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GATE 2020

Production and Industrial Engineering

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SECTION A : GENERAL APTITUDE

Q.1 Select the word that fits the analogy :
White : Whitening : : Light : _____
(a) Enlightening (b) Lightening
(c) Lightning (d) Lighting

Ans. **(b)**

End of Solution

Q.2 In one of the greatest innings evern seen in 142 years of Test history, Ben Stokes upped the tempo in a five-and-a-half hour long stay of 219 balls including 11 fours and 8 sixes that saw him finish on a 135 not out as England squared the five-match series. Based on their connotations in the given passage, which one of the following means DOES NOT match?
(a) saw = resulted in (b) upped = increased
(c) tempo = enthusiasm (d) squared = lost

Ans. **(d)**

End of Solution

Q.3 Climate change and resilience deal with two aspects – reduction of sources of non-renewable energy resources and reducing vulnerability of climate change aspects. The terms 'mitigation' and 'adaptation' are used to refer to these aspects, respectively. Which of the following assertions is best supported by the above information?
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(a) Adaptation deals with actions taken to combat green-house gas emissions.
(b) Mitigation deals with consequences of climate change.
(c) Adaptation deals with causes of climate change.
(d) Mitigation deals with actions taken to reduce the use of fossil fuels.

Ans. **(d)**

End of Solution

Q.4 It was estimated that 52 men can complete a strip in a newly constructed highway connecting cities P and Q in 10 days. Due to an emergency, 12 men were sent to another project. How many number of days, more than the original estimate, will be required to complete the strip?
(a) 5 days (b) 10 days
(c) 13 days (d) 3 days

Ans. **(d)**
52 men can do in 10 days.
Since 12 men were sent out
Remaining men left = 52 – 12 = 40
We know $M_1D_1 = M_2D_2$
$52 \times 10 = 40 \times x$

$$x = \frac{52 \times 10}{40} = 13 \text{ days}$$

Total number of days taken = 13 days
3 days more than the original estimate.

End of Solution

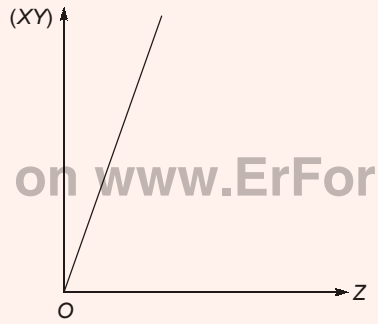
Q.5 The recent measures to improve the output would _____ the level of production to our satisfaction.

(a) speed
(b) equalise
(c) decrease
(d) increase

Ans. **(d)**

End of Solution

Q.6 An engineer measures THREE quantities X, Y and Z in an experiment. She finds that they follow a relationship that is represented in the figure below : (the product of X and Y linearly varies with Z)



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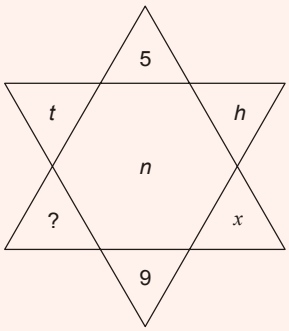
Then, which of the following statements is FALSE?

(a) For fixed Z; X is proportional to Y
(b) $\frac{XY}{Z}$ is constant
(c) For fixed X; Z is proportional to Y
(d) For fixed Y; X is proportional to Z

Ans. **(a)**

End of Solution

Q.7 Find the missing element in the following figure :



(a) *w* (b) *e*
(c) *y* (d) *d*

Ans. **(d)**

This is the log i.e. ($n = 4$)

$5 + 4 = 9$

$t = 20$, $x = 24$

$20 + 4 = 24$

Similarly, $h = 8$

Case-1: $8 + 4 = 12(l)$

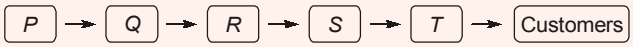
$? + 4 = 8$

$? = 4$ (d)

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End of Solution

Q.8 There are five levels {*P*, *Q*, *R*, *S*, *T*} in a linear supply chain before a product reaches customers, as shown in the figure :



At each of the five levels, the price of the product is increased by 25%. If the product is produced at level *P* at the cost of Rs. 120 per unit, what is the price paid (in rupees) by the customers?

(a) 366.21 (b) 292.96
(c) 234.38 (d) 187.50

Ans. **(a)**

P → Q → R → S → T → Customer

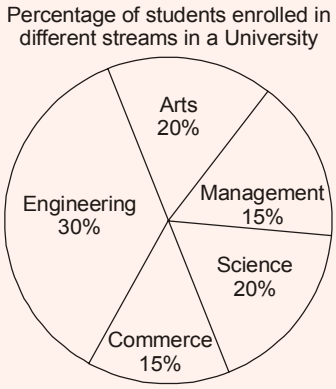
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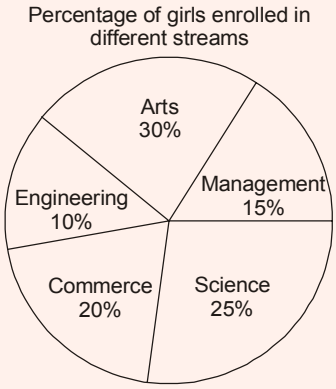
120 at each level increased 25% price paid by customer

$$= 120 \times \frac{125}{100} \times \frac{125}{100} \times \frac{125}{100} \times \frac{125}{100} \times \frac{125}{100} = 366.21$$

End of Solution

Q.9 The two pie-charts given below show the data of total students and only girls registered in different streams in a university. If the total number of students registered in the university is 5000, and the total number of the registered girls is 1500; then the ratio of boys enrolled in Arts to the girls enrolled in Management is _____





(a) 9 : 22
(b) 11 : 9
(c) 22 : 9
(d) 2 : 1

Ans. **(c)**

$$\frac{(\text{Boys})_{\text{Arts}}}{(\text{Girls})_{\text{Management}}} = \frac{20\% \text{ of } 5000 - 30\% \text{ of } 1500}{15\% \text{ of } 1500}$$

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$$= \frac{1000 - 450}{225} = \frac{550}{225}$$

$$= \frac{110}{45} = \frac{22}{9}$$

$$= 22 : 9$$

End of Solution

Q.10 While I agree _____ his proposal this time, I do not often agree _____ him.
(a) to, to
(b) to, with
(c) with, to
(d) with, with

Ans. **(b)**
Agree with - a person,
Agree to - an idea, proposal

End of Solution

SECTION B : TECHNICAL

Q.1 To solve $x^2 - 2 = 0$, the Newton-Raphson method has been employed. If the initial guess $x_0 = 1.0$, the next estimate of the root, x_1, will be

(a) 1.5 (b) 2.0

(c) 1.0 (d) 0.5

Ans. **(a)**

$$f(x) = x^2 - 2$$

$$x_0 = 1.0$$

By Newton-Raphson method,

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

$$= 1 - \left.\frac{x^2 - 2}{2x}\right|_{x_0 = 1}$$

$$= 1 - \frac{(1-2)}{2 \times 1} = 1 - (-0.5) = 1.5$$

End of Solution

Q.2 Self-sharpening tendency of a conventional grinding wheel depends upon

(a) wheel grade (b) grit hardness

(c) grit size (d) wheel structure

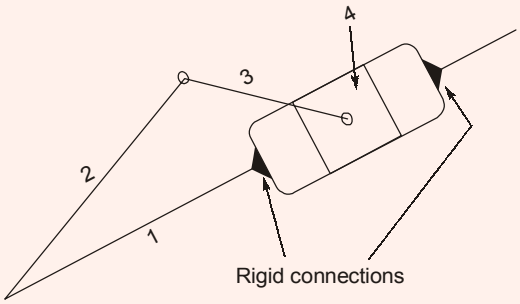
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Ans. **(a)**

- The worn out grit must pull out from the bond and make room for fresh sharp grit in order to avoid excessive rise of grinding force and temperature.
- A soft wheel should be chosen for grinding hard material.
- A hard wheel should be chosen for grinding soft material.

End of Solution

Q.3 The figure shows a mechanism with 3 revolute pairs (between the links 1 and 2, 2 and 3, and 3 and 4) and a prismatic pair (between the links 1 and 4). Which one of the four links should be fixed to obtain the mechanism that forms the basis of the quick-return mechanism widely used in shaper?



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

Ans. **(d)**

It is crank and slotted lever quick return motion mechanism. Here connecting rod is fixed which is here link 2.

End of Solution

Q.4 If x is a random variable with the expected value of 5 and the variance of 1, then the expected value of x^2 is

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(a) 36
(b) 26
(c) 25
(d) 24

Ans. **(b)**

$$E(x) = 5$$
$$\text{Var}(x) = 1$$

then we know that

$$\text{Var}(x) = E(x^2) - (E(x))^2 \Rightarrow E(x^2) = \text{Var}(x) + [E(x)]^2 = 1 + (5)^2 = 26$$

End of Solution

Q.5 The divergence of the vector $\vec{v} = y^2\hat{i} + z^2\hat{j} + x^2\hat{k}$ is

(a) 0
(b) $2z$
(c) $2y$
(d) $2x$

Ans. **(a)**

$$\text{div}\,\vec{v} = \vec{\nabla}\cdot\vec{v} = \frac{\partial}{\partial x}(y^2) + \frac{\partial}{\partial y}(z^2) + \frac{\partial}{\partial z}(x^2)$$
$$= 0$$

End of Solution

Q.6 Which of the following is a casual forecasting method?

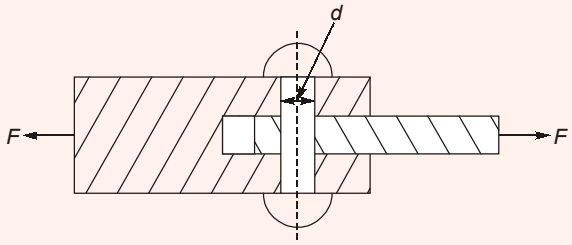
(a) Naive approach
(b) Linear regression
(c) Exponential smoothing
(d) Moving average

Ans. **(b)**

Linear regression is a casual forecasting method.

End of Solution

Q.7 The figure shows two bodies connected through a riveted joint with one rivet. The diameter of the rivet is d (in m). The joint transmits a load of F (in N) whose line of action is perpendicular to and intersects the vertical axis of the rivet. Neglect any effect of bending of the rivet. If the allowable shear stress for the material of the rivet is τ N/m^2, the diameter of the rivet required to prevent failure in shear is



(a) $\sqrt{\frac{4F}{\pi\tau}}$
(b) $\sqrt{\frac{2F}{\pi\tau}}$
(c) $\sqrt{\frac{8F}{\pi\tau}}$
(d) $\sqrt{\frac{F}{\pi\tau}}$

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Ans. **(b)**

Induced shear stress, $\tau = \frac{\text{Load}}{\text{Sheared Area}}$

$$\tau = \frac{F}{2\frac{\pi}{4}\cdot d^2}$$

$$d = \sqrt{\frac{2F}{\pi\tau}}$$

End of Solution

Q.8 The process used for producing long bars of fiber reinforced plastics (FRP) with uniform cross-section is

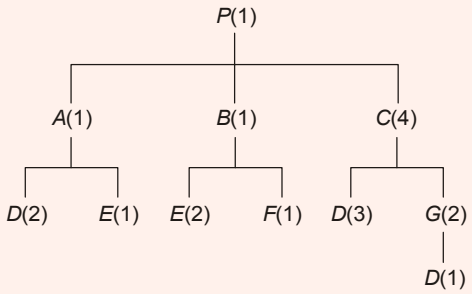
(a) Pultrusion (b) Extrusion
(c) Thermoforming (d) Injection Molding

Ans. **(a)**

The pultrusion process is a low-cost, high volume manufacturing process in which resin-impregnated fibres are pulled through a die to make the part. It creates parts of constant cross-section and continuous length.

End of Solution

Q.9 The product structure tree in the figure below shows the components needed to assemble one unit of product *P*.



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The number of units of component *D* needed to assemble 10 units of product *P* is _____.

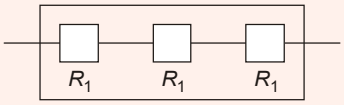
Ans. **(220)**

1*P* requires 1*A* and 4*C*.
1*A* requires 2*D*.
1*C* requires 3*D* and 2*G*.
1*G* requires 1*D*.
∴ 1*C* requires 3*D* and 2*D*, i.e., total 5*D*.
So, for 4*C* = 20*D* are required.
So, for 1*P* = 22*D* are required.
So, for 10*P* = 220D are required.

End of Solution

Q.10 Suppose the control system of a fighter jet consists of three unrelated components in series, and it is desired to have 98% reliability of the system. If the reliability level of all the components is the same, then the reliability of each component (rounded off to three decimal places) is _____

Ans. **(0.993) (0.993 to 0.994)**



Let $R_1 = R_2 = R_3 = R$

$R_s = R_1 \times R_2 \times R_3$

$R_s = R \times R \times R$

$0.98 = R^3$

$R = (0.98)^{1/3} = 0.993$

End of Solution

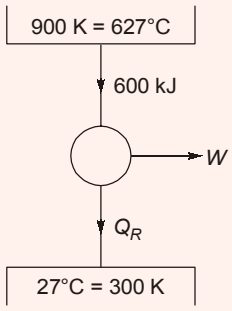
Q.11 A Carnot heat engine receives 600 kJ of heat per cycle from a source of 627°C and rejects heat to a sink at 27°C. The amount of heat rejected to the sink per cycle (rounded off to the nearest integer) in kJ is

(a) 400 (b) 200

(c) 26 (d) 574

Ans. **(b)**

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$$\eta = 1 - \frac{T_L}{T_H}$$

$$\eta = 1 - \frac{300}{900} = 0.667$$

but $$\eta = 1 - \frac{Q_R}{Q_S} = 0.667$$

$\therefore$ $$\frac{Q_R}{600} = 0.333$$

$Q_R = 199.8$ kJ

$Q_R = 200$ kJ

End of Solution

Q.12 Group I lists phases of steel and Group II lists crystal structures in the table below.

Group I	Group II
P. Ferrite	1. Hexagonal Close Packed (HCP)
Q. Austenite	2. Body Centered Cubic (BCC)
R. Martensite	3. Body Centered Tetragonal (BCT)
	4. Face Centered Cubic (FCC)

Match the phase with the corresponding crystal structure.

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

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

Ans. **(c)**

End of Solution

Q.13 End mill cutters are mounted on the spindle of a vertical milling machine using

(a) vice (b) face plate

(c) driver plate (d) collet

Ans. **(d)**

Milling cutters that contain their own straight or tapered shanks are mounted to the milling machine spindle with collet.

End of Solution

Q.14 In manufacturing of self-lubricating bearings by powder metallurgy, an important secondary operation that is carried out after sintering is

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(a) Infiltration (b) Hot isostatic pressing

(c) Impregnation (d) Cold isostatic pressing

Ans. **(c)**

End of Solution

Q.15 An integrating factor for the differential equation $\frac{dy}{dx} + my = e^{-mx}$ is

(a) e^{-mx} (b) e^{m}

(c) e^{mx} (d) e^{-m}

Ans. **(c)**

$$\frac{dy}{dx} + my = e^{-mx},$$

On comparison with $\frac{dy}{dx} + py = Q$, we have $P = m$ and $Q = e^{-mx}$

So, $$IF = e^{\int P dx} = e^{\int m dx}$$
$$= e^{mx}$$

End of Solution

Q.16 Consider flow of an oil with Reynolds number 1500 in a pipe of diameter 5 cm. The kinematic viscosity of the oil, $\nu = 0.75\ cm^2/s$. The value of average velocity in m/s is

(a) 1.50 (b) 4.50

(c) 0.75 (d) 2.25

Ans. **(d)**

$$R_e = 1500$$
$$D = 5 \times 10^{-2}\ m$$
$$\nu = 0.75\ cm^2/s = 0.75 \times 10^{-4}\ m^2/s$$
$$R_e = \frac{VD}{\nu} \Rightarrow V = \frac{Re \cdot \nu}{D} = \frac{1500 \times 0.75 \times 10^{-4}}{5 \times 10^{-2}}$$
$$V = 2.25\ m/s$$

End of Solution

Q.17 The process capability ratio C_p is given by

(a) $\dfrac{6 \times \text{Process Standard Deviation}}{\text{Upper Control Limit} - \text{Lower Control Limit}}$

(b) $\dfrac{6 \times \text{Process Standard Deviation}}{\text{Upper Specification Limit} - \text{Lower Specification Limit}}$

(c) $\dfrac{\text{Upper Specification Limit} - \text{Lower Specification Limit}}{6 \times \text{Process Standard Deviation}}$

(d) $\dfrac{\text{Upper Control Limit} - \text{Lower Control Limit}}{6 \times \text{Process Standard Deviation}}$

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Ans. **(c)**

$$C_P = \frac{USL - LSL}{6\sigma}$$

End of Solution

Q.18 The purpose of the ratchet in a micrometer is to

(a) impart smooth movement to the spindle

(b) maintain sufficient and uniform measuring pressure

(c) prevent rotation of the spindle while reading the scale

(d) compensate for the wear of the screw thread

Ans. **(b)**

End of Solution

Q.19 In a uniaxial tensile test on a specimen of a ductile material, the ultimate tensile strength is found to be 400 MPa and the elongation upto the maximum load is 25%. The true stress at the maximum load in MPa is _____.

Ans. **(500)**

Given, $\sigma_u = 400$ MPa

$e = 0.25$

True stress $= \sigma_u(1 + e)$

$= 400 \times (1 + 0.25) = 500$ MPa

End of Solution

Q.20 For the complex number $z_1 = 2 + 3i$ and $z_2 = 4 - 5i$, the value of $(z_1 + z_2)^2$

(a) $-32 + 24i$ (b) $-32 - 24i$

(c) $32 + 24i$ (d) $32 - 24i$

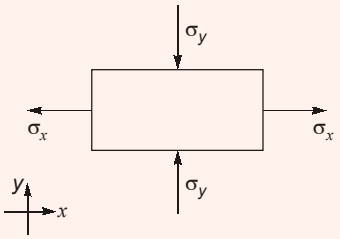
Ans. **(d)**

$$(z_1 + z_2)^2 = [(2 + 3i) + (4 - 5i)]^2 = [(6 - 2i)^2]$$
$$= (6 - 2i)(6 - 2i) = 36 - 12i - 12i + 4i^2$$
$$= 32 - 24i$$

End of Solution

Q.21 The state of stress at a point in a body under plane stress condition is shown in the figure. The positive directions of x and y axes are also shown. The material of the body is homogeneous and isotropic, with modulus of elasticity E and Poisson's ratio ν. The longitudinal strain in the x-direction is

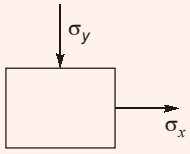
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(a) $-\frac{\sigma_x}{E} + \nu\frac{\sigma_y}{E}$ (b) $\frac{\sigma_x}{E} - \nu\frac{\sigma_y}{E}$

(c) $\frac{\sigma_x}{E} + \nu\frac{\sigma_y}{E}$ (d) $-\frac{\sigma_x}{E} - \nu\frac{\sigma_y}{E}$

Ans. **(c)**



$$\varepsilon_x = \frac{\sigma_x}{E} + \nu\frac{\sigma_y}{E}$$

End of Solution

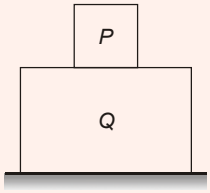
Q.22 The Bellman's principle of optimality is related to

(a) Transportation problem
(b) Linear programming problem
(c) Dynamic programming problem
(d) Assignment problem

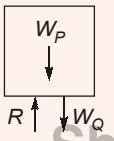
Ans. (c)

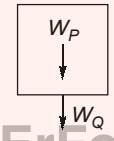
End of Solution

Q.23 The figure shows two bodies P and Q. The body Q is placed on the ground and the body P is placed on top of it. The weights of P and Q are W_P and W_Q, respectively. The bodies are at rest and all the surfaces are assumed to be frictionless. R represents reaction force, if any, between the bodies.

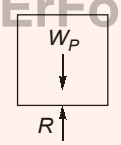


The correct free body diagram of the body P is

(a) 

(b) 

(c) 

(d) 

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Ans. (d)

End of Solution

Q.24 A non-traditional machining process which utilizes mechanical energy as the principal energy source for removing the material is

(a) Laser beam machining
(b) Electric discharge machining
(c) Plasma arc maching
(d) Ultrasonic maching

Ans. (d)

End of Solution

Q.25 An approach used in the product development which combines the efforts of design, manufacturing, and other functions to reduce the total time in introducing a new product in the market is

(a) Break-even analysis
(b) Concurrent engineering
(c) Lean manufacturing
(d) Value engineering

Ans. **(b)**

Concurrent engineering, also known as simultaneous engineering, is a method of designing and developing products, in which the different stages run simultaneously, rather than consecutively. It decreases product development time and also the time to market, leading to improved productivity and reduced costs.

End of Solution

Q.26 In a work study experiment, it is observed that a worker completes a job in an average time of 15 minutes with a performance rating of 120%. The time required for another worker having a performance rating of 80% to complete the same job (rounded off to one decimal place) in minutes is _____.

Ans. **(22.5)**

Given : $t_1 = 15$ minutes

Performance rating = 120%

$r_1 = 1.2$, $t_2 = ?$

Performance rating = 80%

$r_2 = 0.8$

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$t_1 \cdot r_1 = t_2 \cdot r_2$ ...(same job)

$\therefore \quad 15 \times 1.2 = t_2 \times 0.8$

$\therefore \quad t_2 = 22.5$ minutes

End of Solution

Q.27 For $y = -x^2 + 9x - 2$, the value of $\int_1^5 y\,dx$ using Simpson's 1/3 rule with two intervals (rounded off to two decimal places) is _____.

Ans. **(58.67) (58 to 59)**

$$f(x) = -x^2 + 9x - 2,\ a = 1,\ b = 5,\ n = 2,\ h = \frac{b-a}{x} = 2$$

$x =$	1	3	5
$y =$	6	16	18

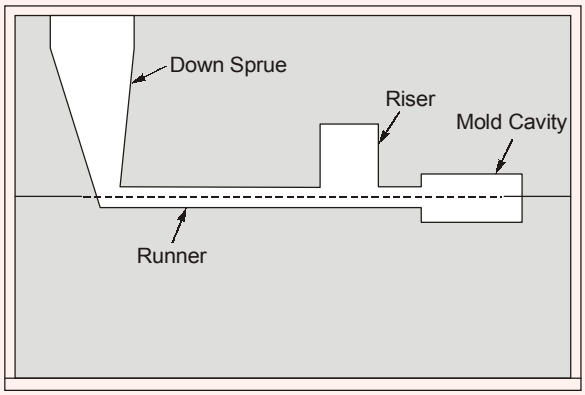
So, $$I = \int_1^5 y\,dx = \frac{h}{3}[y_0 + y_2 + 4(y_1) + 2(0)]$$

$$= \frac{2}{3}[6 + 18 + 4 \times 16]$$

$$= \frac{2}{3}[88] = \frac{176}{3} = 58.67$$

End of Solution

Q.28 To manufacture a product by casting, molten metal is poured in a cavity of rectangular cross-section in a sand mold with a side blind riser as shown in the figure. The dimensions of the mold cavity are 60 cm × 40 cm × 20 cm.



The riser is cylindrical in shape with diameter equal to height. It is required that the solidification time of the riser should be 25% greater than that of the mold. Using Chvorinov's rule, the diameter of the riser (rounded off to one decimal place) in cm should be _____.

Ans. **(36.6 cm) (36 to 37)**

Mold cavity dimensions are 60 cm × 40 cm × 20 cm.

Riser solidification time is greater than 25% of the mould.

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According to Chvorinov's principle :

$$t_s \propto \left(\frac{V}{A}\right)^2$$

$$t_s = K\left(\frac{V}{A}\right)^2$$

where, K = solidification factor

V = Volume

A = Surface area

$(t_s)_r = 1.25(t_s)_c$

$$(t_s)_r = \frac{V}{A} = \frac{\frac{\pi}{4}D^2 \cdot H}{2\cdot\frac{\pi}{4}D^2 + \pi DH} = \frac{D}{6}$$

$$\left(\frac{D}{6}\right)_r^2 = 1.25\left[\frac{60\times 40\times 20}{2(60\times 40 + 40\times 20 + 20\times 60)}\right]^2$$

$D = 36.59$ cm

End of Solution

Q.29 A company is planning to procure a machine to produce a component. There are two alternatives available – machine *A* and machine *B*. The cost of producing x units of the component (in Rs.) using machine *A* is given as $C_A(x) = 10000 + 170x + x^2$. The cost of producing x units of the component (in Rs.) using machine *B* is given as $C_B(x) = 15000 + 400x$. If machine *B* is to be preferred, then the minimum number of units to be produced should be _____.

Ans. **(250)**

To obtain the minimum number of units,

$$C_A(x) = C_B(x)$$
$$10000 + 170x + x^2 = 15000 + 400x$$
$$x^2 - 230x - 5000 = 0$$
$$x^2 - 250x + 20x - 5000 = 0$$
$$x(x - 250) + 20(x - 250) = 0$$
$$(x + 20)(x - 250) = 0$$
$$x = 250 \text{ units}$$

End of Solution

Q.30 If the probability density function of a random variable x is given by

$$f(x) = \begin{cases} \dfrac{kx^2}{2}, & -1 \le x \le 1 \\ 0, & \text{elsewhere} \end{cases}$$

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the value of k is _____.

Ans. **(3)**

If $f(x)$ is probability density function then we have

$$\int_{-\infty}^{\infty} f(x)dx = 1 \Rightarrow \int_{-1}^{1} f(x)dx = 1$$

$$\Rightarrow \int_{-1}^{1} \frac{kx^2}{2}dx = 1 \Rightarrow \left.\frac{kx^3}{6}\right|_{-1}^{1} = 1$$

$$\Rightarrow \frac{k[(1)^3 - (-1)^3]}{6} = 1 \Rightarrow \frac{2k}{6} = 1 \Rightarrow k = 3$$

End of Solution

Q.31 The movement along the *z*-axis of a CNC drilling machine is controlled by using a servo motor, a lead screw and an increment encoder. The lead screw has 2 threads/cm and it is directly coupled to the servo motor. The incremental encoder attached to the lead screw emits 100 pulses/revolution. The control resolution in microns is _____.

Ans. **(50)**

Lead screw has 2 threads/cm.

$$\text{Pitch of lead screw} = \frac{10^4}{2} \text{ microns/thread}$$

$$P = 5 \times 10^3 \text{ microns/thread}$$

$\therefore$ 100 pulses/revolution = 5×10^3 microns/threads

$\therefore$ 1 pulse/revolution = 50 microns

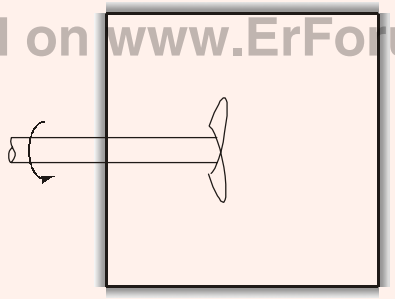
$\therefore$ Control resolution is 50 microns.

End of Solution

Q.32 A mass of 3 kg of Argon gas at 3 bar, 27°C is contained in a rigid, insulated vessel. Paddle wheel work is done on the gas for 30 minutes at the rate of 0.015 kW. Specific heat at constant volume, c_v, for Argon is 0.3122 kJ/kg-K. The final temperature of the gas (rounded off to one decimal place) in kelvin is _____.

Ans. **(328.83 K) (327 to 331)**

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$m = 3$ kg

$P_1 = 3$ bar $= 300$ kPa

$T_1 = 27°C = 300$ K

$c_v = 0.3122$ kJ/kgK

$W = 0.015$ kW

Time = 30 mins.

$\delta Q = dU + \delta W$

$0 = mc_v dT + (-0.015 \times 30 \times 60)$

$0 = 3 \times 0.3122 \times \{T_2 - 300\} - 27$

$\therefore \quad T_2 = 328.83$ K

End of Solution

Q.33 For the matrix $\begin{bmatrix} 1 & 5 \\ 3 & 3 \end{bmatrix}$, the eigen vectors are

(a) $\begin{bmatrix} 1 \\ 3 \end{bmatrix}$ and $\begin{bmatrix} 5 \\ 3 \end{bmatrix}$

(b) $\begin{bmatrix} -1 \\ 1 \end{bmatrix}$ and $\begin{bmatrix} 5/3 \\ 1 \end{bmatrix}$

(c) $\begin{bmatrix} 1 \\ -1 \end{bmatrix}$ and $\begin{bmatrix} 3 \\ -3 \end{bmatrix}$

(d) $\begin{bmatrix} 1 \\ 1 \end{bmatrix}$ and $\begin{bmatrix} -5/3 \\ 1 \end{bmatrix}$

Ans. **(d)**

We can check options in order to find eigen vectors quickly and only option (d) is satisfying the property $AX = \lambda X$ for unique 'λ'.

For $$AX = \begin{bmatrix} 1 & 5 \\ 3 & 3 \end{bmatrix}\begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 6 \\ 6 \end{bmatrix} = 6\begin{bmatrix} 1 \\ 1 \end{bmatrix} = \lambda X$$

So, $$\lambda = 6 \text{ and } X = \begin{bmatrix} 1 \\ 1 \end{bmatrix}.$$

End of Solution

Q.34 In a waterjet machining process, the water pressure used in 500 MPa. The diameter of orifice of the nozzle through which the waterjet comes out is 0.25 mm. Neglecting frictional and other losses, and using the density of water as 1000 kg/m^3, the mass flow rate of the waterjet (rounded off to two decimal places) in kg/min is _____.

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Ans. **(2.94) (2.85 to 3)**

Given : $P = 500 \text{ MPa} = 500 \times 10^6 \text{ Pa}$

$d = 0.25 \text{ mm} = 2.5 \times 10^{-4} \text{ m}$

$\rho = 1000 \text{ kg/m}^3$

$\dot{m} = ?$

$$V = \sqrt{\frac{2\Delta P}{\rho}} = \sqrt{\frac{2\times 500\times 10^6}{1000}} = 1000 \text{ m/s}$$

$$Q = AV = \frac{\pi}{4}\times d^2 \times 1000$$

$$= \frac{\pi}{4}\times (2.5\times 10^{-4})^2 \times 1000$$

$Q = 4.9087 \times 10^{-5} \text{ m}^3/\text{sec}$

$\therefore$ $\dot{m} = \rho.Q = 1000 \times 4.9087 \times 10^{-5} \times 60$

$\dot{m} = 2.94 \text{ kg/min}$

End of Solution

Q.35 A company manufactures products P and Q in quantities x_1 and x_2, respectively, using two resources. The following Linear Programming Problem (LPP) is formulated to maximize the profit Z.

Maximize $Z = 3x_1 + 2x_2$

subject to $x_1 + 2x_2 \le 2$ (for Resource 1)

$2x_1 + x_2 \le 2$ (for Resource 2)

and $x_1, x_2 \ge 0$

The shadow price for Resource 2 is

(a) $\frac{4}{3}$ (b) $\frac{2}{3}$

(c) 0 (d) 1

Ans. **(a)**

According to Simplex Method :

	C_j	3 x_1	2 x_2	0 s_1	0 s_2	θ	θ_{min}
0	s_1	1	2	1	0	2	2
0	s_2	[2]	1	0	1	2	1 ←
	Z_j	0	0	0	0		
	$C_j - Z_j$	3 ↑	2	0	0		

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	C_j	3 x_1	2 x_2	0 s_1	0 s_2	θ	θ_{min}
0	s_1	0	[1.5]	1	–0.5	1	2/3 ←
3	x_1	1	0.5	0	0.5	1	2
	Z_j	3	1.5	0	1.5	3	
	$C_j - Z_j$	0	0.5 ↑	0	–1.5		

	C_j	3 x_1	2 x_2	0 s_1	0 s_2	θ	
2	x_2	0	1	2/3	–1/3	(2/3)	← Optimum Solution
3	x_1	1	0	–2/6	2/3	2/3	
	Z_j	3	2	(1/3)	(4/3) ←		Shadow Price of Resource 2
	$C_j - Z_j$	0	0	–1/2	–4/3		

Hence, optimality condition is achieved and at $x_1 = \frac{2}{3}$ and $x_2 = \frac{2}{3}$. The profit is maximum.

Value of Z_j of S_2 variable of Resource 2 gives the required Shadow Price which is $\frac{4}{3}$.

End of Solution

Q.36 The heat generated in a resistance spot welding operation for joining two metal sheets with a certain set of process parameters is 2000 J. For a second spot welding operation on the same sheets without any change in the overall resistance of the system, the current is increased by 25% and the time for which the current is applied is reduced to half. The heat generated in the second operation (rounded off to one decimal place) in J is _____.

Ans. **(1562.5 J) (1560 to 1563)**

Heat generated (H_g) = 2000 J

Second spot welding operation :

$$R_2 = R_1$$

$$I_2 = 1.25I_1 \quad \text{(from given condition)}$$

$$t_2 = \frac{t_1}{2}$$

$$H_g = I^2Rt$$

$$(H_g)^2 = I_2^2R_2t_2$$

$$= (1.25I_1)^2 \cdot R_1 \cdot \frac{t_2}{2} = \frac{(1.25)^2}{2} I_1^2R_1t_1$$

$$= 0.78125 \times 2000 = 1562.5 \text{ J}$$

Heat generated in second spot welding process is 1562.5 J.

End of Solution

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Q.37 A flywheel is to be used in an IC engine to limit fluctuation of angular speed. the average of the maximum and the minimum angular speed is 500 rpm, and the maximum fluctuation of energy is 10,000 N-m. Neglecting rotary inertia of any other components, the moment of inertia of the flywheel about its axis of rotation required to limit the maximum fluctuation of speed to 30 rpm (rounded off to one decimal place) in kg-m^2 is _____.

Ans. **(60.8 kg-m^2) (59 to 62)**

$$N = 500 \text{ rpm}$$

$$\Delta E_{max} = 10{,}000 \text{ N-m}$$

$$C_s = \left(\frac{30}{500}\right)$$

$$\omega = \frac{2\pi \times 500}{60} = 52.3598 \text{ rad/s}$$

$$\Delta E_{max} = I.\omega^2.C_s$$

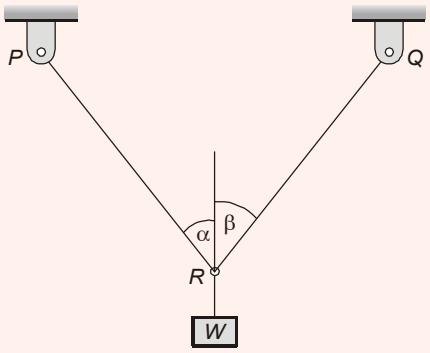
$$10000 = I \times (52.3598)^2 \times \frac{30}{500}$$

$$I = \frac{10000 \times 500}{30 \times (52.3598)^2}$$

$$I = 60.7928 \text{ kg.m}^2$$

End of Solution

Q.38 A truss with two bars *PR* and *QR*, making angles α and β, respectively, with the vertical, is shown in the figure below. The connections at *P*, *Q* and *R* are hinged connections. The truss supports a body of weight *W* (in N) at R as shown. The tension in the bar *QR* (in N) is



(a) $\frac{W\sin\alpha}{\sin(\alpha+\beta)}$

(b) $\frac{W\sin\beta}{\cos(\alpha+\beta)}$

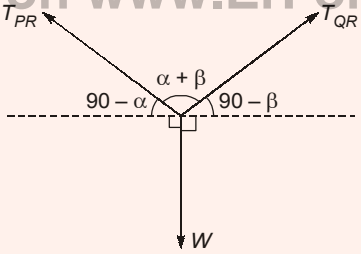
(c) $\frac{W\sin\alpha}{\cos(\alpha+\beta)}$

(d) $\frac{W\sin\beta}{\sin(\alpha+\beta)}$

Ans. **(a)**

Applying Lami's theorem

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$$\frac{T_{PR}}{\sin(180^\circ-\beta)} = \frac{W}{\sin(\alpha+\beta)} = \frac{T_{QR}}{\sin(180-\alpha)}$$

$$T_{QR} = \frac{W\sin\alpha}{\sin(\alpha+\beta)}$$

End of Solution

Q.39 The verticies of rectangle *PQRS* are as follows in a 2-D CAD system.
P(–4, –2); *Q*(–2, –3); *R*(–3, –5); *S*(–5, –4)
The coordinates of the corresponding new verticies, *P′*, *Q′*, *R′*, *S′* after translation of the rectangle along *x*-axis in the positive direction by 6 units and along *y*-axis in the positive direction by 3 units are
(a) *P′*(2, 1); *Q′*(4, 0); *R′*(3, –2); *S′*(1, –1)
(b) *P′*(–10, –5); *Q′*(–8, –6); *R′*(–9, –8); *S′*(–11, –7)
(c) *P′*(2, –5); *Q′*(4, –6); *R′*(3, –8); *S′*(1, –7)
(d) *P′*(–10, 1); *Q′*(–8, 0); *R′*(–9, –2); *S′*(–11, –1)

Ans. **(a)**
Translation :

$$X_{new} = X_{old} + dx$$
$$Y_{new} = Y_{old} + dy$$
$$P'(-4 + 6, -2 + 3) = P'(2, 1)$$
$$Q'(-2 + 6, -3 + 3) = Q'(4, 0)$$
$$R'(-3 + 6, -5 + 3) = R'(3, -2)$$
$$S'(-5 + 6, -4 + 3) = S'(1, -1)$$

End of Solution

Q.40 A solid shaft has to transmit 50 kW of power at a speed of 1910 rpm. Ignore any possible bending of the shaft. The maximum allowable shear stress for the material of the shaft is 80 MPa. The minimum diameter of the shaft required to prevent failure due to shear (rounded off to one decimal place) in cm is _____.

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Ans. **(2.5 cm) (2 to 3)**

$$P = 50 \text{ kW}$$
$$N = 1910 \text{ rpm}$$
$$P = \frac{2\pi NT}{60}$$
$$T = 249.98 \text{ Nm}$$

Now $\tau_{max} = 80 \text{ N/mm}^2$

$$\frac{16T}{\pi d^3} = 80$$
$$d = 25.15 \text{ mm} = 2.515 \text{ cm}$$

End of Solution

Q.41 The availability of an old photocopier was 90% and the Mean Time Between Failure (MTBF) was 200 days. It has been replaced with a new photocopier having an availability of 95%. Now, the Mean Time to Repair (the time during which the photocopier is unavailable for service) has increased by 5 days. The MTBF of the new photocopier (rounded off to the nearest integer) in days is _____.

Ans. **(517) (513 to 523)**

$$A = 90\%$$

$$\text{MTBF} = 200 \text{ days}$$

$$A = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

$$\Rightarrow \quad 0.9 = \frac{200}{200 + \text{MTTR}}$$

$$\Rightarrow \quad 180 + 0.9\,\text{MTTR} = 200$$

$$0.9\,\text{MTTR} = 20$$

$$\text{MTTR} = \frac{20}{0.9} = 22.22 \text{ day}$$

$$\text{New MTTR} = 22.22 + 5 = 27.22 \text{ days}$$

Now, $$A = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} \quad \Rightarrow \quad 0.95 = \frac{\text{MTBF}}{\text{MTBF} + 27.22}$$

$$0.95\,\text{MTBF} + 25.8611 = \text{MTBF}$$

$$0.05\,\text{MTBF} = 25.8611$$

$$\text{MTBF} = 517.22 \approx 517 \text{ days}$$

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End of Solution

Q.42 A car company manufactures 200 units of a component per day. The component is installed in different car models at a rate of 15000 units per year. The company operates its production facility 300 days per year to manufacture the component. The setup cost for each production run is Rs. 200 and the inventory holding cost per year is Rs. 2 per unit. The Economic Production Quantity (EPQ) is _____.

Ans. **(2000)**

Given : $p = 200$ units per day

$D = 15000$ units per year

Operating days $= 300 = n$

$$d = \frac{D}{n} = \frac{15000}{300} = 50 \text{ units per day}$$

$C_o = \text{Rs. } 200$, $C_h = \text{Rs. } 2$ per unit per year

$$\therefore \quad \text{EOQ} = \sqrt{\frac{2DC_o}{C_h} \times \frac{p}{p-d}}$$

$$= \sqrt{\frac{2 \times 15000 \times 200}{2} \times \frac{200}{200 - 50}}$$

$$\text{EOQ} = 2000 \text{ units}$$

End of Solution

Q.43 For a particular tool-workpiece combination, the value of exponent n in the Taylor's tool life equation is 0.5. If the cutting speed is reduced by 50% keeping all the other machining conditions same, the increase in tool life in % is _____.

Ans. **(300%)**

$$V_1 T_1^n = V_2 T_2^n$$

or $$V_1 T_1^{0.5} = \frac{V_1}{2} \times T_2^{0.5}$$

or $$\left(\frac{T_2}{T_1}\right)^{0.5} = 2$$

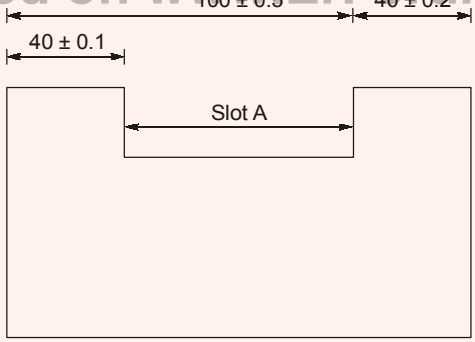
or $$\frac{T_2}{T_1} = 2^{1/0.5} = 4$$

$$\% \text{ change in tool life} = \left(\frac{T_2}{T_1} - 1\right) \times 100\%$$
$$= (4 - 1) \times 100\%$$
$$= 300\%$$

End of Solution

Q.44 The figure shows drawing of a part with dimensions and tolerances, both in mm. The permissible tolerance for slot A (rounded off to one decimal place) in mm is ± _____.

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Ans. **(0.6)**

$$100^{\pm 0.5} + 40^{\pm 0.2} = 40^{\pm 0.1} + A + 40^{\pm 0.2}$$

or $$A = 100^{\pm 0.5} - 40^{\pm 0.1}$$
$$= 60^{\pm 0.5 \pm 0.1} = 60^{\pm 0.6}$$

End of Solution

Q.45 A steel ball of 12 mm diameter is heated to 1225 K. It is then slowly cooled in air to a temperature of 475 K. During the cooling process, the ambient temperture is 325 K and the heat transfer coefficient is 30 W/m^2-K. Assume, the density of steel is 7800 kg/m^3 and the specific heat is 600 J/kg-K. Using the lumped capacitance method of analysis, the calculated time for the required cooling (rounded off to one decimal place) in seconds is _____.

Ans. **(559.0 sec) (557 to 561)**

$d = 12$ mm

$r = 6$ mm

$T_1 = 1225$ K

$T_2 = 475$ K

$T_\infty = 325$ K

$h = 30$ W/m^2-K

$\rho = 7800$ kg/m^3

$c_p = 600$ J/kg-K

Using lumped capacitance method,

$$\frac{T_2 - T_\infty}{T_1 - T_\infty} = e^{-\frac{hA}{\rho V c_p}t}$$

$$\frac{V}{A} = \frac{\frac{4}{3}\pi r^3}{4\pi r^2} = \frac{r}{3} = \frac{0.006}{3}$$

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$$\therefore \quad \frac{475 - 325}{1225 - 325} = e^{-\frac{30\times 3}{7800\times 0.006\times 600}\times t}$$

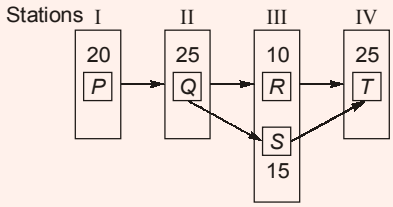
$$\therefore \quad t = 559.03 \text{ sec}$$

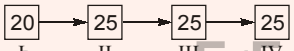
End of Solution

Q.46 A company has to perform five tasks (*P*, *Q*, *R*, *S* and *T*) to make an assembly. Task time and immediate predecessors of the tasks are listed below. If an assembly line is designed to obtain the maximum output rate, the efficiency of the line in % is _____.

Task	Task Time (Seconds)	Immediate predecessor(s)
P	20	–
Q	25	*P*
R	10	*Q*
S	15	*Q*
T	25	*R*,*S*

Ans. **(95%)**





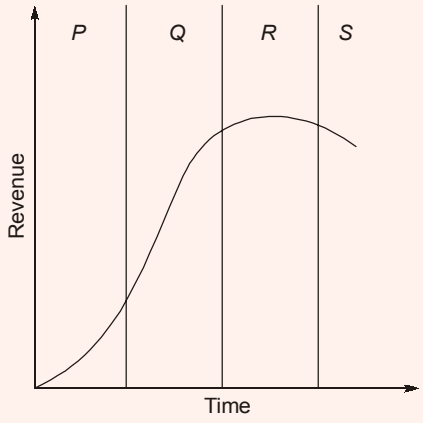
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Line efficiency, $\eta = \frac{TWC}{n \times T_C} = \frac{95}{4 \times 25} \times 100$

$= 95\%$

End of Solution

Q.47 The figure shows revenue generated over different product life cycle stages marked as *P*, *Q*, *R* and *S*. Group I lists these product life cycle stages. Group II lists typical efforts leading to revenue maximization during a stage.



Group I	Group II
P. Introduction	1. efforts to enhance the production capacity
Q. Growth	2. Efforts to rejuvenate the product
R. Maturity	3. Efforts to maximize the product performance
S. Decline	4. Efforts to explore other markets

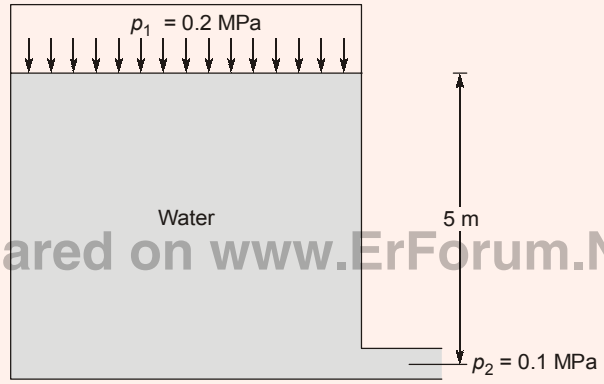
Match the stage with the efforts.

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

Ans. (a)

End of Solution

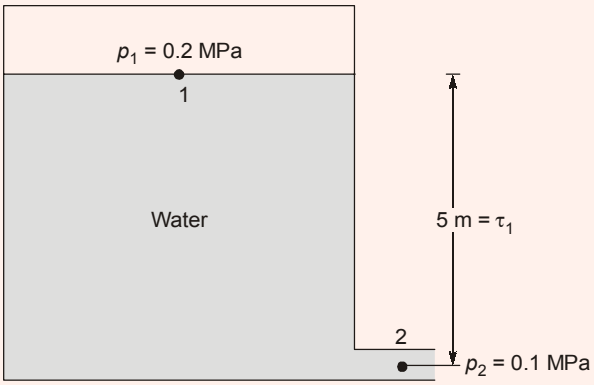
Q.48 A tank of large cross-sectional area contains water up to a height of 5 m as shown in the figure. The top water surface is under a pressure of p_1 = 0.2 MPa. A small, smooth and round tap at the bottom of the tank is opened to the atmosphere (p_2 = 0.1 MPa).



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Use the acceleration due to gravity, g = 9.81 m/s^2, and the density of water, ρ = 1000 kg/m^3. The velocity with which the water will exit from the tap under the conditions shown in the figure (rounded off to one decimal place) in m/s is _____.

Ans. (17.3 m/s)



$$A_1V_1 = A_2V_2$$

$$V_1 = \frac{A_2V_2}{A_1} \text{ (very large)}$$

$$V_1 \approx \text{negligible}$$

By equation between (1) and (2)

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

$$\frac{P_1 - P_2}{w} + Z_1 = \frac{V_2^2}{2g}$$

$$\frac{V_2^2}{2g} = \frac{(0.2 - 0.1) \times 10^6}{9810} + 5$$

$$V_2 = 17.265 \text{ m/s}$$

End of Solution

Q.49 A vertical boring operation is performed in a cast iron plate to enlarge a blind hole to a diameter of 25 mm up to a depth of 100 mm in a single pass. The cutting speed and the feed used in the process are 100 m/min and 0.1 mm/rev, respectively. Considering the allowance for tool approach as 2 mm, the actual machining time (rounded off to two decimal places) in minutes is _____.

Ans. (0.80) (0.78 to 0.82)

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Given : $D = 25$ mm

Depth, $l = 100$ mm

$V = 100$ m/min

$f = 0.1$ mm/rev

Allowance $= x = 2$ mm

$$V = \frac{\pi DN}{1000}$$

$$\therefore \quad 100 = \frac{\pi \times 25 \times N}{1000}$$

$$\therefore \quad N = 1273.239 \text{ rpm}$$

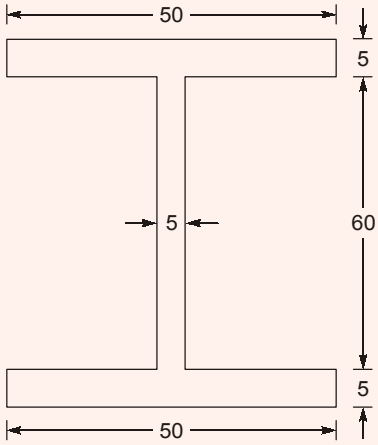
$$\text{Machining time, } t_m = \frac{l + x}{fN}$$

$$= \frac{100 + 2}{0.1 \times 1273.239}$$

$$t_m = 0.80 \text{ minutes}$$

End of Solution

Q.50 A cylindrical billet of 90 mm diameter is extruded to produce an I-section as shown in the figure (all dimensions in mm).



The total extrusion pressure (p_e) in MPa required for the above process is given by

$$p_e = \sigma_m\left[0.8 + 1.2\ln\left(\frac{A_0}{A_f}\right)\right]$$

where, σ_m is the mean flow stress of the material, and A_0 and A_f are the initial and the final cross-sectional areas, respectively. If the mean flow stress of the extruded material is 80 MPa, the force required for the above extrusion (rounded off to one decimal place) in kN is _____.

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Ans. **(1673.5 kN) (1672 to 1675)**

$\sigma_m = 80$ MPa

$A_o = \frac{\pi}{4}\times 90^2 \text{mm}^2 = 6361.73 \text{ mm}^2$

$A_f = 50 \times 5 + 60 \times 5 + 50 \times 5 \text{ mm}^2 = 800 \text{ mm}^2$

$\therefore \quad \frac{A_o}{A_f} = \frac{6361.73}{800} = 7.9522$

$\therefore \quad P_e = 80[0.8 + 1.2 \times \ln 7.9522]$

$= 263.05$ MPa

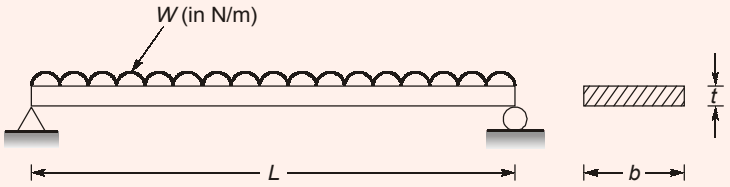
Extrusion Force $= P_e A_o$

$= 263.05 \times 6361.73$ N

$= 1673.46$ kN

End of Solution

Q.51 The figure shows a beam of length L (in m) with a uniformly distributed transverse load of W (in N/m) acting over it. The width and depth of the beam cross section are b (in m) and t (in m), respectively. The magnitude of the maximum bending stress in the beam in N/m^2 is



(a) $\frac{3WL^2}{2bt^2}$ (b) $\frac{2WL^2}{3bt^2}$

(c) $\frac{4WL^2}{3bt^2}$ (d) $\frac{3WL^2}{4bt^2}$

Ans. **(d)**

Maximum B.M., $M_{max} = \frac{WL^2}{8}$

Maximum bending stress,

$$\sigma_{max} = \frac{M_{max}}{z} = \frac{\frac{WL^2}{8}}{\frac{bt^2}{6}}$$

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$$= \frac{3WL^2}{4bt^2}$$

End of Solution

Q.52 A rectifying inspection is performed on a lot of size $N = 1000$ using a Single-Sampling Plan with the sampel size $n = 60$ and the acceptance number $c = 1$. If the Acceptable Quality Level is 1.0%, the producer's risk associated with the sampling plan (rounded off to the nearest integer) in % is

(a) 88 (b) 33

(c) 12 (d) 67

Ans. **(c)**

$N = 1000$

$n = 60$

$c = 1$

$p_i = 0.01$

Producer risk $= \alpha = 1 - L(0.01)$

$$= 1 - \left[{}^{60}C_0 \times 0.01^0 \times 0.99^{60}\right] = \left[{}^{0}C_1 \times 0.01 \times 0.99^{59}\right]$$

$= 1 - 0.8787$

$\alpha = 0.1212$

$\alpha = 12\%$

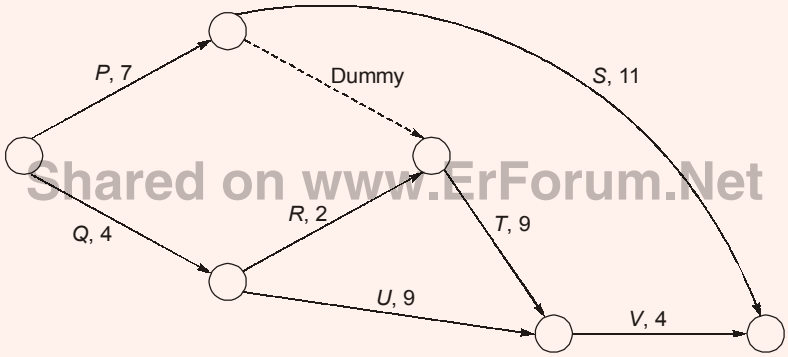
End of Solution

Q.53 A project consists of seven activities as listed in the table. The time required for each activity and its immediate predecessor(s) are also given.

Activity	Time required (in weeks)	Immediate Predecessor(s)
P	7	–
Q	4	–
R	2	*Q*
S	11	*P*
T	9	*P*,*R*
U	9	*Q*
V	4	*T*,*U*

The project completion time using Critical Path Method (CPM) in weeks is _____.

Ans. **(20)**



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Possible numebr of paths

P-*S* = 18

P-Dummy-*T*-*V* = 20

Q-*R*-*T*-*V* = 19

Q-*U*-*V* = 17

Project completion time = 20 weeks

End of Solution

Q.54 General solution of $x^2\frac{d^2y}{dx^2}+x\frac{dy}{dx}-y=0$ is

(a) $y = C_1x + C_2x^3$ (b) $y = C_1x+\frac{C_2}{x}$

(c) $y = \frac{C_1}{x}+\frac{C_2}{x^3}$ (d) $y = C_1x^2+\frac{C_2}{x^2}$

Ans. **(b)**

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

$$[x^2D^2 + xd - 1]y = 0 \quad ...(1)$$

Using $x = e^z$, we have

$$[D_1(D_1 - 1) + D_1 - 1]y = 0$$

$$\Rightarrow [D_1^2 - 1)y = 0 \quad ...(2)$$

AE is $m^2 - 1 = 0 \Rightarrow m = \pm1$

So, C.F. $= C_1e^z + C_2e^{-z}$ and P.I. $= 0$

Hence, general solution is

$$y = CF + PI$$
$$= C_1e^z + C_2e^{-z} \quad \{z = \ln x\}$$
$$= C_1x + C_2(x^{-1})$$
$$y = C_1x + C_2/x$$

End of Solution

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Q.55 The statement that best describes the function of a GO gauge in the context of Taylor's principle of gauging is

(a) GO gauge checks the Maximum Material Condition and is designed to check only one dimension.

(b) GO gauge checks the Maximum Material Condition and is designed to check as many dimensions as possible.

(c) GO gauge checks the Least Material Condition and is designed to check only one dimension.

(d) GO gauge checks that Least Material Condition and is designed to check as many dimensions as possible.

Ans. **(b)**

Taylor's Principle : This principle states that the GO gauge should always be so designed that it will cover the maximum metal condition (MMC) of as many dimensions as possible in the same limit gauges, whereas a NOT GO gauges to cover the minimum metal condition of one dimension only.

End of Solution

■■■■