PRE-GATE-2020

Production & Industrial Engineering

(Questions with Detailed Solutions)

GENERAL APTITUDE

Q. 01 – Q. 05 carry One Mark each.

01. Fill in the blank with an appropriate phrase

Jobs are hard to _____ these days

(A) Come by (B) Come down

(C) Come of (D) Come from

01. Ans: (A)

Sol: 'Come by' means to manage to get something.

02. The question below consists of a pair of related words followed by four pairs of words. Select the pair that best expresses the relation in the original pair.

MONKEY : TROOP:

(A) sheep : hard

(B) elephant : Parliament

(C) bacteria : Colony

(D) wolves : School

02. Ans: (C)

Sol: Troop consists of monkeys just as a colony consists of bacteria.

03. ***Choose the most appropriate word from the options given below to complete the following sentence:***

If you had gone to see him, he _______ delighted.

(A) Would have been

(B) Will have been

(C) Had been

(D) Would be

03. Ans: (A)

Ans: 'A" conditional tense type 3 grammatical code is

If +had+V3, would +have+V3

04. Which of the following options is closest in meaning to the underlined word?

European intellectuals have long debated the consequences of the **hegemony** of American popular culture around the world.

(A) regimen (B) vastness

(C) dominance (D) popularity

04. Ans: (C)

Sol: Dominance means influence or control over another country, a group of people etc.

05. How many one-rupee coins, 50 paise coins 25 paise coins in total of which the numbers are proportional to 5, 7 and 12 are together work ₹115?

(A) 50, 70, 120 (B) 60, 70, 110
(C) 70, 80, 90 (D) None of these

05. Ans: (A)

Sol: $(5 \times 1+7\times0.5+12\times0.25)\ x = 115$

$(5+3.5+3)x = 115$

$11.5x = 115 \Rightarrow x = 10$

$\therefore$ Number of one rupee coin = $5x = 5\times10 = 50$

Number of 5-paise coin = $7x = 7\times10 = 70$

Number of 25-paise coin = $12x$

$= 12\times10 = 120$

Q. 6 – Q. 10 carry Two Marks each.

06. Critical reading is a demanding process. To read critically, you must slow down your reading and, with pencil in hand, perform specific operations on the text mark up the text with your reactions, conclusions, and questions, then you read, become an active participant.

This passage best supports the statement that

(A) Critical reading is a slow, dull but essential process.

(B) The best critical reading happens at critical times in a person's life.

(C) Readers should get in the habit of questioning the truth of what they read.

(D) Critical reading requires thoughtful and careful attention.

06. Ans: (D)

Sol: Choice (A) is incorrect because the author never says that reading is dull.

Choice (B) and (C) are not support by the paragraph.

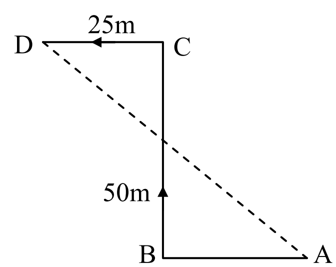
Choice (D) is correct as it is implied in the entire passage.

07. Anil's house faces east from the back-side of the house, he walks straight 50 metres, then turns to the right and walks 50m again finally, he turns towards left and stops after walking 25 m Now Anil is in which direction from the starting point?

(A) South-east (B) South-west
(C) North-east (D) North- west

07. Ans: (D)

Sol: The movement of Anil are shown in the adjoining figure



He starts walking from back of his house (i.e) towards west now, the final position is D, which is to the north west of his starting point A.

08. A and B enter into a partnership, A puts in ₹50 and B puts in ₹45. At the end of 4 months, A withdraws half his capital and at the end of 5 months B withdraws $\frac{1}{2}$ of his, C then enters with a capital of ₹70 at the end of 12 months, the profit of concern is ₹254, how can the profit be divided among A, B and C ?

(A) ₹76, ₹80 and ₹98

(B) ₹80, ₹76 and ₹98

(C) ₹76, ₹98 and ₹80

(D) None of these

08. Ans: (B)

Sol:

A's share	:	**B's share**	:	**C's share**
(50×4+25×8)	:	(45×5+22.5×7)	:	(70×7)
400	:	382.5	:	490
800	:	765	:	980
160	:	153	:	196

Total profit = ₹ 254

Profit of A

$= \frac{160}{160+153+196} \times 254 = \frac{160}{509} \times 254$ = ₹80

Profit of B = $\frac{153}{509} \times 254 =$ ₹76

Profit of C = $\frac{196}{509} \times 254 =$ ₹98

∵ Hence option 'B' is correct.

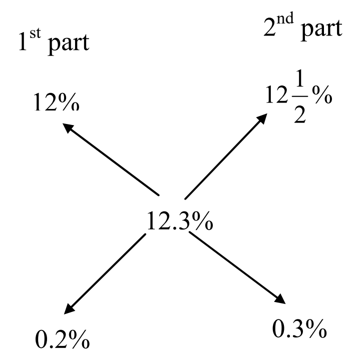
09. A sum of ₹25400 was lent out in two parts, one of 12% and the other at $12\frac{1}{2}$%. If the total annual income is ₹3124.2, the money lent at 12% is

(A) ₹15240 (B) ₹25400

(C) ₹10160 (D) ₹31242

09. Ans: (C)

Sol: Overall rate of interest $\frac{3124.2}{25400} \times 100 = 12.3\%$



∴ The sum will be divided in the ratio

0.2:0.3 (or) 2:3

∴ The sum lent at 12%

$$= 25400 \times \frac{2}{5} = ₹10160.$$

10. The following question is to be answered on the basis of the table given below.

Category of personnel	Number of staff in the year-1990	Number of staff in the year-1995
Data preparation	18	25
Data control	5	8
Operators	18	32
Programmers	21	26
Analysts	15	31
Managers	3	3
Total	80	135

What is the increase in the sector angle for operators in the year 1995 over the sector angle for operators in the year 1990?

(A) 4° (B) 3° (C) 2° (D) 1°

10. Ans: (A)

Sol: Sector angle for operators in the year 1990

$$= \frac{18}{80} \times 360° = 81°$$

Sector angle for operator in the year $1995 = \frac{32}{135} \times 360° = 85.33 \simeq 85\%$

∴ Required difference = 85° – 81° = 4°

Production & Industrial Engineering

Q. 11 – Q. 35 CARRY ONE MARK EACH.

11. If $\tau = \left(\frac{du}{dy}\right)^3$ and $\vec{V} = y^2\hat{i}$, then the apparent viscosity is

(A) 2y (B) $2y^2$

(C) 0 (D) $4y^2$

11. Ans: (D)

Sol: For Non-Newtonian fluids,

$$\tau = A\left(\frac{du}{dy}\right)^n$$

$$\tau = \mu_{app.} \times \left(\frac{du}{dy}\right)$$

where, $\mu_{app} = A\left(\frac{du}{dy}\right)^{n-1}$

For the given of the fluid, i.e., $\tau = \left(\frac{du}{dy}\right)^3$

and $u = y^2$

$\Rightarrow$ A = 1 and n = 3

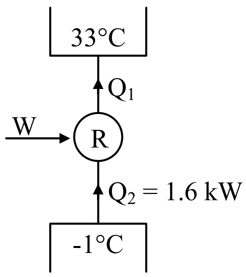
$$\mu_{app} = 1 \times \left[\frac{d}{dy}\left(y^2\right)\right]^2 = 4y^2$$

12. A Carnot refrigerator operating between –1°C and 33°C has a cooling capacity of 1.6 kW. The power consumed by the refrigerator is

(A) 160W (B) 178 W
(C) 200 W (D) 1.8 kW

12. Ans: (C)

Sol:



$T_1 = 33 + 273 = 306$ K

$T_2 = -1 + 273 = 272$ K

For Carnot Refrigerator

$$COP = \frac{T_2}{T_1 - T_2} = \frac{Q_2}{W}$$

$$\Rightarrow \frac{272}{306 - 272} = \frac{1.6}{W}$$

$\Rightarrow W = 0.2$ kW = 200 W

13. For the function $f(x, y) = x^2 - y^2$, the point (0, 0) is
(A) a local minimum
(B) a saddle point
(C) a local maximum
(D) not a stationary point

13. Ans: (B)

Sol: Given $f(x, y) = x^2 - y^2$

$\Rightarrow f_x = 2x,\ f_y = -2y$ and

$f_{xx} = 2,\ f_{xy} = 0,\ f_{yy} = -2$

Consider $f_x = 0$ and $f_y = 0$

$\Rightarrow 2x = 0$ and $-2y = 0$

$\Rightarrow (0,0)$ is a stationary point

At (0, 0), $f_{xx} f_{yy} - (f_{xy})^2 = -4 < 0$

$\therefore$ f(x, y) has neither a maximum nor minimum at (0, 0).

14. Objective function

$Z = 5X_1 + 4X_2$ (Maximize)

Subject to

$0 \le X_1 \le 12$

$0 \le X_2 \le 9$

$3X_1 + 6X_2 \le 66$

$X_1, X_2 \ge 0$

What is the optimum value ?

(A) 6, 9 (B) 0, 9
(C) 4, 10 (D) 12, 5

14. Ans: (D)

Sol: $Z = 5x_1 + 4x_2$

Subject to

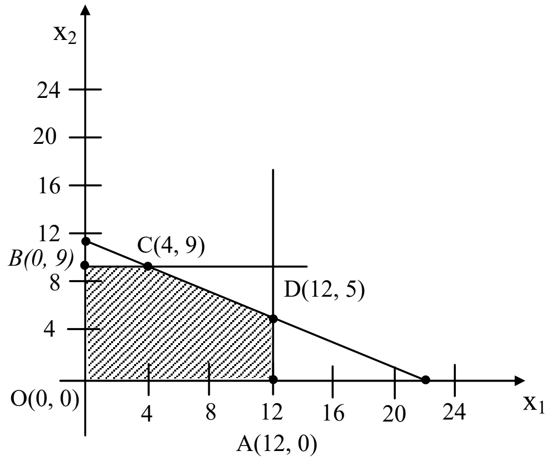
$0 \le x_1 \le 12$

$0 \le x_2 \le 9$

$3x_1 + 6x_2 \le 66$

$x_1, x_2 \ge 0$

$\frac{x_1}{22} + \frac{x_2}{11} \le 1$ ($x_1 \le 12$, $x_2 \le 9$)



$Z = 5x_1 + 4x_2$

$Z_0 = 0$

$Z_A = 5\times12 + 4\times0 = 60$

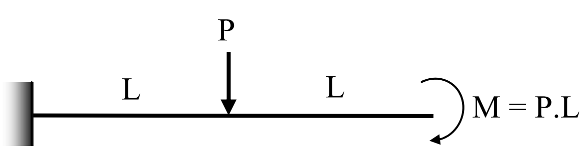
$Z_B = 5\times0 + 4\times9 = 36$

$Z_C = 5\times4 + 4\times9 = 56$

$Z_D = 5\times12 + 4\times5 = 80$

Z_{max} occurs at D (12, 5)

15. A cantilever beam is subjected to the loads as shown in figure. The deflection under the point load is



(A) $\frac{5PL^3}{6EI}$ (B) $\frac{3PL^3}{8EI}$

(C) $\frac{6PL^3}{32EI}$ (D) $\frac{PL^3}{3EI}$

15. Ans: (A)

Sol: Deflection under point load

$$= \frac{PL^3}{3EI} + \frac{ML}{EI}\left(\frac{L}{2}\right)$$

$$= \frac{PL^3}{3EI} + \frac{(PL)L^2}{2EI} = \frac{PL^3}{EI}\left(\frac{1}{3}+\frac{1}{2}\right) = \frac{5PL^3}{6EI}$$

16. A cantilever beam of uniform strength has uniform width 'B', depth 'D' at fixed end and length 'l' is subjected to a concentrated load P at free end. If the Young's modulus of the material of beam is 'E' then the deflection at free end is (where, $I = \frac{BD^3}{12}$)

(A) $\frac{P\ell^3}{3EI}$ (B) $\frac{P\ell^3}{2EI}$

(C) $\frac{2P\ell^3}{3EI}$ (D) $\frac{P\ell^3}{8EI}$

16. Ans: (C)

Sol: As the width of beam is constant, and it is also said that the beam is of uniform strength, depth of the beam at a distance x from free end of beam is represented as

$$D_x = D\left(\frac{x}{\ell}\right)^{1/2}$$

where,

D_x = depth at a distance x from free end.

Using strain energy method, deflection at free end

$$\delta = \int_0^{\ell} \frac{M_x}{E I_x} \frac{\partial M_x}{\partial P} dx$$

Here, $M_x = P.x$

$$\frac{\partial M_x}{\partial P} = x$$

$$I_x = \frac{B D_x^{\ 3}}{12} = \frac{BD^3}{12}\left(\frac{x}{\ell}\right)^{3/2}$$

$$\delta = \int_0^{\ell} \frac{P x \ x}{E \frac{BD^3}{12} \frac{x^{3/2}}{\ell^{3/2}}} \times dx = \frac{2}{3}\frac{P\ell^3}{EI}$$

17. The solution to $x^2y^{11} + xy^1 - y = 0$ is

(A) $y = C_1x^2 + C_2 x^{-3}$

(B) $y = C_1 + C_2x^{-2}$

(C) $y = C_1 x + \frac{C_2}{x}$

(D) $y = C_1 x + C_2 x^4$

17. Ans: (C)

Sol: Put ln x = t so that $x = e^t$ and

let $x\frac{dy}{dx} = Dy$, $x^2 \frac{d^2y}{dx^2} = D(D-1)\, y$

where $D = \frac{d}{dt}$

Given differential equation is

$$x^2y^{11} + xy^1 - y = 0$$

$\Rightarrow$ $D(D-1)y + Dy - y = 0$

$\Rightarrow$ $(D^2 - 1)\, y = 0$

Consider Auxiliary equation f(D) = 0

$\Rightarrow D^2 - 1 = 0$

$\Rightarrow$ D = 1, –1 are different real roots

$\therefore$ The general solution of given equation is

$$y = c_1e^t + c_2e^{-t}$$

$$= c_1 x + \frac{c_2}{x}$$

18. In a two-wire method if *p* denotes pitch (in mm) and *x* denotes thread angle (in degrees), then the diameter of the best size wire d (in mm) is given by

(A) $d = \left(\frac{p}{2}\right)\sec\left(\frac{x}{2}\right)$

(B) $d = \left(\frac{p}{4}\right)\sec\left(\frac{x}{2}\right)$

(C) $d = \left(\frac{p}{2}\right)\operatorname{cosec}\left(\frac{x}{2}\right)$

(D) $d = \left(\frac{p}{2}\right)\cot\left(\frac{x}{2}\right)$

18. Ans: (A)

Sol:

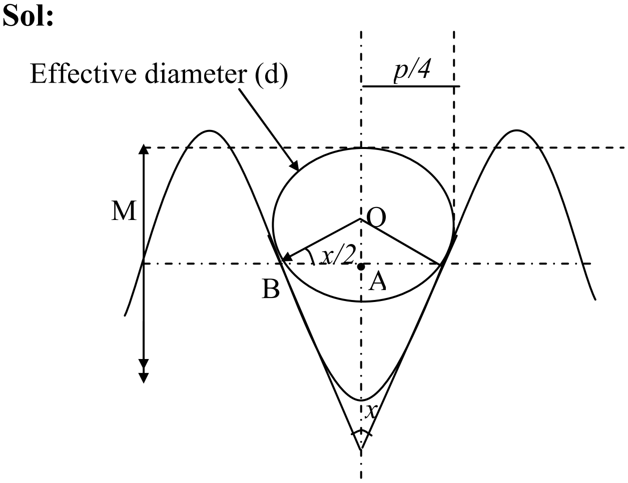


Fig: The best size wire

The above figure shows the condition achieved by the best-size wire.

In triangle OAB, sin (AOB) = AB/OB

$\sin(90 - \frac{x}{2}) = AB/OB$

$$OB = \frac{AB}{\sin(90 - x/2)} = \frac{AB}{\cos(x/2)}$$

$= AB \sec(x/2)$

Diameter of the best-size wire

$= 2(OB) = 2(AB)\sec(x/2)$.

But, AB = p / 4, where p is the pitch of the thread.

∴ Diameter of the best-size wire

(d) = $(p/2)\sec(x/2)$

19. A 20° full depth steel spur pinion is to transmit 3 kW power at a speed of 1200 rpm. The number of teeth on the pinion is 24 and the corresponding form factor is 0.337. The suitable module and face width are 2 mm and 36 mm respectively. If the velocity factor is 1.3 and the allowable bending stress is 75 MPa, then the factor of safety is

(A) 2.38 (B) 1.41
(C) 1.83 (D) 2.72

19. Ans: (B)

Sol: Design condition :

$$F_{eff} = \frac{F_{max}}{FOS}$$

$$C_v C_s F_t = \frac{m \times b \times \sigma_b \times Y}{FOS}$$

$$1.3 \times 1 \times \frac{60P}{2\pi N} \times \frac{1}{r} = \frac{m \times b \times \sigma_b \times Y}{FOS}$$

$$1.3 \times 1 \times \frac{60 \times 3 \times 10^3}{2\pi \times 1200} \times \frac{2}{2 \times 24 \times 10^{-3}} = \frac{2 \times 36 \times 75 \times 0.337}{FOS}$$

∴ FOS = 1.41

20. For a maximization problem of LP model, the following simplex tabular is obtained.

Basic	x_1	x_2	s_1	s_2	R.H.S
z	9/2	0	5/2	0	15
x_2	3/2	1	1/2	0	3
s_2	–1/2	0	–3/2	1	0

From the above table, one can conclude that the LP model has

(A) unique optimal solution
(B) multiple optimal solutions
(C) infeasible solution
(D) degenerate solution

20. Ans: (D)

Sol: Maximization case:

All z-row elements $(z_j - c_j)$ are non-negative and number of zero elements = no. of basic variables ⇒ unique optimal solution.

Unique optimal solution along with a zero basic variable ⇒ Degenerate solution.

21. A continuous random variable X has a probability density function $f(x) = e^{-x}$, $0 < x < \infty$. Then $P(X > 2)$ is

(A) 0.1353 (B) 0.2354

(C) 0.2343 (D) 1.1353

21. Ans: (A)

Sol: $P(X > 2) = \int_2^\infty f(x) \cdot dx$

$$= \int_2^\infty e^{-x} dx$$

$$= \left.\frac{e^{-x}}{-1}\right|_2^\infty$$

$$= e^{-2} = 0.1353$$

22. In the EOQ model, if the unit ordering cost is doubled, the EOQ

(A) Is halved

(B) Is doubled

(C) decreases 1.414 times

(D) increases 1.414 times

22. Ans: (D)

Sol: $EOQ \propto \sqrt{\text{Ordering cost}}$

$$\frac{(EOQ)_1}{(EOQ)_2} = \sqrt{\frac{C_o}{2C_o}}$$

$$\Rightarrow (EOQ)_2 = \sqrt{2} \times (EOQ)_1$$

$$\Rightarrow (EOQ)_2 = 1.414 \times (EOQ)_1$$

23. A grinding wheel marked A-A-46-J-5-V-8 indicates a grinding wheel

(A) with aluminum oxide grains of medium grain size, medium grade and dense structure bonded together with a vitrified bond

(B) with aluminum oxide grains of very fine grain size, medium grade and dense structure bonded together with a vitrified bond

(C) with aluminum oxide grains of medium grain size, hard grade and dense structure bonded together with a vitrified bond

(D) with aluminum oxide grains of medium grain size, hard grade and open structure bonded together with a vitrified bond

23. Ans: (A)

Sol: The grinding wheel marked A-A-46-J-5-V-8 indicates that it has aluminum oxide grains of medium grain size, medium grade and dense structure bonded together with a vitrified bond.

24. Which of the following disadvantages of ultrasonic machining is TRUE?

(A) All abrasives are extremely expensive and tool wear rate is high

(B) Material removal rate is low and tool wear rate is high

(C) Material removal rate is low and process fails in case of electrically conductive materials

(D) All abrasives are extremely expensive and process fails in case of electrically conductive materials

24. Ans: (B)

Sol: Tool wear rate is high. Material removal rate is low. So option (B) is true.

25. In a CNC drilling machine, a number of holes have to be drilled on a rectangular metal plate by the execution of a single program. Part surface is parallel to X-Y plane. The holes are on the circumference of a circle with all their axes parallel to Z axis. In order to drill these holes, which of the following facilities has to be present in the CNC drilling machine ?

(A) Rotary table with rotational axis along Z axis

(B) Circular interpolation in X-Y plane

(C) Linear interpolation in X-Y plane

(D) The coordinate values of the holes to be drilled can be given in PTP mode

25. Ans: (D)

Sol: By just giving the coordinate values of the holes to be drilled can be given in PTP mode. So options (D) is Correct.

26. Patients arrive at a medical clinic with an arrival rate that is Poisson distributed with a mean as 6 per hour. Treatment time averages 6 minutes and it follows exponential distribution. The mean waiting time in the queue is

(A) 15 min (B) 6 min

(C) 25 min (D) 9 min

26. Ans: (D)

Sol: Arrival rate (λ) = 6 /hr

Service rate $(\mu) = \frac{1}{6} \times 60$ = 10 /hr

$$\rho = \frac{\lambda}{\mu} = \frac{6}{10} = 0.6$$

$$L_s = \frac{\rho}{1-\rho} = \frac{0.6}{1-0.6} = 1.5$$

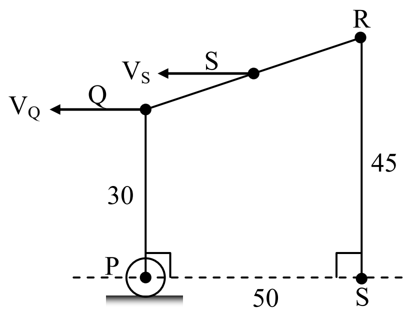
$$W_s = \frac{L_s}{\lambda} = \frac{1.5}{6} = 0.25\,\text{hr}$$

$$W_q = \rho . W_s$$

$$= 0.6 \times 0.25$$

$$= 0.15 \text{ hrs} = 9 \text{ min}$$

27. PQRS is a four bar mechanism. At an instant shown in figure the velocity of point 'Q' is V_Q. Velocity of mid point 'S' of QR, (i.e., V_S) at the same instant is



(A) V_Q (B) $\frac{3}{2}V_Q$

(C) $\frac{2}{3}V_Q$ (D) 2 V_Q

27. Ans: (A)

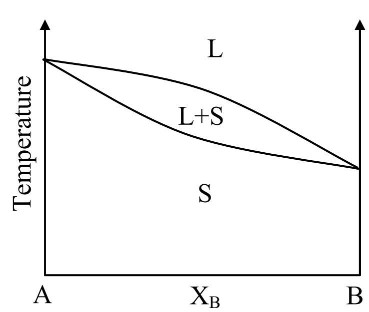
Sol: At the instant shown link QR will have pure sliding motion.

Any point on link with pure sliding will have same velocity.

$\therefore V_Q = V_S = V_R$

28. In a binary isomorphous phase diagram shown below, the degree of freedom in the two phase region is

(A) 3
(B) 2
(C) 1
(D) 0



28. Ans: (C)

Sol: Modified Gibbs phase rule gives:

$F + P = C + 1$

$P = 2(L, S)$

$C = 2(A, B)$

$F + 2 = 2 + 1$

$F = 1$ (Either temperature or chemical composition)

where, F = Degree of freedom,

P = Phase, C = Chemical constituents.

29. A steel rectangular plate with dimensions 80 mm × 120 mm × 20 mm is to be cast using modulus method of riser design (M_r = 1.2 M_c). Assume that the bottom surface of *cylindrical riser* contributes as cooling surface. If the diameter of the riser is equal to its height, then the height of the riser (in mm) is_______. *(Rounded to two decimal places)*

(Where, M_r = Modulus of riser and M_c = Modulus of casting)

29. Ans: 50.82 (Range: 49.50 to 52.50 mm)

Sol: Given:

Rectangular plate

= 80 mm × 120 mm × 20 mm

Modulus method $M_r = 1.2M_c$ (Given)

$M_r \rightarrow$ Cylindrical riser = $\frac{D}{6}$

$D = 7.2\ M_c$

$$= 7.2\left(\frac{V_c}{A_{sc}}\right)$$

$$= 7.2 \times \frac{80 \times 120 \times 20}{2[(80 \times 120) + (120 \times 20) + (80 \times 20)]}$$

$$= \frac{1382400}{27200}$$

The diameter of riser (D) = H = 50.82 mm

30. The welding machine is rated at 52 kVA at 50% duty cycle. Rated voltage is always constant at 24 Volts. If a job requires 1600 Amps current, the maximum welding time (in sec) in a total cycle time of 32 seconds is__________ (Round to one decimal place)

30. Ans: 29.3 (Range: 29.0 to 30.0)

Sol: Given,

Rated power = 52 kVA

$$P_r = V_r I_r$$

$$\Rightarrow I_r = \frac{52 \times 10^3}{24}$$

I_r = 2166.67 Amps

Rated duty cycle, D_r = 50%.

If desired current, I_d = 1600 Amps

Desired Duty,

$$D_d = \frac{I_r^2 D_r}{I_d^2} = \frac{(2166.67)^2(50)}{(1600)^2}$$

D_d = 91.68 %

$$D_d = \frac{\text{Arc on time}}{\text{Total welding time}}$$

Arc on time = D_d × Total welding time

$$= \frac{91.68}{100} \times 32$$

Maximum welding time (or) Arc on time

= 29.3 sec

31. If directional derivative of $\phi = 2xz - y^2$, at the point (1, 3, 2) becomes maximum in the direction of $\bar{a}$, then magnitude of $\bar{a}$ is

31. Ans: 7.48 (Range 7.4 to 7.5)

Sol: Given $\phi = 2xz - y^2$

$$\nabla\phi = \frac{\partial\phi}{\partial x}\bar{i} + \frac{\partial\phi}{\partial y}\bar{j} + \frac{\partial\phi}{\partial z}\bar{k}$$

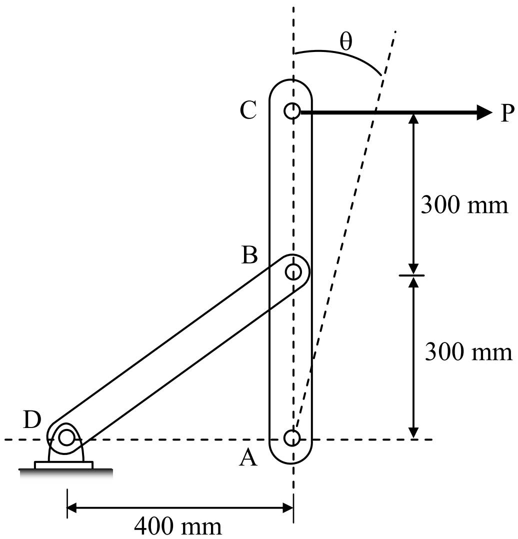
$$= 2z\,\bar{i} - 2y\bar{j} + 2x\,\bar{k}$$

∴ Required direction vector = $\bar{a} = (\nabla\phi)$ at (1, 3, 2) = $(4\bar{i} - 6\bar{j} + 2\bar{k})$

Magnitude of $\bar{a} = \sqrt{16 + 36 + 4}$

$= \sqrt{56} = 7.48$

32. The rigid link ABC is initially in vertical position. A deformable link BD is attached to rigid link as shown in figure. If load P is applied at 'C', rigid link rotates by an angle θ = 0.3°, then the normal strain in the deformable link is ________ mm/m. (Rounded off to two decimal places).



32. Ans: 2.51 (Range 2.4 to 2.6)

Sol: ℓ_1 = Initial length of link BD

$$= \sqrt{AB^2 + AD^2}$$

$$= \sqrt{300^2 + 400^2} = 500 \text{ mm}$$

ℓ_2 = Final length of link BD

$$= \sqrt{AB^2 + AD^2 - 2AB \times AD \times \cos\alpha}$$

where, α = final angle between side AD and AB

$$= 90 + 0.3 = 90.3°$$

$$\ell_2 = \sqrt{300^2 + 400^2 - 2 \times 300 \times 400 \times \cos(90.3)}$$

$$= 501.255 \text{ mm}$$

Normal strain in link BD

$$\varepsilon_{BD} = \frac{\ell_2 - \ell_1}{\ell_1}$$

$$= \frac{501.255 - 500}{500}$$

$$= 0.00251 \text{ mm/mm}$$

$$= 0.00251 \frac{\text{mm}}{10^{-3}\text{ m}} = 2.51 \text{ mm/m}$$

33. During plain turning of mild steel by a tool of geometry, 0°, 0°, 8°, 7°, 15°, 90°, 0 (mm) (ORS) at feed of 0.2 mm/rev, the chip thickness was found to be 0.5 mm. The shear angle (in degrees) is ______. (Rounded upto one decimal place)

33. Ans: 21.8 [Range: 21.0 to 22.6]

Sol: Given,

Tool Geometry: 0°, 0°, 8°, 7°, 15°, 90°, 0 (mm) (ORS),

Rake angle (α)= 0° = side rake angle in ORS

Feed (f) = 0.2 mm/rev

Chip thickness (t_2) = 0.5 mm

Uncut chip thickness,

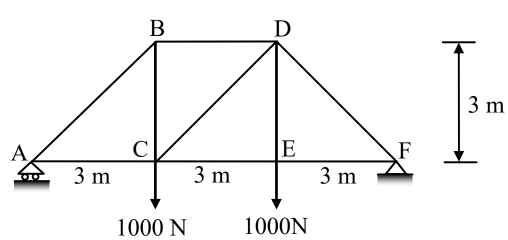
$t_1 = f \sin\lambda = 0.2 \sin 90° = 0.2$ mm

$$r = \frac{t_1}{t_2} = \frac{0.2}{0.5} = 0.4$$

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right) = \tan^{-1}\left(\frac{0.4\cos 0}{1 - 0.4\sin 0}\right)$$

$$= 21.8°$$

34. A simple plane truss is shown in figure. Two 1000N loads are acting on pins C and E as shown in figure below. The force in member CD is ________ N



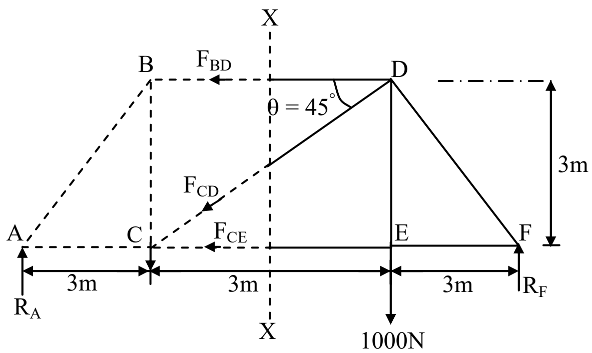
34. Ans: 0

Sol: Taking moment about A and F we will get

$R_A = R_F = 1000$ N

Cut section XX as shown in figure.

Let F_{BD} be the force in member BD, F_{CD} be the force in member CD and F_{CE} be the force in member CE.



$\Sigma F_y = 0$

$-F_{CD} \sin 45 - 1000 + 1000 = 0$

$F_{CD} = 0$

35. The ratio of press force required to punch a circular hole of 30 mm diameter in a 1 mm thick steel sheet to that needed to punch a circular hole of 60 mm diameter in a 2 mm thick steel sheet is_______ (Rounded to two decimal places)

35. Ans: 0.25 (Range 0.25 to 0.25)

Sol: Ratio of force

$$= \frac{F_{1\max}}{F_{2\max}} = \frac{\pi d_1 t_1 \tau_u}{\pi d_2 t_2 \tau_u} = \frac{\pi \times 30 \times 1}{\pi \times 60 \times 2} = 0.25$$

Q. 36 – Q. 65 CARRY TWO MARKS EACH.

36. Which one of the following statements is CORRECT concerning Jominy end quench test?

(A) Large number of samples is required.

(B) Water is sprayed from the top side (hanged side) and heat transfer occurs from bottom side to top side in Jominy end quench.

(C) Steels with very high hardenability would have very high depth up to which martensite can form.

(D) The greater the depth to which hardness increases, the lesser the hardenability of the alloy.

36. Ans: (C)

Sol: Hardenability is the ability of a steel to partially or completely transform from austenite to some fraction of martensite at a given depth below the surface, when cooled under a given condition. For example, a steel of a high hardenability can transform to a high fraction of martensite to depths of several millimetres under relatively slow cooling, such as an oil quench, whereas a steel of low hardenability may only form a high fraction of martensite to a depth of less than a millimetre, even under rapid cooling such as a water quench. Hardenability therefore describes the capacity of the steel to harden *in depth* under a given set of conditions. So option (C) is CORRECT.

37. Given matrix $[A] = \begin{bmatrix} 4 & 2 & 1 & 3 \\ 6 & 3 & 4 & 7 \\ 2 & 1 & 0 & 1 \end{bmatrix}$, then the system AX = O, where $X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix}$ has

(A) no solution
(B) a unique solution
(C) only one independent solution
(D) two linearly independent solutions

37. Ans: (D)

Sol: Given $A = \begin{bmatrix} 4 & 2 & 1 & 3 \\ 6 & 3 & 4 & 7 \\ 2 & 1 & 0 & 1 \end{bmatrix}$

$R_2 \to 4R_2 - 6R_1$;

$R_3 \to 2R_3 - R_1$

$$\sim \begin{bmatrix} 4 & 2 & 1 & 3 \\ 0 & 0 & 10 & 10 \\ 0 & 0 & -1 & -1 \end{bmatrix}$$

$R_3 \to (10)R_3 + R_2$

$$\sim \begin{bmatrix} 4 & 2 & 1 & 3 \\ 0 & 0 & 10 & 10 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$\therefore \rho(A) = 2$

$\therefore$ Number of linearly independent solutions

= Number of variables – Rank of A

= 4 – 2 = 2

38. The velocity of water (before mixing with abrasives) at the orifice of the abrasive water jet machining head is 900 m/s. After complete mixing with the abrasive, the velocity of the water-abrasive jet is 787.6 m/s. Discharge coefficients etc to be considered unity. If the water mass flow rate is 2.8 kg/min, by considering velocity of abrasives at entry is zero, the abrasive mass flow rate is nearest to

(A) 0.1 kg/min (B) 0.2 kg/min
(C) 0.4 kg/min (D) 0.6 kg/min

38. Ans: (C)

Sol: Given, $V_w = 900$ m/s

$V = 787.6$ m/s

$m_w = 2.8$ kg/min

$$m_a V_a + m_w V_w = V(m_w + m_a)$$

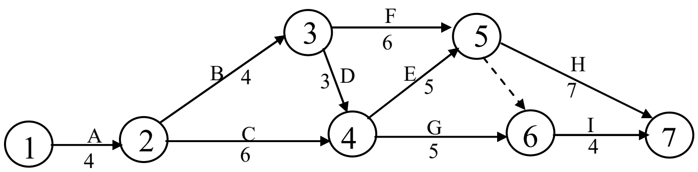
$$m_w \times V_w = V(m_w + m_a)$$

($\because V_a = 0$, negligible velocity)

$2.8 \times 900 = 787.6\ (2.8 + m_a)$

$\Rightarrow m_a = 0.399 \approx 0.4$ kg/min

39. The CPM network Diagram of a project by network technique is given below:



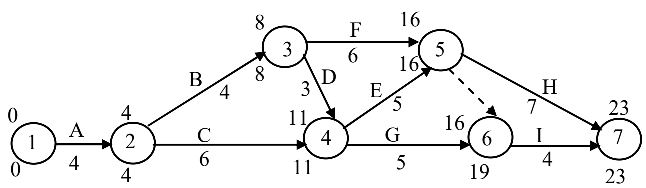
Calculate the Sum of Free float of activity 2-4, Independent float of activity 4-6 and Total float of activity 6-7.

(A) 4 (B) 6

(C) 5 (D) 3

39. Ans: (A)

Sol: The CPM network Diagram:



Free float (F_F) of activity (2-4)

$= (T_E^j - T_E^i) - t_{ij} = (11 - 4) - 6 = 1$

Independent float (I_F) of activity (4-6)

$= (T_E^j - T_L^i) - t_{ij} = (16 - 11) - 5 = 0$

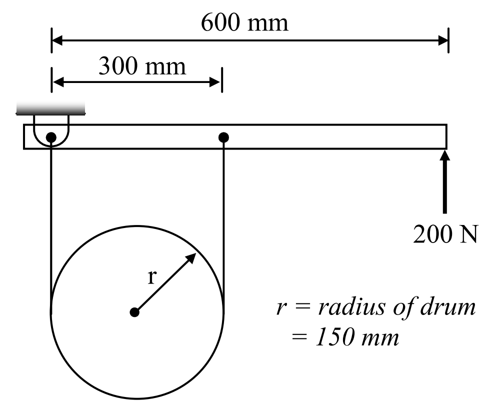
Total float (T_F) of activity (6-7)

$= (T_L^j - T_E^j) - t_{ij} = (23 - 16) - 4 = 3$

Sum of Free float (F_F) of activity (2-4), Independent float (I_F) of activity (4-6) and Total float (T_F) of activity (6-7)

$=1 + 0 + 3 = 4$

40. A simple band brake is used for braking a rotating drum as shown in figure. The angle of wrap of band around the drum is 180° and the coefficient of friction between band and drum is 0.35. The braking torque required during clockwise rotation and counter clockwise rotation of drum are T_1 and T_2 respectively. The magnitude of $\frac{T_1}{T_2}$ is



(A) 3 (B) 1

(C) $\frac{1}{9}$ (D) $\frac{1}{3}$

40. Ans: (D)

Sol: *Clockwise rotation of drum :*

Let, $P = 200$ N,

$\ell = 600$ mm,

$a = 300$ mm,

T_t = tension on tight side,

$$T_f = \frac{P \times \ell}{a}$$

∴ Braking torque,

$$T_1 = T_f\left(1 - \frac{1}{e^{\mu\theta}}\right) r$$

Counter clockwise rotation of drum :

T_s = Tension on slack side

$$T_s = \frac{P \times \ell}{a}$$

$\therefore$ Braking torque,

$$T_2 = T_s\left(e^{\mu\theta} - 1\right) r$$

$$\frac{T_1}{T_2} = \frac{T_t\left(1 - \frac{1}{e^{\mu\theta}}\right) r}{T_s\left(e^{\mu\theta} - 1\right) r}$$

$$\frac{T_1}{T_2} = \frac{1}{e^{\mu\theta}}$$

$$= \frac{1}{e^{0.35\times\pi}}$$

$$\frac{T_1}{T_2} = 0.33$$

41. Consider the following project data :

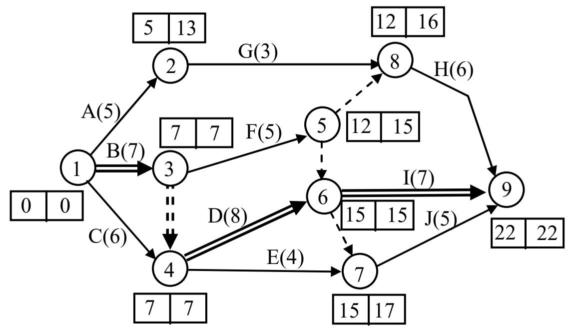
Activity	**Predecessor**	**Duration (days)**
A	-	5
B	-	7
C	-	6
D	B, C	8
E	B, C	4
F	B	5
G	A	3
H	F, G	6
I	D, F	7
J	D, E, F	5

The project duration (in days) and minimum number of dummy activities required in 'AOA' diagram are respectively

(A) 22 and 0 (B) 22 and 3
(C) 22 and 4 (D) 13 and 1

41. Ans: (C)

Sol:



42. The annual precipitation data of a city is normally distributed with mean and standard deviation as 1000 mm and 200 mm, respectively. The probability that the annual precipitation will be more than 1200 mm is

(A) 0.1587 (B) 0.3174
(C) 0.3456 (D) 0.2345

42. Ans: (A)

Sol: Let X = annual precipitation

We know area under normal curve in the interval $(\mu - \sigma, \mu + \sigma) = 0.6826$

where μ is mean and σ is standard deviation

$\Rightarrow P(800 < X < 1200) = 0.6826$

Required probability = P(X > 1200)

$$= \frac{1-0.6826}{2} = 0.1587$$

43. A GO-NOGO plug gauge is to be designed for measuring 75 ± 0.05 mm diameter holes. The dimensions (in mm) of the GO-NOGO plug gauge as per the unilateral tolerance system (in mm) are:

Consider:

1. *Gauge makers tolerance is 10% work tolerance.*
2. *Wear allowance is 5% work tolerance.*

(A) $75.05^{+0.01}$; $74.955^{-0.01}$

(B) $74.05^{+0.01}$; $75.955^{-0.01}$

(C) $75.955^{+0.01}$; $74.05^{-0.01}$

(D) $74.955^{+0.01}$; $75.05^{-0.01}$

43. Ans: (D)

Sol: Given:

High limit of hole = 75.05 mm,

Low limit of hole = 74.95 mm

Work tolerance = 75.05 – 74.95 = 0.1 mm

Gauge makers tolerance

= 10% × 0.1 = 0.01 mm,

Wear allowance = 5%×0.1 = 0.005 mm

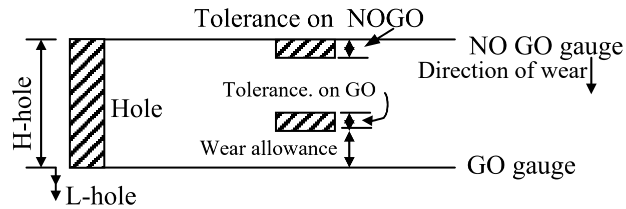
Go side of plug gauge = Lower limit of hole (M.M.C) = 74.95 mm

L-limit of Go plug gauge after the application of wear allowance

= 74.95 + 0.005 = 74.955 mm

H-limit of Go plug gauge

= 74.955 + 0.01 = 74.965mm



Go gauge dimensions $74.955^{0.01}_{0.00}$

H-limit of NOGO gauge = 75.05 mm,

L-limit of NOGO gauge

= 75.05 – 0.01 = 75.04 mm

No Go gauge dimensions $75.05^{-0.00}_{-0.01}$

44. Consider the differential equation $\frac{dy}{dx} + 2xy = e^{-x^2}$ with initial condition $y(0) = 1$. The value of y(1) = _____.

44. Ans: 0.7357 (Range 0.73 to 0.74)

Sol: Given $\frac{dy}{dx} + 2xy = e^{-x^2}$ …….. (1)

with y(0) = 1 …….. (2)

$\therefore$ I. F. = $e^{\int 2x\,dx} = e^{x^2}$

Now, the general solution of (1) is

$$\Rightarrow y.\, e^{x^2} = \int e^{x^2} .\, e^{-x^2} dx + c$$

$$\Rightarrow y.\, e^{x^2} = x + c \quad …….. (3)$$

Using (2), (3) becomes

$\Rightarrow 1 = 0 + c \Rightarrow c = 1$

$$y = x\, e^{-x^2} + e^{-x^2}$$

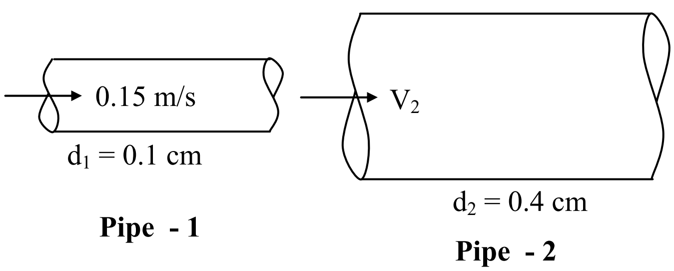
$$y = (x + 1)\, e^{-x^2}$$

$\therefore\ y(1) = 2 \times e^{-1} = 0.7357$

45. The ratio of friction factors (f_1/f_2) in two different pipes with same fluid is 0.5. The average flow velocity in pipe-1 is 0.15 m/s and the pipe diameter is 0.1 cm. The flow in the pipes can be assumed to be laminar. The radius of pipe-2 is 0.2 cm. The average velocity in pipe-2 is ______ m/s. (Rounded off to three decimal places)

45. Ans: 0.019 (Range: 0.018 to 0.020)

Sol:



Given:

$$\frac{f_1}{f_2} = 0.5$$

Flow is laminar in both pipes.

We know that in laminar flow through a pipe,

$$f = \frac{64}{Re} = \frac{64\nu}{Vd}$$

Thus,

$$\frac{f_1}{f_2} = 0.5 = \frac{64\nu}{0.15 \times 0.1 \times 10^{-2}} \times \frac{V_2 \times 0.4 \times 10^{-2}}{64\nu}$$

On simplification

$$0.5 = \frac{V_2 \times 0.4}{0.15 \times 0.1}$$

$\Rightarrow V_2 = 0.01875$ m/s ≈ 0.019 m/s

46. The voltage arc length characteristic of a DC arc is given by V = 20 + 4L where V is the arc voltage in volts and L is the arc length in mm. The static volt ampere characteristics of the power source is approximated by a straight line with open circuit voltage as 80 V and short circuit current as 900 Amps. The maximum power for stable equilibrium conditions of welding equipment (in kW) is__________ *(Round to one decimal place)*.

46. Ans: 18.0 (Range: 17.0 to 19.0)

Sol: Given, $V_o = 80$ V, $I_S = 900$ A

$V_a = 20 + 4L;$

$$V_P = V_o - \frac{V_o}{I_s} \times I$$

At equilibrium condition

$$V_a = V_P$$

$$20 + 4L = 80 - \frac{80}{900} \times I$$

$$\frac{80}{900} I = 60 - 4L$$

$\Rightarrow I = \frac{900}{80}(60 - 4L)$

Power (P) = VI

$$P = (20 + 4L)\left[\frac{900}{80}(60 - 4L)\right]$$

$$= \frac{900}{80}\left[1200 - 80L + 240L - 16L^2\right]$$

$$= \frac{900}{80}\left(1200 + 160L - 16L^2\right)$$

For optimum power and optimum arc length

$\frac{dP}{dL} = 0 \Rightarrow 160 - 32L = 0$

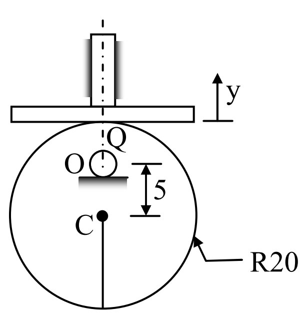
$$\Rightarrow L = \frac{160}{32} = 5\,mm$$

$\therefore V = 20 + 4 \times 5 = 40$ V

$I = \frac{900}{80}(60 - 4 \times 5) = 450\,A$,

P = VI = 40 × 450 = 18 kW

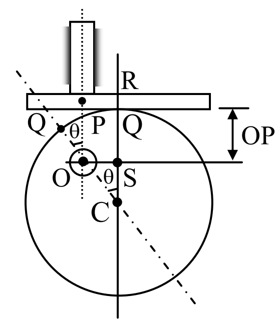
47. A circular disc cam with flat foot follower is shown in figure. Radius, eccentricity of circular cam is 20 cm and 5 cm respectively. Cam is rotating with 10 rad/s.



Maximum velocity of the follower in meters per second is ______ m/s.

47. Ans: 0.5 (Range 0.47 to 0.53)

Sol: F.B.D of cam and follower system after small rotation of cam (θ) is



Follower lift, y = OP – OQ

But from above figure,

OP = RS = RC – CS

= R – OC × cosθ

OP = (R – ρ cosθ)

∴ y = R – ρ cosθ – (R – ρ)

∴ y = ρ – ρ cosθ

y = ρ (1 – cosθ)

∴ Velocity, $V = \frac{dy}{dt} = \frac{dy}{d\theta} \times \frac{d\theta}{dt}$

$$V = \rho \times \sin\theta \times \frac{d\theta}{dt}$$

$$V = \rho\,\omega\,\sin\theta$$

Maximum velocity is ρω,

$V_{max} = 5 \times 10$ cm/s

= 50 cm/s ≈ 0.5 m/s

48. Standard times (ST) and labour rates are as in the table.

Labour overheads are 20% of labour cost.

Activity	ST.min	Labour rate Rs/hr
Cutting	2	550
Inspecting	0.5	440
Packaging	0.5	400

If the material cost is Rs. 25/unit, the total cost of production in Rs./unit is ________

48. Ans: 55 (Range 54 to 56)

Sol: Material cost = Rs.25 per unit

Cutting cost $= \frac{2}{60}\times 550$ = Rs. 18.33

Inspection cost = $\frac{0.5}{60}\times 400$ = Rs. 4.33

Packaging cost = $\frac{0.5}{0.6}\times 400$ = Rs. 3.33

Total Labor cost = Rs. 25

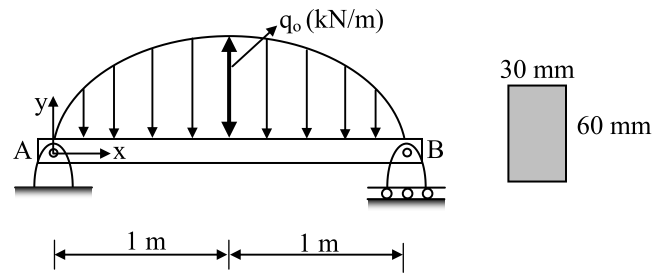
Labour overhead (20%) = Rs. 5

Total cost

= Material cost + Total Labour cost + OH

= Rs. 55/-

49. A simply supported beam of rectangular cross section (30 mm × 60 mm) is subjected to a parabolically distributed load of intensity, $q_x = q_o.x\ (2 - x)$, where x is in 'm', 'q_X' is in kN/m, q_o is the maximum intensity of load. If the allowable stress in bending is limited to 100 MPa then the magnitude of q_o is ______ kN/m. (Rounded upto two decimal places)



49. Ans: 4.32 (Range 4.00 to 4.50)

Sol: Given,

$q_x = q_o\,x(2-x)$

[Here x(2 – x) is just a factor]

Shear force at a distance 'x',

$$V_x = \int q_x\,dx + C_1$$

$$= q_o\int\left(2 - x^2\right)dx + C_1$$

$$V_x = q_o\left(x^2 - \frac{x^3}{3}\right) + C_1$$

Bending moment at a distance 'x'

$$M_x = \int V_x\ dx + C_2$$

$$= q_o\left(\frac{x^3}{3} - \frac{x^4}{12}\right) + C_1\ x + C_2$$

Boundary conditions :

At x = 0 ; $M_x = 0$

$\therefore\ 0 = q_o\ (0 - 0) + C_1\ (0) + C_2$

$\therefore\ C_2 = 0$

At x = 2 ; $M_x = 0$

$$0 = q_o\left(\frac{8}{3}-\frac{16}{12}\right)+C_1\times 2$$

$$C_1 = -q_o\times\frac{2}{3}$$

At x = 1, $M_x = M_{max}$ [∵ Symmetric loading]

$$M_{max} = q_o\left(\frac{1}{3}-\frac{1}{12}\right)-q_o\times\frac{2}{3} = q_o\times\frac{1}{4}-q_o\times\frac{2}{3}$$

$$= -q_o\left(\frac{5}{12}\right)\text{ kN.m}$$

$$= -q_o\left(\frac{5}{12}\right)\times 10^6\text{ N.mm}$$

Design condition :

$$\sigma_{allowable} = \sigma_{max}$$

$$100\text{ N/mm}^2 = \frac{6\,M_{max}}{b\times d^2\ (mm^3)}$$

$$= \frac{6\times q_o\times\frac{5}{12}\times 10^6}{30\times 60^2}$$

⇒ $q_o = 4.32$ kN/m

50. In a slab milling operation, a cutter of 90 mm diameter with 10 numbers of teeth on cutter is used. The depth of cut and table feed are set at 3 mm and 180 mm/min respectively. If the cutting speed is 40 m/min, the average chip thickness in milling (in mm) is __________.
(Round to three decimal places)

50. Ans: 0.023 [Range: 0.020 to 0.026]

Sol: Given, slab milling operation,

D = 90 mm

Z = 10, v = 40 m/min

d = 3 mm, f = 180 mm/min

$$N = \frac{1000\times v}{\pi\times D} = \frac{1000\times 40}{\pi\times 90} = 141.47\text{ rpm}$$

$$t_{1max} = \frac{2f_m}{NZ}\sqrt{\frac{d}{D}}$$

$$= \frac{2\times 180}{141.47\times 10}\sqrt{\frac{3}{90}} = 0.0465\text{ mm}$$

$t_{1\,min} = 0$

$$t_{1avg} = \frac{t_{1max}+t_{1min}}{2}$$

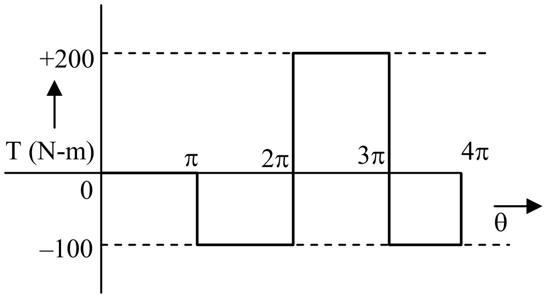
The average chip thickness in milling

$$= \frac{0.0465+0}{2} = 0.02325 \cong 0.023\text{ mm}\quad\text{(OR)}$$

$$t_{1avg} = \frac{f_m}{NZ}\sqrt{\frac{d}{D}} =$$ Average uncut chip thickness $$= \frac{180}{141.47\times 10}\sqrt{\frac{3}{90}}$$

$$= 0.02325\text{ mm} \approx 0.023$$

51. A simplified turning moment diagram of an engine is shown in figure. Mass moment of inertia of flywheel required to keep fluctuation within 2% of mean speed 10 rad/s is _______ (in kg-m^2).
(Rounded to one decimal place).



51. Ans: 314.2 (Range 313.35 to 315.5)

Sol: E = Net energy per cycle = ΣA_i

$= 0 - 100 \times \pi + 200\times\pi - 100\times \pi = 0$

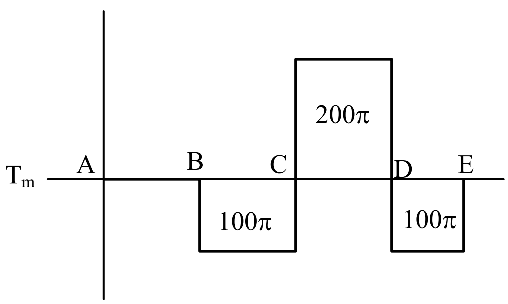
E = 0 N-m (No energy)

But $E = T_m \times$ cycle angle

$= T_m \times 4\pi = 0$

$\therefore T_m = 0$

$\therefore$ Redrawing T vs θ diagram as areas above/below mean torque line will result.



$\therefore$ ΔE = Maximum fluctuation of energy

= Area of central loop

$\Delta E = 200 \times \pi$

where, $C_s = 0.02$, $\omega = 10$ rad/s

But $\Delta E = I\,\omega^2 C_s$

$200\times\pi = I \times 10^2 \times 0.02$

$\Rightarrow I = 100 \times \pi$ kg-m^2 = 314.2 kg-m^2

52. In a CNC machine with contouring control, the following commands are executed:

N01 G90 G00 X100 Y200 Z 20

N02 G01 X130 Y240 F500

where, *F* defines feed rate in mm/min. In that case the feed velocity of the cutter with respect to the work piece in the *X* direction in line N02 is nearest to ______ mm/min.

52. Ans: 300 (Range: 298 to 302)

Sol: The displacement triangle and the velocity triangle are similar and hence $X/Y = V_x/V_y$

$30/40 = V_x/V_y$

$$V_y = \frac{V_x}{0.75}$$

Also $V^2 = 500^2 = V_x^2 + V_y^2$

$$500^2 - \left(\frac{V_x}{0.75}\right)^2 = V_x^2$$

$$500^2 = V_x^2 + \left(\frac{V_x}{0.75}\right)^2$$

$$500^2 = \frac{V_x^2 + 0.5625\,V_x^2}{0.5625}$$

$$V_x = 300\,\text{mm/min}$$

The feed velocity of the cutter in the X direction = 300 mm/min

(OR)

Actual distance travelled by the tool

$= (30^2 + 40^2)^{0.5} = 50$ mm

Time taken for travelling 50 mm

= 50/500 = 0.1 min

Velocity in X-direction = distance in X-direction/time = 30/0.1 = 300mm/min

53. The value of the double integral $\int_0^8 \left(\int_{y/2}^{(y/2)+1} \left(\frac{2x-y}{2} \right) dx \right) dy$, using the substitution $u = \left(\frac{2x-y}{2} \right)$ and $v = \frac{y}{2}$ or otherwise is ______.

53. Ans: 4 (Range 3.9 to 4.1)

Sol: Given $u = \frac{2x-y}{2}$ and $v = \frac{y}{2}$

$\Rightarrow du = dx,\ dv = \frac{dy}{2}$ and $dy = 2\,dv$

If $x = \frac{y}{2}$ then $u = 0$

If $x = \frac{y}{2}+1$ then $u = 1$

If $y = 0$ then $v = 0$

If $y = 8$ then $v = 4$

$$\int_0^8 \left[\int_{\frac{y}{2}}^{\frac{y}{2}+1} \left(\frac{2x-y}{2} \right) dx \right] dy = \int_{v=0}^{4} \int_{u=0}^{1} 2u \; du\, dv = 4$$

54. The dimension of an annular cylinder of outside diameter 8 cm, inside diameter 3 cm and height 5 cm steel casting are to be made. Assume the cylindrical side riser with height is equal to diameter. For tabulated shape factor values given below, the diameter of the riser (in cm) is________

(Round to one decimal place)

Shape factor	3	5	7	9	11
$\frac{\textbf{Riser volume}}{\textbf{Casting volume}}$	0.85	0.625	0.525	0.45	0.375

54. Ans: 4.9 Range: (4.5 to 5.5)

Sol: In casting shape factor (SR) = $\frac{L+W}{t}$

Weight (W) = 5 cm

Length, $L = \pi \times D_{mean} = \pi\left(\frac{8+3}{2} \right)$

$= 17.27$ cm

$t = \frac{8-3}{2} = 2.5$ cm

Shape factor $= \frac{17.27+5}{2.5} = 8.91 \approx 9$

From the given table for shape factor, the ratio

$\frac{V_r}{V_c} = 0.45$

$V_r = 0.45 \times V_c$

$\frac{\pi}{4} D^3 = 0.45 \times \frac{\pi}{4}\left(8^2 - 3^2\right) \times 5$

$\Rightarrow$ D = 4.98 cm

55. 7, 7, 7, 6, 6, 9, 8 and 6 are the times recorded for one element of operation. How many cycles are necessary for time study if the errors is not to exceed 5 percent at the confidence level of 99.7% is _______.

55. Ans: 73.46 (Range 72 to 76)

Sol:

S.No.	x	x^2
1	7	49
2	7	49
3	7	49
4	6	36
5	6	36
6	9	81
7	8	64
8	6	36
n = 8	**Σx = 56**	**$\Sigma x^2 = 400$**

Error, h = 0.05

Confidence level 99.7% ,

Z = 3

$$n = \frac{Z^2\left\{n\Sigma x^2 - (\Sigma x)^2\right\}}{h^2(\Sigma x)^2}$$

$$= \frac{3^2\left(8\times 400 - (56)^2\right)}{(0.05)^2 \times (56)^2}$$

$$= \frac{9(3200-3136)}{3136\times 0.05^2} = 73.46$$

56. In a manufacturing company the daily requirement is 100 units and the same is produced @ 120 units per day. The company works for 250 days in a year. The setup cost per setup is Rs. 500 and inventory holding cost is estimated as Rs. 2.167 per unit per month. The maximum inventory level is ______.

56. Ans: 400 (Range: 399 to 401)

Sol: Rate of consumption (d) = 100 units/day

Rate of production (k) = 120 units/day

Annual demand (D) = d × 250

= 100 × 250 = 25000 units

Setup cost (C_o) = Rs. 500/setup

Carrying cost (C_c) = 2.167×12/unit/year

= Rs. 26/unit/year

$$EBS = \sqrt{\frac{2DC_o}{C_c}}\sqrt{\frac{k}{k-d}}$$

Maximum inventory level,

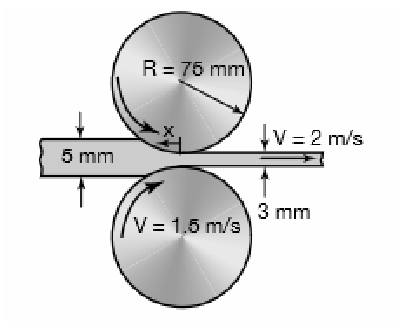
$$(Q_{max}) = EBS\left(\frac{k-d}{k}\right)$$

$$= \sqrt{\frac{2\times 25000\times 500}{26}}\sqrt{\frac{120}{120-100}}\left(\frac{120-100}{120}\right)$$

= 2400×0.167 = 400.28 units

57. An aluminium metallic strip having a thickness of 5 mm is to be rolled using hardened steel rolls, each of 150 mm diameter under the condition shown in the figure below. It is noted that there are front and back tensions that have not been specified. The surface roughness of the rolls

is 0.02 μm and rolling temperature is 210°C. The position x_n (in mm) of the neutral point is _____. (Rounded to two decimal places)



57. Ans: 8.64 [Range: 8.00 to 9.00]

Sol: Given,

Inlet conditions: $H_0 = 5$ mm, $V_0 = ?$

Outlet conditions: $V_1 = 2$ m/sec, $H_1 = 3$ mm

At neutral point: H, V

$D = 150 \text{ mm} \Rightarrow r = 75$ mm

Volume before = Volume after

$V_0\, b_0\, H_0 = V_1\, b_1\, H_1$

$V_0 \times 5 = 2 \times 3$

$V_0 = 1.2$ m/s

At the neutral point the velocity is the roll velocity, $VH = V_1 H_1$

$1.5 \times H = 2 \times 3$

$H = 4$ mm

Assuming the material is incompressible,

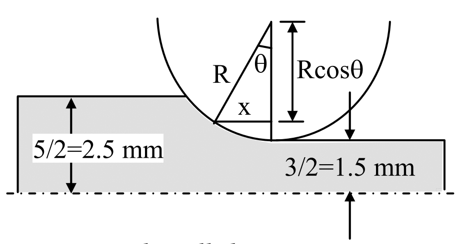


Fig: The rolls bite geometry.

θ can be calculated from above diagram:

$$75 - 75\cos\theta = \frac{4-3}{2}$$

$\theta = 6.62°$.

∴ The position x_n (in mm) of the neutral point

$= R\sin\theta = 75\sin 6.62°$

$= 8.64$ mm

58. The surface integral $\iint_s (\bar{F}.\bar{n})\,dS$ over the surface S of the sphere $x^2 + y^2 + z^2 = 9$, where $F = (x+y)\bar{i} + (x+z)\bar{j} + (y+z)\bar{k}$ and $\bar{n}$ is the unit outward surface normal, yields ______.

58. Ans: 226.08 (Range 226 to 227)

Sol: $\vec{F} = (x+y)\vec{i} + (x+z)\vec{j} + (y+z)\vec{k}$

$\text{div } \vec{F} = 1 + 1 = 2$

$$\iint_S \vec{F}.\vec{n}\,dS = \iiint_V \text{div}\,\vec{F}\,dx\,dy\,dz$$

(By Gauss divergence theorem)

$$= \iiint 2\,dx\,dy\,dz$$

$= 2$

(volume of the sphere $x^2 + y^2 + z^2 = 9$)

$$= 2 \times \frac{4}{3}\pi(3)^3 = 72\,\pi = 226.08$$

59. Air at 80 kPa, 27°C and 220 m/s enters a diffuser at a rate of 2.5 kg/s and leaves at 42°C. The air is estimated to lose 18 kW of heat during this process. If the exit area of diffuser is 400 cm^2 then the exit pressure (in kPa) of the air is _____. (Round off one decimal place)

(Take, c_p = 1.005 kJ/kg°C ;

R = 0.287 kJ/kg°C for air, γ = 1.4)

59. Ans: 91.1 (Range 90.7 to 91.5)

Sol: By using S.F.E.E at inlet and exit of nozzle,

$$\dot{m}\left(h_1 + \frac{V_1^2}{2000}\right) + \frac{dQ}{dt} = \dot{m}\left(h_2 + \frac{V_2^2}{2000}\right)$$

$$2.5\left(1.005\times300+\frac{220^2}{2000}\right)-18 = 2.5\left(1.005\times315+\frac{V_2^2}{2000}\right)$$

$\therefore$ V_2 = 62 m/s

$$\dot{m} = \rho_2\ A_2\ V_2$$

$$2.5 = \frac{P_2}{RT_2}\times400\times10^{-4}\times62$$

$\therefore$ P_2 = 91.1 kPa

60. In an orthogonal cutting with a tool of 0º rake angle, the cutting force is 200 N and the cutting velocity is 90 m/min. Assuming that 90% of the total work has been utilized for plastic deformation and shearing and gets converted to heat, out of which 10% heat goes into the workpiece, the heat flow (in W) in the workpiece will be______.

60. Ans: 27 [Range: 26 to 28]

Sol: Given,

Orthogonal cutting, $\alpha = 0°$,

Cutting force, F_C = 200 N

Cutting velocity, V_C = 90 m/min

The deformation power along the shear plane is = 90% of total work

$= 0.9 \times F_C \times V_C$

$= 0.9 \times 200 \times 90/60 = 270$ W

Total heat generated in the shearing zone

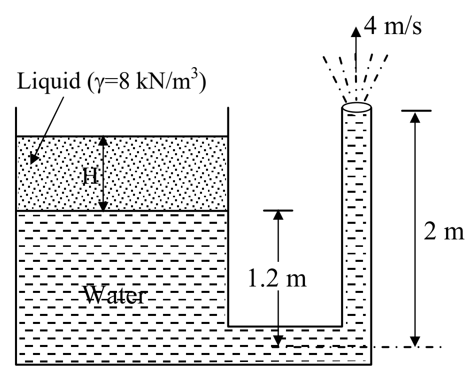
= 270 W

Heat flow in the workpiece

$= 270 \times 0.1 = 27$ W

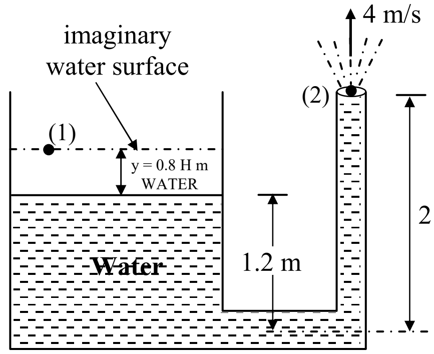
61. A large tank contains water and a liquid (Specific weight = 8 kN/m^3) as shown in the figure. Water is leaving steadily at 4 m/s through the small pipe. The depth, H of liquid is _____ m.

(Assume g = 10 m/s^2)



61. Ans: 2

Sol:



Equivalent height (y) of H m of liquid in terms of m of water column is

$$\gamma \times H = \gamma_w \times y$$

Or, $$y = \frac{\gamma}{\gamma_w} H = \frac{8}{10} H = 0.8 H$$

Applying Bernoulli's equation for points (1) (lying on the imaginary water surface) and (2) (exit of the pipe), we get

$$\frac{P_1}{\gamma_w} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma_w} + \frac{V_2^2}{2g} + Z_2$$

where, $P_1 = P_2 = P_{atm} = 0$;

$V_1 = 0$; $V_2 = 4$ m/s;

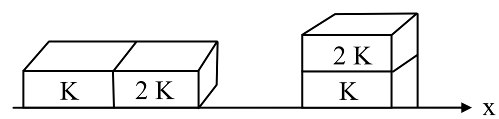
$Z_1 = 1.2 + 0.8$ H and $Z_2 = 2$ m

$$0 + 0 + 1.2 + 0.8H = 0 + \frac{4^2}{2 \times 10} + 2$$

$$0.8H = 0.8 + (2 - 1.2)$$

$$\Rightarrow H = \frac{1.6}{0.8} = 2\,m$$

62. Two rectangular blocks, having identical dimensions can be arranged either in configuration I or in configuration II as shown in the figure. The blocks have thermal conductivities K and 2K, as shown in the figure below. The temperature difference between the ends along the x-axis is the same in both the configurations. It takes 9 sec to transport a certain amount of heat from the hot end to the cold end in the configuration I. The time to transport the same amount of heat from the hot end to cold end in the configuration II is ____ sec.



(Configuration I) **(Configuration II)**

62. Ans: 2

Sol: Heat transfer rate through the bocks for given configurations is

$$\frac{Q}{t} = \frac{\Delta T}{R_{th}}$$

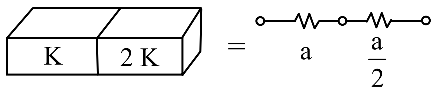
where Q is amount of heat flow, R_{th} is the corresponding thermal resistance and t is the time taken to transport the heat.

∴ For same amount of heat flow and temperature difference :

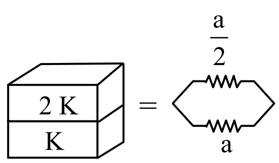
$\Rightarrow t \propto R_{th}$

or $$\frac{t_1}{t_2} = \frac{R_{th1}}{R_{th2}} \qquad \text{------(i)}$$

Let L be the length of the blocks parallel to x-axis and $\frac{L}{KA} = a$



(Configuration I)



(Configuration II)

For configuration I,

$$R_{th1} = \frac{L}{KA} + \frac{L}{2KA} = a + \frac{a}{2} = \frac{3a}{2} \quad \text{-----(ii)}$$

For configuration II,

$$R_{th2} = \frac{\left(a.\frac{a}{2}\right)}{a + \frac{a}{2}} = \frac{\frac{a^2}{2}}{\frac{3a}{2}} = \frac{a^2}{2} \times \frac{2}{3a} = \frac{a}{3} \quad \text{-----(iii)}$$

From eq.(i), (ii) and (iii),

with $t_1 = 9$ sec (given)

then $\frac{9}{t_2} = \frac{\frac{3a}{2}}{\frac{a}{3}}$

$\Rightarrow \quad t_2 = 2$ sec

The required time to transport heat in configuration II is 2 seconds.

63. The stress matrix for a particle is given by

$$\sigma_{ij} = \begin{bmatrix} 40 & 0 & 27 \\ 0 & 20 & 0 \\ 27 & 0 & -32 \end{bmatrix} \text{MPa}$$

where, *i* represents the direction of area, *j* represents the direction of load.

For the given state of stress, the largest possible diameter of Mohr's circle (in MPa) is ______

63. Ans: 90

Sol: Given data,

$\sigma_{xx} = 40$, $\tau_{xy} = 0$

$\sigma_{yy} = 20$, $\tau_{yz} = 0$

$\sigma_{zz} = -32$, $\tau_{xz} = 27$

There is no shear stress in y-direction.

Hence, σ_{yy} is considered to be the principal stress.

$\sigma_{yy} = \sigma_2 = 20$ MPa

$$\sigma_1 = \frac{\sigma_x + \sigma_z}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_z}{2}\right)^2 + \tau_{xz}^2}$$

$$= \frac{40 - 32}{2} + \sqrt{\left(\frac{40 + 32}{2}\right)^2 + (27)^2}$$

$= 4 + 45 = 49$ MPa

$$\sigma_3 = \frac{\sigma_x + \sigma_z}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_z}{2}\right)^2 + \tau_{xz}^2}$$

$= 4 - 45 = -41$ MPa

τ_{max} = largest possible radius of Mohr's circle

$$= \max\left\{\left|\frac{\sigma_1 - \sigma_2}{2}\right|, \left|\frac{\sigma_2 - \sigma_3}{2}\right|, \left|\frac{\sigma_3 - \sigma_1}{2}\right|\right\}$$

Largest possible diameter of Mohr's circle

$= \max \{|\sigma_1 - \sigma_2|, |\sigma_2 - \sigma_3|, |\sigma_3 - \sigma_1|\}$

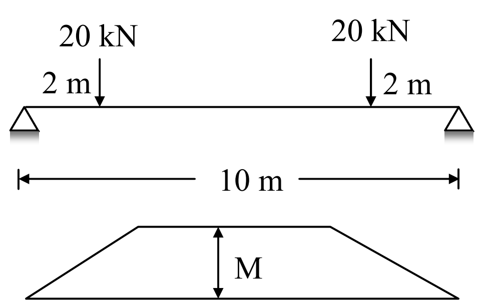
$= \max \{|49 - 20|, |20 + 44|, |-41 - 49|\}$

$= 90$ MPa

64. A simply supported beam of 10 m span is subjected to two point loads of 20 kN each placed at a distance of 2 m from each of the free ends. The cross-section of the beam is 200 mm wide and 400 mm deep. The major principal stress at the middle of the beam at the bottom extreme fibre is _____ MPa. (Rounded to one decimal place)

64. Ans: 7.5

Sol:



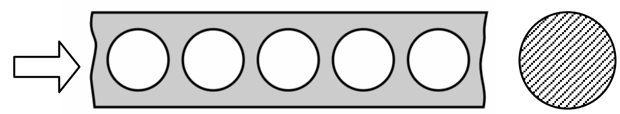
Maximum BM, M = 20 × 2 = 40 kN-m

(at mid span)

At the extreme bottom fibre of the mid span, maximum bending stress is the major principal stress

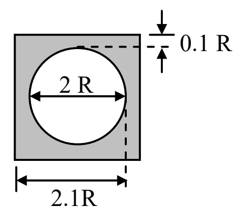
$$F = \frac{M}{I} \times y_{max} = \frac{40 \times 10^6}{\left[\frac{200 \times 400^2}{6}\right]} = 7.5 \text{ MPa}$$

65. The percent scrap in producing round blanks, if the clearance between blanks is one tenth of the radius of the blank of sheet metal as shown in the figure, is ________. (Rounded to two decimal places)



65. Ans: 32% **[Range: 31 to 33]**

Sol:



The area of the unit cell is

$A = (2.2R)(2.1R) = 4.62R^2$

The area of the circle is $3.14R^2$.

∴ The percent of scrap

$= (4.62\,R^2 - 3.14R^2) / 4.62R^2 \times 100$

$= 32\ \%$