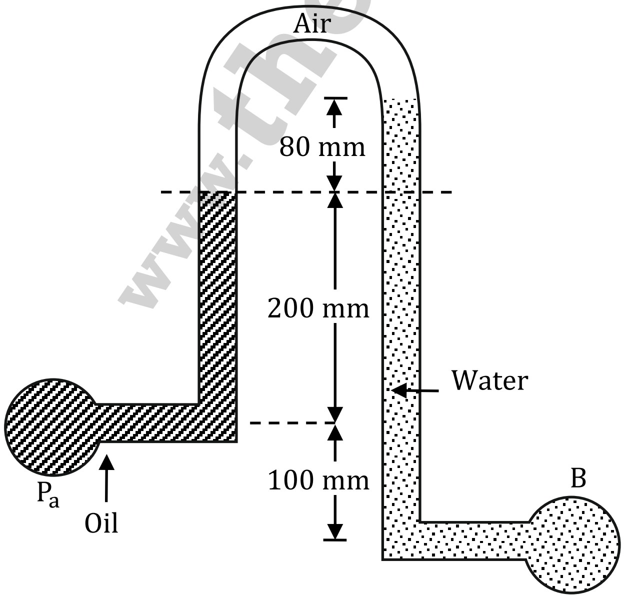
Von mises:

$$\frac{s_{yt}}{h_T} = \sqrt{\frac{1}{2}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]}$$

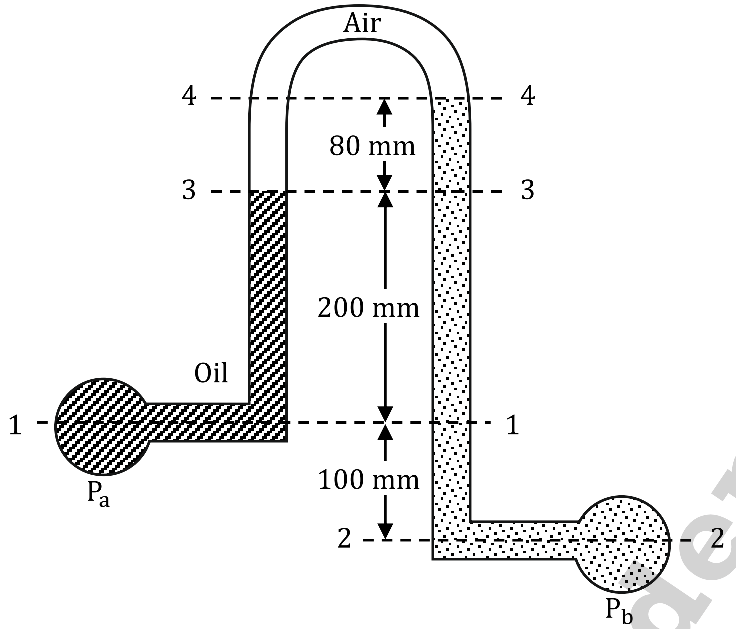
$$\frac{200}{h_T} = \sqrt{\frac{1}{2}[0^2 + 100^2 + 100^2]}$$

$$\frac{200}{h_T} = 100 \Rightarrow h_T = 2$$

39. An inverted U-tube manometer is used to measure the pressure difference between two pipes A and B, as shown in the figure. Pipe A is carrying oil (specific gravity = 0.8) and pipe B is carrying water. The densities of air and water are 1.16 kg/m^3 and 1000 kg/m^3, respectively. The pressure difference between pipes A and B is ________kPa.
Acceleration due to gravity $g = 10$ m/s^2.



[Ans. *] Range: −2.21 to − 2.19; 2.19 to 2.21



Given that $S_{oil} = 0.8, \rho_{oil} = 800 kg/m^3$

Applying the pascal's law at manometric section $4 - 4$,

$PA - \rho g w_{oil} - \rho_{air} g H_{air} = P_B - \rho_{water} g H_{water}$

$\Rightarrow P_A - 800 \times 10 \times 200 \times 10^{-3} - 1.16 \times 10 \times 80 \times 10^{-3} = P_B - 1000 \times 10 \times 380 \times 10^{-3}$

$\Rightarrow |P_A - P_B| = 2199.072\ N/m^2$

$\Rightarrow |P_A - P_B| = 2.199\ kPa$

40. Oil (kinematic vicosty, $\nu_{oil} = 1 \times 10^{-5}\ m^2/s$) flow through a pipe diameter with a velocity of 10 m/s $\nu_{\omega} = 0.89 \times 10^{-6}\ m^2/s$) diameter flowing through a model pipe of diameter 10 mm for satisfying the dynamic similarity, the velocity of water (in m/s) is ________

[Ans. *] Range: 22.0 to 22.5

$Re_{oil} = Re_{water}$

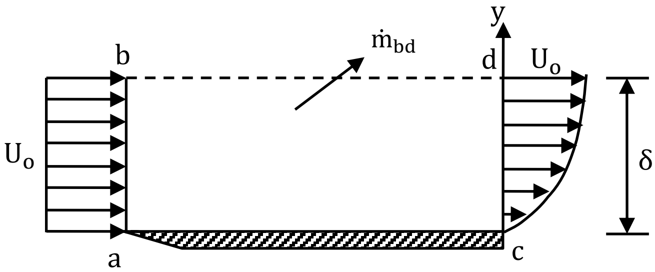
$$\Rightarrow \left(\frac{VD}{u}\right)_{oil} = \left(\frac{VD}{u}\right)_{water}$$

$$\Rightarrow \frac{10 \times 0.5}{1.0 \times 10^{-5}} = \frac{V_{water} \times 20/1000}{0.89 \times 10^{-6}}$$

$$\Rightarrow 500000 = \frac{V_{water} \times 20}{1000 \times 0.89 \times 10^{-6}}$$

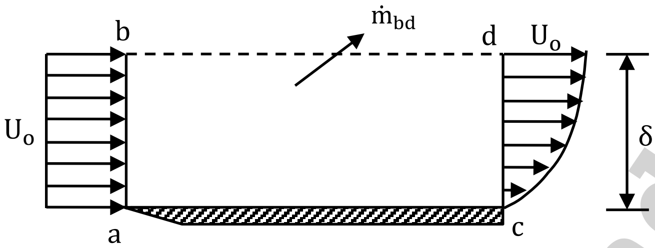
$V_{water} = 22.25\ m/s$

41. A steady laminar boundary layer is formed over a flat plate as shown in the figure. The free stream velocity of the fluid is U_o. The velocity profile at the inlet a-b is uniform, while that at a downstream location c-d is given by $u = U_o\left[2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2\right]$.



The ratio of the mass flow rate, *m b*, leaving through the horizontal section b-d to that entering through the vertical section a-b is ________

[Ans. *] Range: 0.32 to 0.34



$$\frac{\dot{m}_{bd}}{\dot{m}_{ab}} = \frac{1}{3}$$

$$\dot{m}_{ab} = \int_0^{\delta} \delta\, V_o\, dy = \delta V_o \delta$$

$$\dot{m}_{bd} = \int_0^{\delta} \delta\, u\, dy = \int_0^{\delta} \delta V_o \left[2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2\right] dy$$

$$= \int_0^{\delta} \delta V_o \left[2\frac{y^2}{2\delta} - \frac{y^3}{3\delta^2}\right]_0^{\delta}$$

$$= \delta V_o \left[\frac{2\delta^2}{2\delta} - \frac{\delta^3}{3\delta^2}\right] = \delta V_o \left[\delta - \frac{1}{3}\delta\right]$$

$$= \delta V_o \delta \times \frac{2}{3}$$

$$\dot{m}_{ab} > \dot{m}_{cd}$$

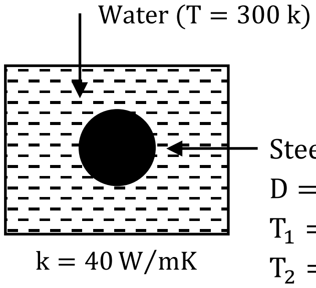
$$\dot{m}_{ab} = \dot{m}_{bd} + \dot{m}_{cd}, \Rightarrow 1 = \frac{\dot{m}_{bd}}{\dot{m}_{ab}} + \frac{\dot{m}_{cd}}{\dot{m}_{ab}}$$

$$\Rightarrow \frac{\dot{m}_{cd}}{\dot{m}_{ab}} = \frac{\dot{m}_{bd}}{\dot{m}_{ab}}$$

$$\therefore \frac{\dot{m}_{bd}}{\dot{m}_{ab}} = -\frac{\delta V_o \delta \times \frac{2}{3}}{\delta V_o \delta} = \frac{1}{3}$$

42. A steel ball of 10 mm diameter at 1000 K is required to be cooled to 350 K by immersing it in a water environment at 300 K. The convective heat transfer coefficient is 1000 W/m^2- K. Thermal conductivity of steel is 40 W/m-K. The time constant for the cooling process τ is 16 s. The time required (in s) to reach the final temperature is ________

[Ans. *] Range: 42.0 to 42.5



$D = 10$ mm
$T_1 = 1000$ K
$T_2 = 350$ K
$h = 100\ W/m^2K$

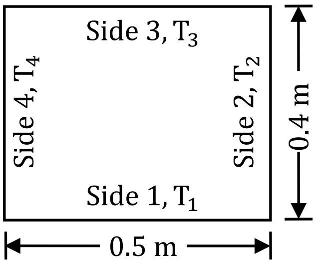
From the transient heat condition equation,

$$\frac{T - T_\infty}{T_i - T_\infty} = e^{-\frac{\tau}{\tau_{th}}}$$

$$\frac{350 - 300}{1000 - 300} = e^{-\frac{\tau}{16}}$$

$\Rightarrow \tau_{th} = 42.225$sec

43. An infinitely long furnace of $0.5\ m \times 0.4\ m$ cross-section is shown in the figure below. Consider all surfaces of the furnace to be black. The top and bottom walls are maintained at temperature $T_1 = T_3 = 927°C$ while the side walls are at temperature $T_2 = T_4 = 527°C$. The view factor, F1-2 is 0.26. The net radiation heat loss or gain on side 1 is________ W/m.
Stefan-Boltzmann constant $= 5.67 \times 10^{-8}\ W/m^2\text{-}K^4$



[Ans. *] Range: 24528 to 24532

Given, $\sigma = 5.67 \times 10^{-8} \frac{N}{m^2K^4}$

$T_1 = T_3 = 927 + 273 = 1200$ K
$T_2 = T_4 = 527 + 273 = 800$ K
$F_{1-2} = 0.25$

Radiation heat or change,

$Q = Q_{1-2} + Q_{1-3} + Q_{1-4}$

$\sigma A_1 F_{1-2}(T_1^4 - T_2^4) + \sigma A_1 F_{1-3}(T_1^4 - T_4^3) + \sigma A_1 F_{1-4}(T_1^4 - T_4^4)$

Since, $T_1 = T_3$
$T_2 = T_4$
$F_{1-2} = F_{1-4} = 0.26$

$Q = 2\sigma A_1 F_{1-2}(T_1^4 - T_2^4)$ ... (1)

$Q = 2 \times 5.67 \times 10^{-8} \times 0.5 \times 1 \times 0.26 \times (1200^4 - 800^4)$

$\Rightarrow Q = 24530.668 \frac{W}{m}$

44. A fluid (Prandtl number, Pr = 1) at 500 K flows over a flat plate of 1.5 m length, maintained at 300 K. The velocity of the fluid is 10 m/s. Assuming kinematic viscosity, $\nu = 30 \times 10 - 6\ m^2/s$, the thermal boundary layer thickness (in mm) at 0.5 m from the leading edge is ________

[Ans. *] Range 6.00 to 6.25

$Pr = 3$

$T_\infty = 500\ k$

$6 = 1.5\ m$

$T_3 = 300\ k, x = 0.5\ m$

$V = 10\ m/s$

$v = 30 \times 10^6\ m^2/s$

$$Re = \frac{VL}{v} = \frac{10 \times 1.5}{30 \times 10^{-6}} = 5 \times 10^5$$

Laminar flow

$$\frac{s}{x} = \frac{5}{\sqrt{Re_x}}$$

$$Re_x = \frac{Vx}{v} = \frac{10 \times 0.5}{30 \times 10^{-6}} = 166666.67$$

$$\therefore \delta = \frac{5x}{\sqrt{166666.67}} = \frac{5 \times 0.5}{\sqrt{166666.67}} = 0.00612\ m$$

$$\frac{\delta_{th}}{S} = (P_r)^{-1/3}$$

$$S_{th} = \delta = 0.00612\ m = 6.12\ mm$$

45. F or water at 25°C, $dp_s/dT_s = 0.189\ kPa/K$ (p_s is the saturation pressure in kPa and T_s is the saturation temperature in K) and the specific volume of dry saturated vapour is $43.38\ m^3/kg$. Assume that the specific volume of liquid is negligible in comparison with that of vapour. Using the Clausius-Clapeyron equation, an estimate of the enthalpy of evaporation of water at 25°C (in kJ/kg) is ________

[Ans. *] Range: 2400 to 2500

$$\frac{dP}{dT_G} = \frac{dfg}{T_B(V_g.V_f)} \Rightarrow 0.189 = \frac{hfg}{(23+273)(43.38-0)} \Rightarrow dfy = 2443.248\ kJ/kg$$

46. An ideal gas undergoes a reversible process in which the pressure varies linearly with volume. The conditions at the start (subscript 1) and at the end (subscript 2) of the process with usual notation are: $p_1 = 100$ kPa, $V_1 = 0.2\ m^3$ and $p_2 = 200$ kPa, $V2 = 0.1\ m^3$ and the gas constant, R = 0.275 kJ/kg-K. The magnitude of the work required for the process (in kJ) is _______

[Ans. *] Range 14.75 to 15.25

$$W_2 = \frac{1}{2}(P_1 + P_2)(V_2 - V_1)$$

$$= \frac{1}{2}(100 + 200)(0.2 - 0.1) = 15\ kJ$$

47. I n a steam power plant operating on an ideal Rankine cycle, superheated steam enters the turbine at 3 MPa and 350°C. The condenser pressure is 75 kPa. The thermal efficiency of the cycle is _______ percent.

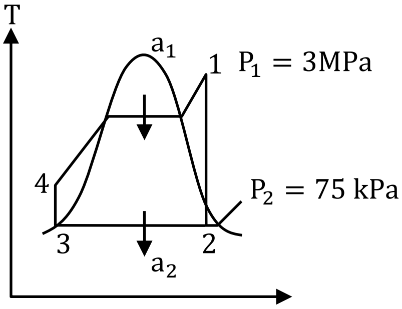
Given data:

For saturated liquid, at P = 75 kPa, $h_f = 384.39$ kJ/kg, $v_f = 0.001037\ m^3/kg$, $s_f = 1.213$ kJ/kg- K

At 75 kPa, $h_{fg} = 2278.6$ kJ/kg, $s_{fg} = 6.2434$ kJ/kg- K

At P = 3 MPa and T = 350°C [Superheated steam], h = 3115.3kJ/kg, s = 6.7428 kJ/kg- K

[Ans. *] Range 25.8 to 26.1



$$\eta = \frac{w_{net}}{Q_3} = \frac{(h_1 - h_2) - (h_4 - h_3)}{(h_1 - h_4)} = \frac{(3115.3 - 2389.558) - (3.033225)}{(3115.3 - 387.423)}$$

$= 0.2649 = 26.49\%$

$\therefore S_1 = S_2$

$\Rightarrow 6.7428 = S_f + x\, S_{fg}$

$\Rightarrow 6.7428 = 1.213 + x \times 6.2434$

$\therefore x = 0.88$

$h_2 = h_f + xh_{fg} = 384.39 + 0.88 \times 2278.6$

$= 2389.558$ kJ/kg

$h_1 = 3115.3$ kJ/kg

$h_3 = 384.39$ kJ/kg

$$\dot{w}_{3-4} = \int_3^4 V_f\, dp$$

$\Rightarrow h_4 - h_3 = 0.001037 \times (3 \times 10^3 - 75)$kJ/kg

$h_4 = 3.033225 + h_3 = 3.033335 + 384.39 = 387.423$ kJ/kg

$W_{net} = W_T - W_P$

$= (h_1 - h_2) - W_P$

$= (3115.3 - 2402.55) - 3.033$

$= 709.72$ kJ/kg

$Q_S = h_1 - h_4$

$= 3115.3 - 387.37$

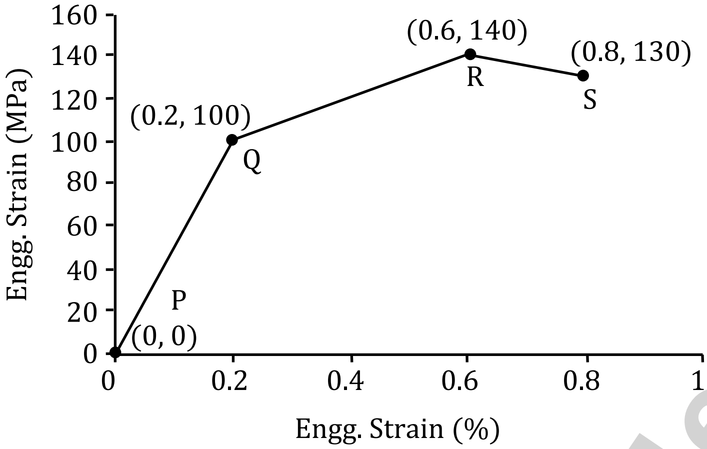
$= 27217.93$ kJ/kg

$$\eta_{th} = \frac{W_{net}}{Q_s}$$

$$= \frac{709.72}{2727.93} \times 100$$

$= 26\%$

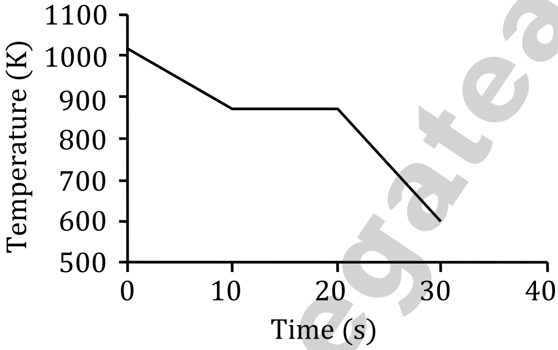
48. A hypothetical engineering stress-strain curve shown in the figure has three straight lines PQ, QR, RS with coordinates P(0,0), Q(0.2,100), R(0.6,140) and S(0.8,130). 'Q' is the yield point, 'R' is the UTS point and 'S' the fracture point.



The toughness of the material [in MJ/m^3] is ________

[Ans. *] Range 0.849 to 0.851

49. H eat is removed from a molten metal of mass 2 kg at a constant rate of 10 kW till it is completely solidified. The cooling curve is shown in the figure.



Assuming uniform temperature throughout the volume of the metal during solidification, the latent heat of fusion of the metal (in kJ/kg) is ________

[Ans. *] Range: 49.9 to 50.1

50. The tool life equation for HSS tool is $VT^{0.14}f^{0.7}d^{0.4}$ = Constant. The tool life (T) of 30 min is obtained using the following cutting conditions:

V = 45 m/min, f = 0.35 mm, d = 2.0 mm

If speed (V), feed (f) and depth of cut (d) are increased individually by 25%, the tool life (in min) is

(A) 0.15
(B) 1.06
(C) 22. 50
(D) 30.0

[Ans. B]

Given tool life equation

$VT^{0.14}\, f^{0.7}\, d^{0.4} = C$

$T_1 = 30$ min

And $V_1 = 45$ m/min , $f_1 = 0.35$ mm, $d_1 = 2.0$ mm

$C = V_1(T_1)^{0.14}(f_1)^{0.7}(d_1)^{0.4}$
$C = 45(30)^{0.14}\,(0.35)^{0.7}(2)^{0.4}$
$= 45.8425$
$V_2(T_2)^{0.14}(f_2)^{0.7}(d_2)^{0.4} = 45.8425$
$(1.25 \times 45)(T_2)^{0.14} \times (1.25 \times 0.35)^{0.7} \times (1.25 \times 2)^{0.4} = 45.8425$
$\Rightarrow T_2 = 1.06$ min

51. A cylindrical job with diameter of 200 mm and height of 100 mm is to be cast using modulus method of riser design. Assume that the bottom surface of cylindrical riser does not contribute as cooling surface. If the diameter of the riser is equal to its height, then the height of the riser [in mm] is

(A) 150
(B) 200
(C) 100
(D) 125

[Ans. A]

$$D = 6 \times \frac{\frac{\pi}{4}(200)^2 \times 100}{2 \times \frac{\pi}{4}(200)^2 + \pi \times 200 \times 100}$$

$$D = H = \frac{6 \times 200 \times 100}{400 + 400}$$

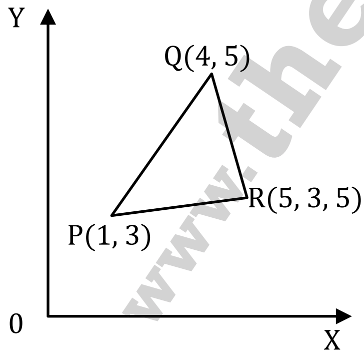
$= 150$

52. A 300 mm thick slab is being cold rolled using roll of 600 mm diameter. If the coefficient of friction is 0.08, the maximum possible reduction (in mm) is ________

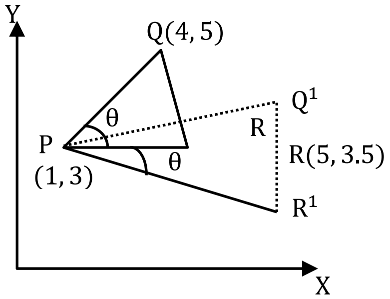
[Ans. *] Range 1.90 to 1.94

$(\Delta h)_{max} = \mu^2 R = (0.08)^2 \times 300 = 1.92$ mm

53. The figure below represents a triangle PQR with initial coordinates of the vertices as P(1,3), Q(4,5) and R(5,3.5). The triangle is rotated in the X-Y plane about the vertex P by angle θ in clockwise direction. If $\sin\theta = 0.6$ and $\cos\theta = 0.8$, the new coordinates of the vertex Q are



[Ans. A]



Since the triangle is rotated in CW direction, hence, for the new point $Q'(x, y)$,
$x > 4$ and $y < 5$ ________(1)
and $PQ = PQ'$ or $QR = Q'R'$
$\Rightarrow \sqrt{(4-1)^2 + (5-3)^2} = \sqrt{(x-1)^2 + (y-3)^2}$
$\Rightarrow (x-1)^2 + (y-3)^2 = 13$ ________(2)
Now we can get the answer easily by checking the option

54. The annual demand for an item is 10,000 units. The unit cost is Rs. 100 and inventory carrying charges are 14.4% of the unit cost per annum. The cost of one procurement is Rs. 2000. The time between two consecutive orders to meet the above demand is ______ month(s).

[Ans. *] Range 1.9 to 2.1

$$Q^A = \sqrt{\frac{2DC_o}{C_h}} = \sqrt{\frac{2 \times 10000 \times 2000}{0.144 \times 100}} = 1666.67 \text{ units}$$

$$Q^A = TD \Rightarrow T = \frac{Q^A}{D} = \frac{1666.67}{10000} = 0.1667 \text{ years}$$

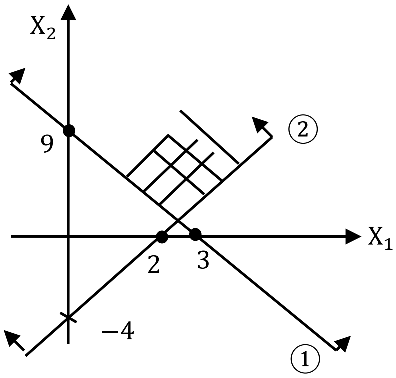
$$= 2 \text{ months}$$

55. Maximize $Z = 15X_1 + 20X_2$
subject to
$12X_1 + 4X_2 \geq 36$
$12X_1 - 6X_2 \leq 24$
$X_1, X_2 \geq 0$
The above linear programming problem has

(A) Infeasible solution
(B) Unbounded solution
(C) Alternative optimum solutions
(D) Degenerate solution

[Ans. B]

Max $z = 15x_1 + 20x_2$
Converting constraints equation, we get
$12x_1 + 4x_2 = 36 \ldots\ldots\ldots$ ①
$12x_1 - 6x_2 = 24 \ldots\ldots\ldots$ ②



We cannot optimize the constraints, as this does not have any bounded region.
Hence, solution is unbounded.