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GATE 2022

PRODUCTION & INDUSTRIAL ENGG.

Exam held on **06/02/2022**

Questions & Solutions

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SECTION - A GENERAL APTITUDE

Q.1 Consider the following inequalities.

(i) $3p - q < 4$

(ii) $3q - p < 12$

Which one of the following expressions below satisfies the above two inequalities?

(a) $8 \le p + q < 16$ (b) $p + q = 8$

(c) $p + q \ge 16$ (d) $p + q < 8$

Ans. (d)

Adding both inequalities,

$$2p + 2q < 16$$

$$p + q < 8$$

End of Solution

Q.2 Rice, a versatile and inexpensive source of carbohydrate, is a critical component of diet worldwide. Climate change, causing extreme weather, poses a threat to sustained availability of rice. Scientists are working on developing Green Super Rice (GSR), which is resilient under extreme weather conditions yet gives higher yields sustainably.

Which one of the following is the CORRECT logical inference based on the information given in the above passage?

(a) GSR grows in an extreme weather, but the quantity of produce is lesser than regular rice.

(b) Regular rice will continue to provide good yields even in extreme weather.

(c) GSR is an alternative to regular rice, but it grows only in an extreme weather.

(d) GSR may be used in future in response to adverse effects of climate change.

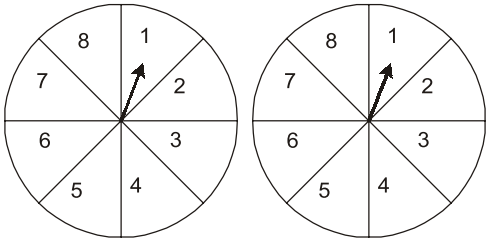
Ans. (d)

GSR may be used in future in response to adverse effects of climate change.

End of Solution

Q.3 A game consists of spinning an arrow around a stationary disk as shown below. When the arrow comes to rest, there are eight equally likely outcomes. It could come to rest in any one of the sectors numbered 1, 2, 3, 4, 5, 6, 7 or 8 as shown. Two such disks are used in a game where their arrows are independently spun.

What is the probability that the sum of the numbers on the resulting sectors upon spinning the two disks is equal to 8 after the arrows come to rest?



(a) $\frac{7}{64}$ (b) $\frac{3}{32}$

(c) $\frac{5}{64}$ (d) $\frac{1}{16}$

Ans. (a)

Probability of getting any number on one disk = $\frac{1}{8}$

As the spins are independent, probability of getting any number on each disc is

$$P = \frac{1}{8} \times \frac{1}{8}$$

Possible outcomes for the sum of 8

$$= \{(1, 7), (2, 6), (3, 5), (4, 4), (5, 3), (6, 2), (7, 1)\}$$

$$\text{Required probability} = \frac{7}{64}$$

End of Solution

Q.4 Pipes P and Q can fill a storage tank in full with water in 10 and 6 minutes, respectively. Pipe R draws the water out from the storage tank at a rate of 34 litres per minute. P, Q and R operate at a constant rate.
If it takes one hour to completely empty a full storage tank with all the pipes operating simultaneously, what is the capacity of the storage tank (in litres)?

(a) 127.5 (b) 120.0

(c) 26.8 (d) 60.0

Ans. (b)

Let the capacity of storage tank is x liters. Amount of water drawn only by pipe R in one minute is

$$\frac{x}{60} + \left(\frac{x}{6} + \frac{x}{10}\right) = +\frac{17x}{60}$$

Total time taken by R to draw water from the storage tank

$$= \frac{x}{\frac{17x}{60}} = \frac{60}{17}\text{min}$$

$$\text{Capacity of tank} = \frac{60}{17} \times 34 = 120 \text{ liters}$$

End of Solution

Q.5 Inhaling the smoke from a burning _____ could _____ you quickly.

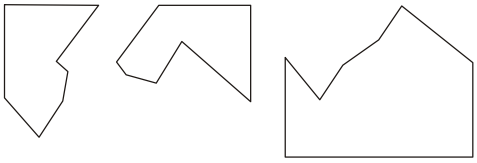
(a) tyre / tier (b) tire / tier

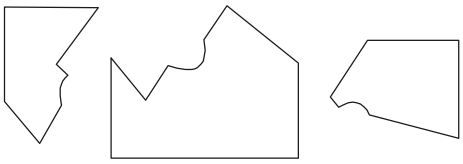
(c) tyre / tire (d) tire / tyre

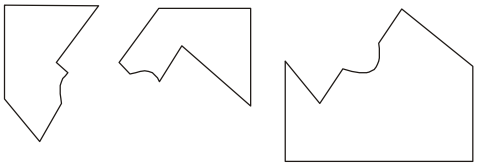
Ans. (c)

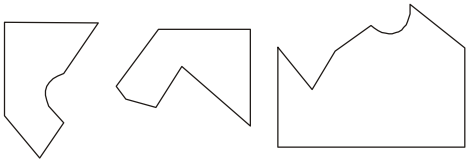
End of Solution

Q.6 Which one of the following sets of pieces can be assembled to form a square with a single round hole near the center? Pieces cannot overlap.

(a) 

(b) 

(c) 

(d) 

Ans. (c)

End of Solution

Q.7 A sphere of radius r cm is packed in a box of cubical shape.
What should be the minimum volume (in cm^3) of the box that can enclose the sphere?

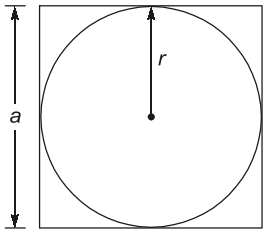
(a) r^3

(b) $8r^3$

(c) $\frac{r^3}{8}$

(d) $2r^3$

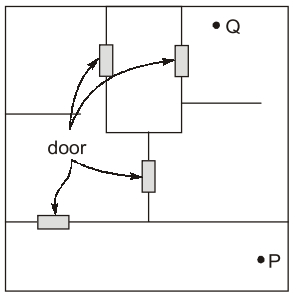
Ans. (b)



Side of cube = Diameter of sphere
$a = 2r$
Volume of cube = $(2r)^3$
$= 8r^3$

End of Solution

Q.8 A building has several rooms and doors as shown in the top view of the building given below. The doors are closed initially.
What is the minimum number of doors that need to be opened in order to go from the point *P* to the point *Q*?



(a) 4
(b) 1
(c) 2
(d) 3

Ans. (c)

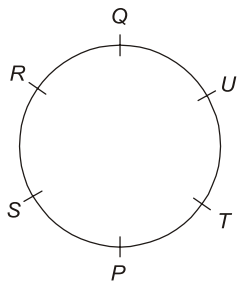
End of Solution

Q.9 Six persons *P*, *Q*, *R*, *S*, *T* and *U* are sitting around a circular table facing the center not necessarily in the same order. Consider the following statements:

- *P* sits next to *S* and *T*.
- *Q* sits diametrically opposite to *P*.
- The shortest distance between *S* and *R* is equal to the shortest distance between *T* and *U*.

Based on the above statements, *Q* is a neighbor of
(a) *P* and *S*
(b) *R* and *U*
(c) *U* and *S*
(d) *R* and *T*

Ans. (b)



End of Solution

Q.10 Given below are three statements and four conclusions drawn based on the statements.

Statement 1: Some engineers are writers.
Statement 2: No writer is an actor.
Statement 3: All actors are engineers.

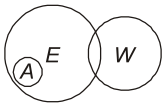
Conclusion I: Some writers are engineers.
Conclusion II: All engineers are actors.
Conclusion III: No actor is a writer.
Conclusion IV: Some actors are writers.

Which one of the following options can be logically inferred?

(a) Only conclusion I and conclusion III are correct
(b) Only conclusion II and conclusion III are correct
(c) Only conclusion I is correct
(d) Either conclusion III or conclusion IV is correct

Ans. (a)

E : Engineers
W : Writers
A : Actors



End of Solution

■■■■

SECTION - B TECHNICAL

Q.1 In an electro-discharge machining process, the discharge voltage is V_b. Tlie energy dissipated per spark across the inter-electrode gap is proportional to

(a) $V_b^{0.5}$ (b) V_b^3

(c) V_b^2 (d) V_b

Ans. (c)

As we know that energy released per spark across the inter electrode gap (IEG) is

$$E = \frac{1}{2}CV_d^2$$

where V_d = breakdown voltage or discharge voltage

So, $E \propto V_d^2$

End of Solution

Q.2 A company procures 384 parts annually. The annual holding cost per part is ₹30. If the ordering cost is ₹1000, then the economic order quantity is_____. [in integer]

Ans. (160) (160 to 160)

Given, Annual Demand, D = 384 parts

Holding cost, C_h = ₹30

Ordering cost, C_o = ₹1000

Economic order quantity is given as,

$$\Rightarrow \quad EOQ = \sqrt{\frac{2DC_o}{C_h}} = \sqrt{\frac{2\times 384\times 1000}{30}}$$

$$\Rightarrow \quad EOQ = \sqrt{25600} = 160 \text{ parts}$$

End of Solution

Q.3 The numerical integration of the function $y = 2x + 5$ is carried out between $x = 1$ and $x = 3$. by using ordinates at $x = 1$, 2 and 3. Which one of the following statements is TRUE?

(a) Neither Simpson's 1/3 rule nor trapezoidal rule will provide exact result.

(b) Simpson's 1/3 rule will provide exact result but trapezoidal rule will not.

(c) Trapezoidal rule will provide exact result but Simpson's 1/3 rule will not.

(d) Both Simpson's 1/3 and trapezoidal rules will provide exact result.

Ans. (c)

Given function, $y = 2x + 5$

This is a polynomial of degree 1

Trapezoidal rule will give exact value for polynomial of degree 1, while Simpson's 1/3 rule will give exact value for polynomial of degree 2.

End of Solution

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Q.4 A company buys a machine worth ₹65000, which has a salvage value of ₹5000. The annual depreciation cost is ₹10000 based on the straight line depreciation method. The useful life (in year) of the machine is_____. [in integer]

Ans. **(6) (6 to 6)**

Given,

Cost of machine, C = ₹ 65,000

Salvage value, S = ₹ 5000

Annual depreciation, D = ₹ 10,000

$\Rightarrow$ Total depreciation cost, $T = C - S$

$\Rightarrow$ T = 65000 – 5000 = ₹ 60,000

$\Rightarrow$ Useful life of the machine = $\frac{60,000}{10,000} = 6$ years

End of Solution

Q.5 In a manufacturing system, four different types of products (P, Q, R and S) are produced. The batch size of each product is 2×10^7. The numbers of defective units are 60, 71, 80 and 55, for P, Q, R and S, respectively. Which one of the following statements is TRUE?

(a) Except R, all other products conform to six sigma standard.

(b) All products conform to six sigma standard.

(c) Products P and S conform to six sigma standard.

(d) Only product S conforms to six sigma standard.

Ans. **(c)**

For six sigma : 3.4 errors per million.

So, in 20 million 68 or less error or defects.

Products P and S have less defects i.e. 60 and 55 than 68 so products P and S conform to six sigma standard.

End of Solution

Q.6 The absolute deviations of 8 points from the datum line of a surface are 10, 15, 12, 10, 13, 12, 20 and 25 μm. The root mean square value of the surface roughness (in μm) is_____. [round off to one decimal place]

Ans. **(15.4)(15.3 to 15.5)**

Absolute deviations: 10, 15, 12, 10, 13, 12, 20 and 25 μm

Root mean square (RMS)

$$R_{rms} = \sqrt{\frac{\Sigma\left[h^2\right]_{i=1}^{n}}{n}}$$

$$= \sqrt{\frac{10^2 + 15^2 + 12^2 + 10^2 + 13^2 + 12^2 + 20^2 + 25^2}{8}}$$

$$= 15.439 \approx 15.4$$

End of Solution

Q.7 Matrix A as product of two other matrices is given by

$$A = \begin{bmatrix} 3 \\ 2 \end{bmatrix} [1 \quad 4].$$

The value of det(A) is_____. [round off to nearest integer]

Ans. (0)(0 to 0)

Given, $A = \begin{bmatrix} 3 \\ 2 \end{bmatrix}_{2\times 1} [1 \quad 4]_{1\times 2}$

$$A = \begin{bmatrix} 3 & 12 \\ 2 & 8 \end{bmatrix}$$

Thus, $|A| = 24 - 24 = 0$

End of Solution

Q.8 Air at an initial temperature and pressure of 15°C and 1 bar, respectively is heated in an irreversible process. The final temperature and pressure are 303°C and 2 bar, respectively. Take gas constant for air as R = 287 J/kg-K, the ratio of the specific heats as γ = 1.4, and treat air as a calorically perfect gas. The change of entropy (in J/kg-K) in the process is_____. [round off to nearest integer]

Ans. (497) (496 to 450)

$$T_1 = 15°C = 288\ K$$
$$P_1 = 1\ bar = 100\ kPa$$
$$T_2 = 303°C = 576\ K$$
$$P_2 = 2\ bar = 200\ kPa$$
$$R = 287\ J/kg\text{-}K$$
$$\gamma = 1.4$$
$$C_p = \frac{R\gamma}{\gamma - 1} = 1004.5\ J/kg\text{-}k$$
$$(\Delta S)_{irr} = (\Delta S)_{rev}$$
$$\Delta S = C_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}$$
$$= 1004.5\ln\frac{576}{288} - 287\ln\frac{200}{100}$$
$$= 497.33\ J/kg\text{-}k$$

End of Solution

Q.9 If $\vec{a}$, $\vec{b}$ and $\vec{c}$ are three vectors, the vector triple product $(\vec{a}\times\vec{b})\times\vec{c}$ is given by

(a) $(\vec{a}\cdot\vec{b})\vec{c} - (\vec{a}\cdot\vec{c})\vec{b}$

(b) $(\vec{a}\cdot\vec{c})\vec{b} - (\vec{b}\cdot\vec{c})\vec{a}$

(c) $(\vec{b}\cdot\vec{c})\vec{a} - (\vec{a}\cdot\vec{c})\vec{b}$

(d) $(\vec{a}\cdot\vec{c})\vec{b} - (\vec{a}\cdot\vec{b})\vec{c}$

Ans. (b)

Vector triple product is given by,

$$(\vec{a}\times\vec{b})\times\vec{c} = (\vec{a}\cdot\vec{c})\vec{b}-(\vec{b}\cdot\vec{c})\vec{a}$$

End of Solution

Q.10 A shaft is used to transmit a power of 10 kW. The shear yield stress of the material is 150 MPa and factor of safety is 2. The shaft rotates at 1440 revolutions per minute. The diameter of the shaft (in mm) based on static strength is_____. [round off to two decimal places]

Ans. (16.51) (16.20 to 16.70)

$$\text{Power} = 10 \text{ kW}$$
$$\tau_{material} = 150 \text{ MPa}$$
$$\text{FOS} = 2$$
$$N = 1440 \text{ rpm}$$
$$d = ?$$
$$P = \frac{2\pi NT}{60}$$
$$T = \frac{60\times P}{2\pi\times N} = \frac{60\times 10{,}000}{2\pi\times 1440} = 66.314 \text{ N-m}$$
$$\tau = \frac{16T}{\pi d^3}$$
$$\tau = \frac{16\times 66.314\times 10^3}{\pi d^3}$$
$$\tau \le \frac{\tau_{material}}{\text{FOS}}$$
$$\frac{16\times 66.314\times 10^3}{\pi d^3} \le \frac{150}{2}$$
$$\Rightarrow \quad d \ge 16.51 \text{ mm}$$

End of Solution

Q.11 If G denotes the shear modulus of an isotropic material, then the maximum possible value of Young's modulus of the material is

(a) $4G$ (b) G

(c) $3G$ (d) $2G$

Ans. (c)

$$E = 3G(1-2\mu)$$
$$E_{max} = 3G \quad \text{at } \mu = 0$$

End of Solution

Q.12 Match the processing steps related to production of powder metallurgy parts with their descriptions.

Processing step	Description
P. Atomization	1. Blended powders are pressed into shapes using dies and pressure.
Q. Sintering	2. A process for producing metal powder
R. Compaction	3. Metal powders are heated below their melting points to allow bonding.
S. Infiltration	4. A slug of low melting point metal is placed in contact with the sintered part and heated.
	5. Metal powders are heated significantly above their melting point for bonding.

(a) P-1, Q-5, R-2, S-3
(b) P-2, Q-5, R-1, S-4
(c) P-3, Q-2, R-1, S-5
(d) P-2, Q-3, R-1, S-4

Ans. (d)

In sintering metal powders are heated below their melting points to allow bonding, it generally heated to $0.75 \times T_{melt}$.

Infiltration is an operation in which the pores of the powder metallurgy part are filled with molten metal. The melting point of the filler metal must be below that of the powder metallurgy part.

This implies option (d) as correct answer.

End of Solution

Q.13 In a gas tungsten arc welding process under steady state condition, the input voltage and current are measured as 18 V and 160 A, respectively. Heat loss during creation of arc is 40% of the input power. Heat loss through convection and radiation from the workpiece is 800 W. The effective power (in W) utilized to melt the workpiece is_____. [round off to nearest integer]

Ans. (928) (928 to 928)

Given: Input voltage, $V = 18$ V

Input current, $I = 160$ A

$\eta_h = 0.6$ (40% losses on arc)

Heat losses through convection and radiation from workpiece,

$H_L = 800$ W

Heat supplied, $H_s = VI \times \eta_h$

$= 18 \times 160 \times 0.6 = 1728$ W

Heat losses $= H_s - H_m$

$800 = 1728 - H_m$

$H_m = 1728 - 800 = 928$ W

End of Solution

Q.14 During straight turning of a 20 mm diameter steel bar at a spindle speed of 400 revolutions per minute (RPM) with an HSS tool, a tool life of 10 minute was observed. When the same bar was turned at 200 RPM, the tool life increased to 40 minute. The tool life (in minute) while machining the bar at 300 RPM is____. [round off to nearest integer]

Ans. **(18) (17 to 18)**

Given: $d = 20$ m, $N_1 = 400$ rpm, $N_2 = 200$ rpm,
`Tool life, $T_1 = 10$ min, $T_2 = 40$ min
If, $N_3 = 300$ rpm
$T_3 = ?$
We know that by Taylor's tool life equation

$$VT^n = \text{constant}$$

So, $$V_1T_1^n = V_2T_2^n$$

$$\pi dN_1 \times T_1^n = \pi dN_2 \times T_2^n$$

$$\Rightarrow \quad N_1T_1^n = N_2T_2^n$$

$$400 \times 10^n = 200 \times 40^n$$

$$2 = 4n$$

$$\Rightarrow \quad n = \frac{1}{2} = 0.5$$

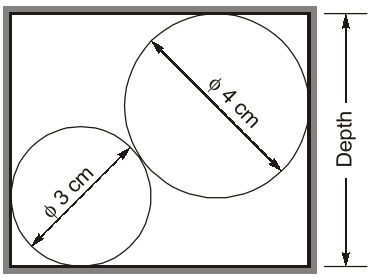
Now again, $$N_2T_2^n = N_3T_3^n$$

$$200 \times 40^{0.5} = 300 \times T_3^{0.5}$$

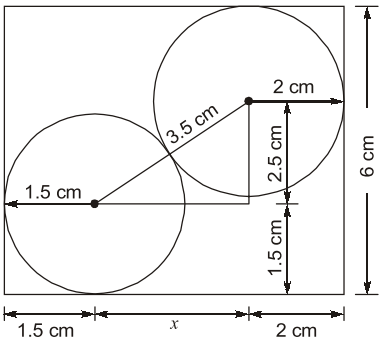
$$\Rightarrow \quad T_3 = 17.77 \text{ min} \approx 18 \text{ min}$$

End of Solution

Q.15 The diameter of a cylindrical cavity is measured by using two spherical steel balls of diameters 3 cm and 4 cm. The balls are placed inside the cavity such that the bigger ball is above the smaller one as shown in the figure. If the depth of cavity is 6 cm, then the diameter (in cm) of cavity is_____. [round off to two decimal places]



Ans. (5.94) (5.90 to 5.99)



$$x = \sqrt{3.5^2 - 2.5^2} = 2.44\,\text{cm}$$

Diameter of cavity = 1.5 + 2.44 + 2 = 5.94 cm

End of Solution

Q.16 An operator manufactures 10 identical spur sears in a lot. One spur gear is defective in the lot. Three spur gears are drawn at random without replacement. The probability of getting all three gears as non-defective is_____. [round off to two decimal places]

Ans. (0.70) (0.70 to 0.70)

Probability that the 1st gear drawn is non-defective, $P_1 = \frac{9}{10}$

Probability that the 2nd gear drawn is non-defective, $P_2 = \frac{8}{9}$

Probability that the 3rd gear drawn is non-defective, $P_3 = \frac{7}{8}$

Thus, the required probability is

$$P_1 \times P_2 \times P_3 = \frac{9}{10} \times \frac{8}{9} \times \frac{7}{8} = \frac{7}{10} = 0.70$$

End of Solution

Q.17 It is required to cut a single-start thread of 2 mm pitch in a lathe machine with a single-start lead screw of 4 mm pitch. For one revolution of the workpiece, the number of revolution of the lead screw is_____. [round off to two decimal places]

Ans. (0.50) (0.50 to 0.50)

Single start thread		Lead screw
$p_s = 2$ mm		$p_L = 4$ mm
$n_s = 1$ mm		$n_L = 1$

Let, N_s = Spindle/workpiece revolution = 1

N_L = Lead screw revolution

$\because$ $N_s \times p_s \times n_s = N_L \times n_L \times p_L$

$1 \times 2 \times 1 = N_L \times 1 \times 4$

$$N_L = \frac{2}{4} = 0.50$$

End of Solution

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Total Marks : 100 | Negative Marking : 0.66 Marks

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Q.18 Yielding starts in a material when the principal stresses are 100 MPa, 100 MPa and 200 Mpa. As per the von Mises criterion, yield stress (in MPa) of the material is_____. [round off to nearest integer]

Ans. (100) (100 to 100)

Given, $\sigma_1 = 100$ MPa; $\sigma_2 = 100$ MPa, $\sigma_3 = 200$ MPa

As per Von mises criterion,

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \le 2\left(\frac{S_{yt}}{N}\right)^2$$

$$(100 - 100)^2 + (100 - 200)^2 + (200 - 100)^2 \le 2\left(\frac{S_{yt}}{1}\right)^2$$

$$\Rightarrow \quad 0 + 100^2 + 100^2 \le 2\,(S_{yt})^2$$

$$\Rightarrow \quad 2 \times 100^2 \le 2(s_{yt})^2$$

$$\Rightarrow \quad S_{yt} \ge 100 \text{ MPa}$$

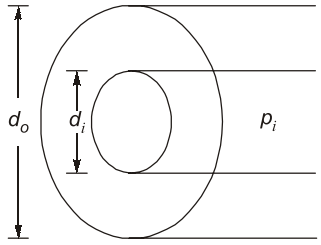
End of Solution

Q.19 A thick-cylinder has inner diameter of 20 mm and outer diameter of 40 mm. It is subjected to an internal pressure of 100 MPa. Follow the convention of taking tensile stress as positive and compressive stress as negative. The stun of radial and hoop stresses (in MPa) at a radius of 15 mm is_____. [round off to two decimal places]

Ans. (66.66)

Thick cylinder, $d_i = 20$ mm

$d_o = 40$ mm



Internal pressure, $p_i = 100$ MPa

$$\sigma_r = \frac{r_i^2 \times p_i}{r_o^2 - r_i^2}\left(1 - \frac{r_o^2}{r^2}\right)$$

$$\sigma_\theta = \frac{r_i^2 \times p_i}{r_o^2 - r_i^2}\left(1 + \frac{r_o^2}{r^2}\right)$$

$$\sigma_r + \sigma_\theta\big|_{r=15\,mm} = \frac{2 \times r_i^2 \times p_i}{r_o^2 - r_i^2} = \frac{2 \times 10^2 \times 100}{20^2 - 10^2} = 66.66 \text{ MPa}$$

End of Solution

Q.20 A project comprises of seven activities. The expected durations of activities and their variances are as follows:

Activity	Expected duration (minutes)	Variance (minute)
A	4	1
B	5	1
C	4	1
D	1	0
E	7	4
F	6	1
G	8	4

The critical path consists of activities *B*, *E* and *G*. The standard deviation (in minute) of the project duration is_____. [round off to two decimal places]

Ans. **(3) (3 to 3)**

Variances along critical paths are,

$$V_B = 1,\ V_E = 4,\ V_G = 4$$

$\therefore$ Total variance, $V = V_B + V_E + V_G$

$\Rightarrow$ $V = 1 + 4 + 4 = 9$

$\therefore$ Standard deviation, $\sigma = \sqrt{V} = \sqrt{9} = 3$

End of Solution

Q.21 Match the processes of product development with their characteristics.

Process	Characteristic
P. Product synthesis	1. Process of conversion of conceptual design into engineering science based model.
Q. Product simplification	2. Process related to design conceptualization.
R. Product analysis	3. Process of maintaining uniformity and consistency.
S. Product standardization	4. Process of reducing the number of parts without losing the functionalities.

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

Ans. **(b)**

Product synthesis relates to the process at design conceptualization.

Product simplication refers to reducing the number of parts in a machine without lasing the functionalities.

Product analysis refers to process of conversion of conceptual design into engineering science-based model.

Product standardisation refers to process of maintaining uniformity and consistency.

End of Solution

Q.22 Which one of the following metals has a face-centered cubic (FCC) structure?

(a) Chromium (b) Magnesium
(c) Aluminium (d) Alpha iron

Ans. (c)

Metals	Structure
Chromium	→ BCC (at room temperature)
Magnesium	→ HCP
Aluminium	→ FCC
Alpha iron	→ BCC

End of Solution

Q.23 Match the types of layout with the types of production.

Type of layout	Type of production
P. Process layout	1. Job production
Q. Product layout	2. Batch production
R. Fixed position layout	3. Mass production

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

Ans. (d)

In process layout, the machines are arranged according to the nature or the type of the operations. This layout is suitable for non-repetitive jobs.
In product layout, only are product of one type is produced as a mass scale.
In fixed position layout all machines, operators, tools etc. are brought at one location for the job.

End of Solution

Q.24 Match the codes used in CNC part programming with their functions.

Code	Function
P. G91	1. End of program
Q. M02	2. Programming in incremental coordinates
R. G32	3. Spindle stop
S. M05	4. Thread cutting in turning

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

Ans. (b)

G91 → Programming in incremental cordinates.
M02 → Program stop/End of program
M05 → Spindle stop
This implies option (b).

End of Solution

Q.25 A time study engineer recorded the cycle time (in minute) for machining of a component. The recorded time study data is provided in the table. The performance rating of the worker is 110%. The standard time for machining (in minute) the component by assuming 10% allowance is _____. [round off to nearest integer]

Time study data	
Cycle time (minute)	**Frequency**
42	1
43	2
44	3
45	2
46	1

Ans. **(53) (51 to 55)**

Operating time is given by

$$OT = \frac{42+43\times2+44\times3+45\times2+46}{9} = 44 \text{ minutes}$$

$$\text{Normal time (NT)} = OT \times \text{Rating factor}$$
$$= 44 \times 1.1 = 48.4 \text{ minutes}$$

Now standard time is given as,

$$ST = NT + \text{allowances}$$
$$= 48.4 + 10\% \text{ of } 48.4$$
$$= 53.24 \approx 53$$

End of Solution

Q.26 A eutectoid steel with 100% austenite is cooled from a temperature of 750°C to a room temperature of 35°C. Match the cooling methods with transformed structures.

Cooling method	Transformed structure
P. Water quenching	1. Coarse pearlite
Q. Oil quenching	2. Fine pearlite
R. Air cooling	3. Martensite
S. Furnace cooling	4. Very fine pearlite

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

Ans. **(d)**

By water quenching martensite forms
By oil quenching very fine pearlite forms
By air cooling fine pearlite forms
By furnace cooling coarse pearlite forms

End of Solution

Q.27 During a hot-working process, the homologous temperature is 0.8. The melting point of the work metal is 800°C. The temperature (in °C) during hot-working is _____. [round off to nearest integer]

Ans. **(585) (585 to 586)**

Given: Melting temperature T_{melt} = 800°C = 1073 K

Homologous temperature = 0.8

So, temperature during hot working = 0.8 × 1073

= 858.4 K

= (858.4 – 273)°C

= 585.4 ≈ 585°C

End of Solution

Q.28 Consider the following ordinary differential equation:

$$4\frac{d^2y}{dx^2} - 4\frac{dy}{dx} + y = 0$$

Given that c_1 and c_2 are constants, the general solution of the differential equation is

(a) $y = (c_1 + c_2x)e^{x/2}$ (b) $y = (c_1 + c_2x)e^{x}$

(c) $y = c_1e^{x/2} + c_2e^{x}$ (d) $y = c_1e^{x} + c_2e^{2x}$

Ans. **(a)**

Given differential equation,

$$4\frac{d^2y}{dx^2} - 4\frac{dy}{dx} + y = 0$$

Corresponding auxilliary equation,

$$4m^2 - 4m + 1 = 0$$

$$m = \frac{-(-4) \pm \sqrt{(-4)^2 - 4(4)(1)}}{2(4)}$$

$$m = \frac{4 \pm \sqrt{16-16}}{8} = \frac{1}{2}, \frac{1}{2}$$ (real and equal roots)

Thus, the general solution is given by,

$$y = (C_1 + xC_2)e^{x/2}$$

End of Solution

Q.29 A company forecasts the weekly demand of oxygen cylinders using exponential smoothing method with smoothing constant $\alpha = 0.2$. The actual demands in Week 1, Week 2, Week 3 and Week 4 were 375, 412, 592 and 439 units, respectively. The forecasted demand for Week 3 was 500 units. The forecast (in unit) for the Week 5 is_____.[in integer]

Ans. **(503) (503 to 503)**

Given: D_1 = 375, D_2 = 412, D_3 = 592, D_4 = 439 as the demand in units for week 1, 2, 3 and 4 respectively.

$$F_3 = 500$$

as the forecast for week 3.

Calculation of forecast for week 4,

$$F_4 = F_3 + \alpha (D_3 - F_3)$$
$$= 500 + 0.2(592 - 500)$$
$$= 518.4 \text{ units}$$
$$F_5 = F_4 + \alpha (D_4 - F_4)$$
$$= 518.4 + 0.2(439 - 518.4)$$
$$= 518.4 - 15.88 = 502.52$$
$$\approx 503 \text{ units}$$

End of Solution

Q.30 Which one of the following statements is TRUE?

(a) Concurrent engineering carries out all product development functions in a sequential manner.

(b) Concurrent engineering is a non-integrated approach for designing a product.

(c) Concurrent engineering reduces the lead time for the product development.

(d) Concurrent engineering increases the lead time for the product development.

Ans. (c)

Concurrent engineering is a method of developing products in which different stages are worked simultaneously.

It is an integrated approach and reduces the lead time.

End of Solution

Q.31 Match the casting methods with products.

Casting method	Products
P. Continuous casting	1. Thin and intricate shaped components
Q. Investment casting	2. Hollow axisymmetric parts (such as pipes)
R. Centrifugal casting	3. Slabs and strips

(a) P-3, Q-1, R-2

(b) P-3, Q-2, R-1

(c) P-2, Q-3, R-1

(d) P-2, Q-1, R-3

Ans. (a)

End of Solution

Q.32 A vaccine has to be distributed from two warehouses to three hospitals. The supplies at warehouses W_1 and W_2 are 200 and 150, respectively. The demands at hospitals H_1, H_2 and H_3 are 100, 150 and 125, respectively. The transportation cost (in ₹) per vaccine is as follows:

	H_1	H_2	H_3
W_1	5	7	3
W_2	4	6	7

The initial basic feasible solution using the Northwest-corner method provides the total transportation cost (in ₹) as _____. [round off to nearest integer]

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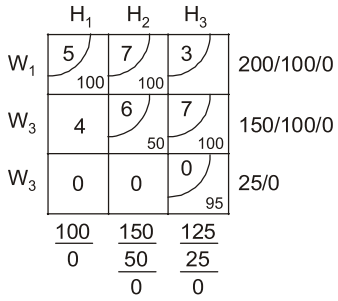
Ans. (2200)

The given problem is unbalanced. To balance the problem, we need to add a dummy row.



Total transportation cost is given by

$\Rightarrow$ $5 \times 100 + 7 \times 100 + 6 \times 50 + 7 \times 100 + 0 \times 25$

$\Rightarrow$ ₹ 2200

End of Solution

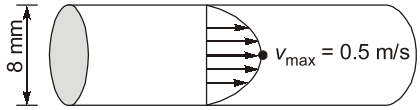
Q.33 Water (kinematic viscosity $\nu = 1 \times 10^{-6}$ m^2/s) is flowing through a circular horizontal pipe of diameter 8 mm. If the flow is laminar and fully developed with a maximum axial velocity of 0.5 m/s, the Reynolds number is_____. [round off to nearest integer]

Ans. (2000) (2000 to 2000)

Given: Kinematic viscosity, $\nu = 1 \times 10^{-6}$ m^2/sec

Diameter of pipe, $D = 8$ mm $= 8 \times 10^{-3}$ m

Maximum velocity, $v_{max} = 0.5$ m/sec



The average velocity is half of the maximum velocity for fully-developed laminar flow in a pipe.

$$v_{avg} = 0.5\ v_{max} = 0.5 \times 0.5 = 0.25 \text{ m/sec}$$

Reynolds number is given by,

$$Re = \frac{\rho v_{avg} D}{\mu} = \frac{v_{avg} D}{\nu}$$

$$= \frac{0.25 \times 8 \times 10^{-3}}{1 \times 10^{-6}} = 2000$$

End of Solution

Q.34 A cylindrical workpiece is turned using two different tools. Tool 1 has zero nose radius; side and end cutting edge angles are 20° and 10°, respectively. Tool 2 has 0.5 mm nose radius. Both the tools machine at a feed of 0.2 mm/rev. The ratio of ideal maximum height of unevenness on the surface produced by Tool 1 to that produced by Tool 2 is _____. [round off to one decimal place]

Ans. (3.3) (3.2 to 3.4)

For tool 1:

Nose radius $R_1 = 0$

Side cutting edge angle, $C_s = 20°$

End cutting edge angle, $C_e = 10°$

Feed, $f = 0.2$ mm/rev

For tool 2:

Nose radius $R_2 = 0.5$ mm

Feed, $f = 0.2$ mm/rev

As we know that (for nose radius = 0)

$$h_{max1} = \frac{f}{\tan C_s + \cot C_e} = \frac{0.2}{\tan 20° + \cot 10°}$$

$$h_{max1} = 0.03313 \text{ mm} = 33.13 \ \mu\text{m}$$

$$h_{max2} = \frac{f^2}{8R_2} = \frac{(0.2)^2}{8 \times 0.5} = 0.010 = 10 \ \mu\text{m}$$

$$\frac{h_{max1}}{h_{max2}} = \frac{33.13}{10} = 3.3$$

End of Solution

Q.35 The worktable of an open loop positioning system is driven by a lead screw with a pitch of 4 mm. The lead screw is connected to the shaft of a stepper motor. A gear of 80 teeth mounted on the stepper motor shaft meshes with a gear of 20 teeth mounted on the lead screw. The step angle of the stepper motor is 9°. The number of pulses required to move the table by 200 mm is_____. [in integer]

Ans. (8000) (8000 to 8000)

Given: Pitch = 4 mm, Gear ratio, $\frac{20}{80} = 1:4$, step angle = 9°

So, Number of pulses/revolution = $\frac{360°}{9°} = 40$ pulses/rev

1 mm of table gives 360° of motor and 90° of lead screw.

So, for 200 mm of table it gives 200 revolution.

⇒ Number of pulses required = 200 × 40 = 8000 pulses

End of Solution

Q.36 Consider the linear programming problem:

Maximize $z = 20x_1 + 6x_2 + Px_3$,

subject to

$8x_1 + 2x_2 + 3x_3 \le 250$, (C_1)

$4x_1 + 3x_2 \le 150$, (C_2)

$2x_1 + x_3 \le 50$, (C_3)

$x_1, x_2, x_3 \ge 0$.

The optimal solution is given as $x_1^* = 0, x_2^* = 50$ and $x_3^* = 50$. The dual variables of constraints C_1, C_2 and C_3 are y_1, y_2 and y_3, respectively. The optimal values of dual variables are $y_1^* = 0, y_2^* = 2$ and $y_3^* = 8$. The value of parameter P in the objective function is _____. [round off to one decimal place]

Ans. **(8) (8 to 8)**

From the data given,

$$\text{Max}Z\,(\text{primal}) = \text{min}Z\,(\text{dual})$$

$$\Rightarrow \quad 20x_1 + 6x_2 + Px_3 = 250y_1 + 150y_2 + 50y_3$$

$$\Rightarrow 20 \times (0) + 6(50) + P(50) = 250(0) + 150(2) + 50(8)$$

$$0 + 300 + 50P = 0 + 300 + 400$$

$$300 + 50P = 700$$

$$50P = 400$$

$$P = 8$$

End of Solution

Q.37 A single-point cutting tool with zero rake angle is used for orthogonal machining. If the chip-compression ratio is 1.25, then the shear angle (in degree) during machining is _____. [round off to one decimal place]

Ans. **(38.7) (38.6 to 38.7)**

Given: Chip compression ratio, $h = \dfrac{1}{r} = 1.25$

Where, r = Chip thickness ratio

$$\Rightarrow \quad r = \frac{1}{1.25} = 0.8$$

$$\text{Rake angle} = 0°$$

$$\text{Shear angle, } \phi = ?$$

So,
$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} = \frac{r\cos 0°}{1 - r\sin 0°}$$

$$\tan\phi = r = 0.8$$

$$\Rightarrow \quad \phi = \tan^{-1}(0.8)$$

$$= 38659 \approx 38.7$$

End of Solution

Q.38 The control chart for a number of defects in a welded joint is

(a) c – chart (b) R – chart

(c) p – chart (d) $\bar{X}$ – chart

Ans. **(c)**

p-chart is used for the number of deflectives of a particular body.

End of Solution

Q.39 A market survey with a sample size of 1000 was conducted for a parameter that follows normal distribution. The confidence interval was estimated as [500, 700] with a mean of 600. It is now desired to reduce the confidence interval to [550, 650]. The sample size for achieving the desired interval at the same confidence level is

(a) 1000 (b) 4000
(c) 9000 (d) 16000

Ans. (b)

Given: Sample size of first survey, $n_1 = 1000$

First confidence interval, $C_1 = 700 - 500 = 200$

Second confidence interval, $C_2 = 650 - 550 = 100$

Mean of confidence intervals,

$$S_1 = \frac{700+500}{2} = 600\,; \quad S_2 = \frac{650+550}{2} = 600$$

Since confidence level is same in both cases,

$$\Rightarrow \quad z_1 = z_2$$

$$0.5 \times C_1 \times \frac{\sqrt{n_1}}{S_1} = 0.5 \times C_2 \times \frac{\sqrt{n_2}}{S_2}$$

$$\Rightarrow \quad 0.5 \times 200 \times \frac{\sqrt{1000}}{600} = 0.5 \times 100 \times \frac{\sqrt{n_2}}{600}$$

$$200\sqrt{1000} = 100\sqrt{n_2}$$

Squaring both sides,

$$n_2 = \frac{200^2 \times 1000}{1000} = 4000$$

End of Solution

Q.40 In injection blow molding of plastic beverage bottles, the blowing is accomplished by

(a) hot oil (b) hot air
(c) hot water (d) alcohol

Ans. (b)

Injection blow moulding process is used to produce hollow objects madeup of plastic. To hollow cavity air, hot air, inert gas will be foced with high pressure.

End of Solution

Q.41 Match the therblig symbols with their meanings.

Therblig symbol		Meaning
P.		1. Rest for overcoming fatigue
Q.		2. Avoidable delay

R. 

3. Inspect

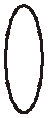
S. 

4. Search

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

Ans. (b)

Therbligs refer primarily to the motions of the human body at the work place and to the mental activities associated with them. Following Therblig symbols have their meaning attached:

	Denotes search
	Denotes inspection
	Denotes rest for overcoming fatigue
	Denotes avoidable delay

End of Solution

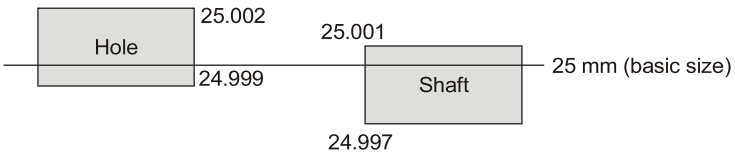
Q.42 In an assembly comprising shaft and hole, the nominal sizes with tolerances are specified as

Hole: $25.000^{+0.002}_{-0.001}$ mm, Shaft: $25.000^{+0.001}_{-0.003}$ mm,

The type of fit is

(a) Transition fit
(b) Interference fit
(c) Running fit
(d) Clearance fit

Ans. (a)



As both tolerance zone overlapping each other so this is a transition fit.

End of Solution

Q.43 A workpiece of 30 mm diameter and 40 mm height is compressed between two platens in an open die forging process. Assume a perfectly plastic material with a flow stress of 300 MPa. The ideal forging load (in kN) at 30% reduction (in height) is _____. [round off to nearest integer]

Ans. **(303)**

$d_0 = 30$ mm; $h_0 = 40$ mm; $\sigma_0 = 300$ MPa;

$$h_f = 0.7\ h_0 \text{ (30\% reduction)}$$

$$h_f = 0.7 \times 40 = 28 \text{ min}$$

$$\text{Forging load} = \sigma_0 \times A_f$$

In forging load calculation always we have to consider final area.

$$F = \sigma_0 \times A_f$$

$$= 300 \times \frac{\pi}{4} d_f^2$$

$$\frac{\pi}{A} d_0^2 h_0 = \frac{\pi}{4} d_f^2 h_f$$

$$(30)^2 \times 40 = d_f^2 \times 28$$

$$d_f = 35.857 \text{ mm}$$

$$F = 300 \times \frac{\pi}{4} (35.857)^2$$

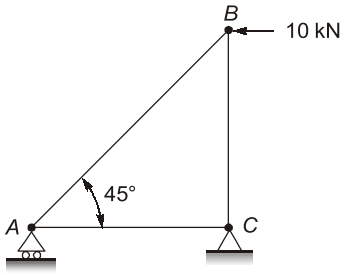
$$F = 302{,}788.11 \text{ N}$$

$$F = 302.788 \text{ kN}$$

$$F = 303 \text{ kN}$$

End of Solution

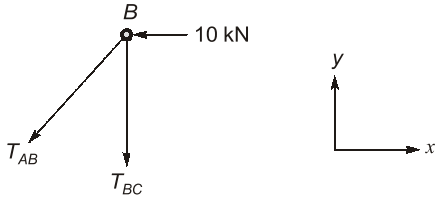
Q.44 In the three-member truss shown in the figure, $AC = BC$. An external force of 10 kN is applied at B, parallel to AC. The force in the member BC is



(a) 10 kN (compressive)
(b) 7.07 kN (tensile)
(c) 10 kN (tensile)
(d) zero

Ans. **(c)**

It joint B,



than $\Sigma F_X = 0$

$$\Rightarrow \quad T_{AB} \sin 45° + 10 = 0$$

$$\Rightarrow \quad T_{AB} = \frac{-10}{\sin 45^\circ} = -10\sqrt{2}$$

(–ve sign represent opposite sense or compressive)

and $\Sigma Fy = 0$

$$\Rightarrow \quad T_{AB}\cos 45^\circ + T_{BC} = 0$$

$$\Rightarrow \quad -10\sqrt{2} \times \frac{1}{\sqrt{2}} + T_{BC} = 0$$

$$\Rightarrow \quad T_{BC} = +10 \text{ kN (Tensile)}$$

End of Solution

Q.45 In a mobile screen manufacturing process on a mass scale basis. 5 samples of size 80 are inspected. Consider a p-chart with ±3σ limits (σ is the standard deviation). The numbers of defective items are given in the table.

Sample No.	Number of defective items
1	4
2	10
3	5
4	6
5	5

The upper control limit of the defective item (in fraction defective) is _____. [round off to two decimal places]

Ans. (13.07)

Given: Sample size, $n = 80$

Let $\bar{p}$ denotes the fraction of defectives produced by the entire manufacturing process.

$$\Rightarrow \quad \bar{p} = \frac{\sum p_i}{5 \times 80} = \frac{30}{5 \times 80} = 0.075$$

$$\Rightarrow \quad n\bar{p} = 80 \times 0.075 = 6$$

Upper control limit of the *p*-chart is given as,

$$\Rightarrow \quad \text{UCL} = n\bar{p} + 3\sqrt{n\bar{p}(1-\bar{p})}$$

$$= 6 + 3\sqrt{6(1-0.075)} = 13.067$$

$$= 13.07$$

End of Solution

Q.46 If a matrix is squared, then

(a) both eigenvalues and eigenvectors are retained.

(b) eigenvalues get squared but eigenvectors are retained.

(c) both eigenvalues and eigenvectors must change.

(d) eigenvalues are retained but eigenvectors change.

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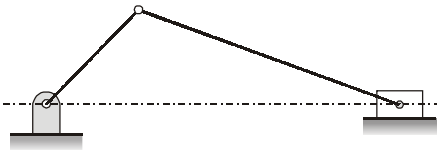
Ans. (b)

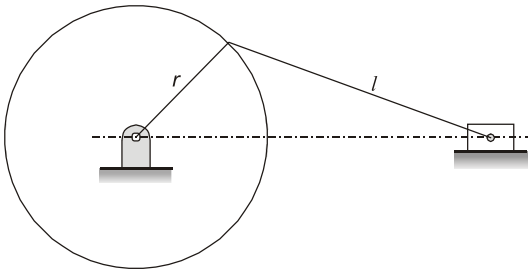
If X is an eigen vector of A for eigen value λ, then X is also an eigen vector of A^2 for eigen value λ^2.

End of Solution

Q.47 In a slider crank mechanism (schematic shown in the figure), the crank rotates at 60 revolutions per minute, The radius of the crank is 30 mm and the length of the connecting rod is 120 mm. The average speed (in mm/s) of the piston over one revolution of the crank is _____. [round off to nearest integer]



Ans. (120)(120 to 120)



Given: Radius of crank, r = 30 mm
Length of connecrting rad, l = 120 mm
Revolution per minut, N = 60 rpm

$\therefore$ Angular speed of crank, $\omega = \dfrac{2\pi N}{60} = \dfrac{2\pi \times 60}{60} = 2\pi$ rad/sec

$\therefore$ Time taken to complete one revolution by crank,

$\Rightarrow \quad \theta = \omega t$

$\Rightarrow \quad t = \dfrac{\theta}{\omega} = \dfrac{2\pi}{2\pi} = 1$ second

Now, length of stroke is given by

$L = 2r = 2 \times 30 = 60$ mm

Total distance travelled by the piston in one revolution of the crank is $2L$ i.e. 120 mm.

Average speed of piston, $v_{avg} = \dfrac{2L}{t} = \dfrac{120}{1} = 120$ mm/sec

End of Solution

Q.48 For an electrochemical machining process

$$\frac{dy}{dt} = \frac{\lambda}{y} - f,$$

where y is the inter-electrode gap in mm at time t in minute, and f is the feed of the tool in mm/minute. The value of λ is 6×10^{-3} cm^2/minute. For maintaining a constant inter-electrode gap of 0.1 mm, the feed (in mm/minute) should be _____. [round off to one decimal place]

Ans. **(6.0) (6.0 to 6.0)**

Given: $\lambda = 6 \times 10^{-3}$ cm^2/min $= 6 \times 10^{-3} \times 100$ mm^2/min $= 0.6$ mm^2/min

$$y = 0.1 \text{ mm}$$

$$\frac{dy}{dt} = \frac{\lambda}{y} - f$$

So, for constant inter electrode gap

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

$$\Rightarrow \quad \frac{\lambda}{y} - f = 0$$

$$\Rightarrow \quad f = \frac{\lambda}{y} = \frac{0.6}{0.1} = 6 \text{ mm/min}$$

So, Feed = 6 mm/min

End of Solution

Q.49 A machine component is to be processed at 5 workstations sequentially. The table provides the cycle time (in second) of each workstation. In mass production, the number of components produced per hour (in steady state) is _____. [in integer]

Workstation	Cycle time of each workstation (second)
WS-1	85
WS-2	55
WS-3	90
WS-4	65
WS-5	70

Ans. **(40) (40 to 40)**

Cycle time (T_C) = max(WS-1, WS-2, WS-3, WS-4, WS-5)

= 90 sec

So, number of components produced per hour

$$= \frac{1 \times 60 \times 60}{T_C}$$

$$= \frac{60 \times 60}{90} = 40 \text{ products/hr}$$

End of Solution

Q.50 A company is planning to produce 24 electric cars per day. The setup cost of the plant is estimated as ₹ 19476 million and the variable cost is ₹ 0.6 million per car. The car will be sold at a price of ₹ 1.5 million, The number of days required for achieving the breakeven is _____. [round off to nearest integer]

Ans. **(902) (902 to 902)**

Given: Set up cost of the plant, F = ₹19476 million

Variable cost, v = ₹0.6 million per car

Sellling price, s = ₹1.5 million per car

∴ Breakeven quantity is given by,

$$\Rightarrow \quad x_{BEP} = \frac{F}{s-v} = \frac{19476}{1.5-0.6} = \frac{19476}{0.9}$$

$$= 21640 \text{ cars}$$

Time taken to produce break even quantity,

$$t = \frac{x_{BEP}}{24} = \frac{21640}{24} = 901.66$$

$$t = 902 \text{ days}$$

End of Solution

Q.51 In a factory, 100 bulbs are in use. The table lists the cumulative probability of the failure of a bulb for various durations.

Duration (month)	Cumulative probability
1	0.10
2	0.25
3	0.47
4	0.68
5	1.00

The factory follows the individual replacement policy. If the cost of replacing a bulb is ₹ 300, then the expected cost (in ₹) of replacement per month is _____. [round off to nearest integer]

Ans. **(6000) (6000 to 6000)**

Probabilities for different months,

Month 1, $P_1 = 0.10$

Month 2, $P_2 = 0.25 - 0.1 = 0.15$

Month 3, $P_3 = 0.47 - 0.25 = 0.22$

Month 4, $P_4 = 0.68 - 0.47 = 0.21$

Month 5, $P_5 = 1 - 0.68 = 0.32$

Let 'D' be the defective bulbs per month, therefore,

$D_1 = 0.1 \times 100 = 10,$

$D_2 = 0.15 \times 100 = 15,$

$D_3 = 0.22 \times 100 = 22,$

$D_4 = 0.21 \times 100 = 21,$

$$D_5 = 0.32 \times 100 = 32$$

$\therefore$ Average cost for one month

$$\text{Cost} = \frac{(10+15+22+21+32)}{5} \times 300 = ₹6000$$

End of Solution

Q.52 If the interarrival time is exponential and 8 customers per hour arrive in a bank, then the probability of no arrival of customer during a period of 15 minutes is _____. [round off to two decimal places]

Ans. (0.14) (0.12 to 0.16)

$$\lambda = 8 \text{ customer per hour} = 8/\text{hr}$$

Probability of no. arrival of customer during a period of 15 minute.

$$P(n, T) = \frac{e^{-\lambda T} \cdot (\lambda T)^n}{n!} \qquad \lambda T = \frac{8}{60} \times 15 = 2$$

$$P\left(0, \frac{1}{4}\right) = \frac{e^{-2} \cdot (2)^0}{0!} = e^{-2} = 0.1353 \approx 0.14$$

End of Solution

Q.53 The order of the following differential equation is _____. [in integer]

$$\left(\frac{dy}{dx}\right)^2 + 5\frac{dy}{dx} + 4y = 5x^3$$

Ans. (1) (1 to 1)

The highest order of the derivative present in given differential equation is 1, hence its order is 1.

End of Solution

Q.54 The value of

$$\lim_{x \to 1} \frac{x^3 - 3x + 2}{x^3 - x^2 - x + 1}$$

is _____. [round off to one decimal place]

Ans. (1.5) (1.5 to 1.5)

$$\lim_{x \to 1} \frac{x^3 - 3x + 2}{x^3 - x^2 - x + 1} \qquad \left(\frac{0}{0}\text{form}\right)$$

By using L' Hospital's rule,

$$\lim_{x \to 1} \frac{3x^2 - 3}{3x^2 - 2x - 1} \qquad \left(\frac{0}{0}\text{form}\right)$$

$$= \lim_{x \to 1} \frac{6x}{6x - 2} = \frac{6}{6-2} = \frac{6}{4} = 1.5$$

End of Solution

Q.55 In a machine there are two motors, but only one motor is needed for the functioning of the machine. The reliabilities of the motors are 0.90 and 0.70. The overall reliability of the machine is _____. [round off to two decimal places]

Ans. (0.97)

Given: reliability of first motor, $R_1 = 0.90$

Reliability of second motor, $R_2 = 0.70$

Overall, reliability of the machine,

$$\Rightarrow \quad R_s = R_1Q_2 + R_2Q_1 + R_1R_2$$

$$= 0.9 \times 0.3 + 0.7 \times 0.1 + 0.9 \times 0.7$$

$$\Rightarrow \quad R_s = 0.97$$

End of Solution

■■■■