Q.30 An irreversible heat engine extracts heat from a high temperature source at a rate of 100 kW and rejects heat to a sink at a rate of 50 kW. The entire work output of the heat engine is used to drive a reversible heat pump operating between a set of independent isothermal heat reservoirs at 17 °C and 75 °C. The rate (in kW) at which the heat pump delivers heat to its high temperature sink is

(A) 50 (B) 250 (C) 300 (D) 360

Q.31 You are asked to evaluate assorted fluid flows for their suitability in a given laboratory application. The following three flow choices, expressed in terms of the two-dimensional velocity fields in the *xy*-plane, are made available.

P. $u = 2y, v = -3x$

Q. $u = 3xy, v = 0$

R. $u = -2x, v = 2y$

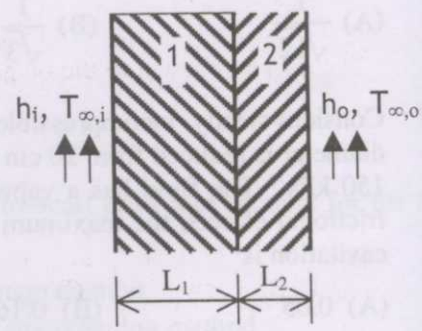
Which flow(s) should be recommended when the application requires the flow to be incompressible and irrotational ?

(A) P and R (B) Q (C) Q and R (D) R

Q.32 Water at 25 °C is flowing through a 1.0 km long G.I. pipe of 200 mm diameter at the rate of 0.07 m^3/s. If value of Darcy friction factor for this pipe is 0.02 and density of water is 1000 kg/m^3, the pumping power (in kW) required to maintain the flow is

(A) 1.8 (B) 17.4 (C) 20.5 (D) 41.0

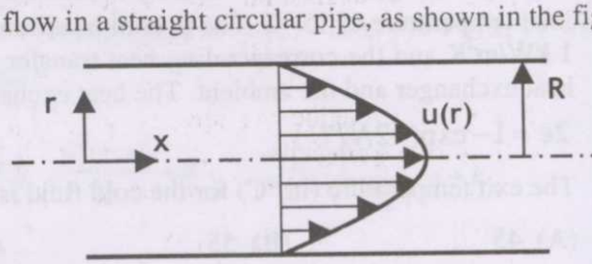
Q.33 Consider steady-state heat conduction across the thickness in a plane composite wall (as shown in the figure) exposed to convection conditions on both sides.



Given: $h_i = 20$ W/m^{2}K; $h_o = 50$ W/m^{2}K; $T_{\infty,i} = 20$ °C; $T_{\infty,o} = -2$ °C; $k_1 = 20$ W/mK; $k_2 = 50$ W/mK; $L_1 = 0.30$ m and $L_2 = 0.15$ m. Assuming negligible contact resistance between the wall surfaces, the interface temperature, T (in °C), of the two walls will be

(A) – 0.50 (B) 2.75 (C) 3.75 (D) 4.50

Q.34 The velocity profile of a fully developed laminar flow in a straight circular pipe, as shown in the figure, is given by the expression



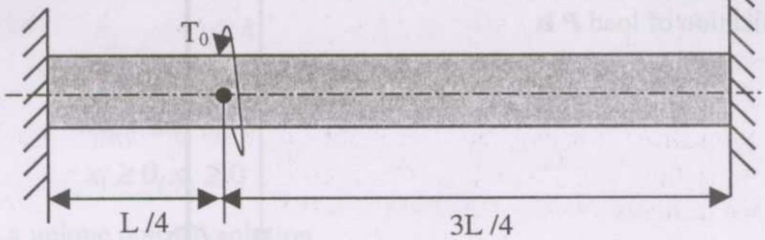
$$u(r) = -\frac{R^2}{4\mu}\left(\frac{dp}{dx}\right)\left(1 - \frac{r^2}{R^2}\right)$$

where $\frac{dp}{dx}$ is a constant.

The average velocity of fluid in the pipe is

(A) $-\frac{R^2}{8\mu}\left(\frac{dp}{dx}\right)$ (B) $-\frac{R^2}{4\mu}\left(\frac{dp}{dx}\right)$ (C) $-\frac{R^2}{2\mu}\left(\frac{dp}{dx}\right)$ (D) $-\frac{R^2}{\mu}\left(\frac{dp}{dx}\right)$

Q.35 A solid shaft of diameter, d and length, L is fixed at both the ends. A torque, T_0 is applied at a distance, $L/4$ from the left end as shown in the figure given below.



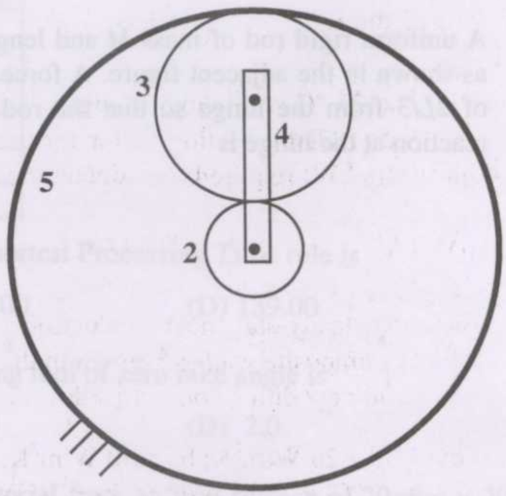
The maximum shear stress in the shaft is

(A) $\frac{16T_0}{\pi d^3}$ (B) $\frac{12T_0}{\pi d^3}$ (C) $\frac{8T_0}{\pi d^3}$ (D) $\frac{4T_0}{\pi d^3}$

Q.36 An epicyclic gear train is shown schematically in the adjacent figure.

The sun gear 2 on the input shaft is a 20 teeth external gear. The planet gear 3 is a 40 teeth external gear. The ring gear 5 is a 100 teeth internal gear. The ring gear 5 is fixed and the gear 2 is rotating at 60 rpm ccw (ccw = counter-clockwise and cw = clockwise).

The arm 4 attached to the output shaft will rotate at



(A) 10 rpm ccw (B) 10 rpm cw (C) 12 rpm cw (D) 12 rpm ccw

Q.37 A forged steel link with uniform diameter of 30 mm at the centre is subjected to an axial force that varies from 40 kN in compression to 160 kN in tension. The tensile (S_u), yield (S_y) and corrected endurance (S_e) strengths of the steel material are 600 MPa, 420 MPa and 240 MPa respectively. The factor of safety against fatigue endurance as per Soderberg's criterion is

(A) 1.26 (B) 1.37 (C) 1.45 (D) 2.00

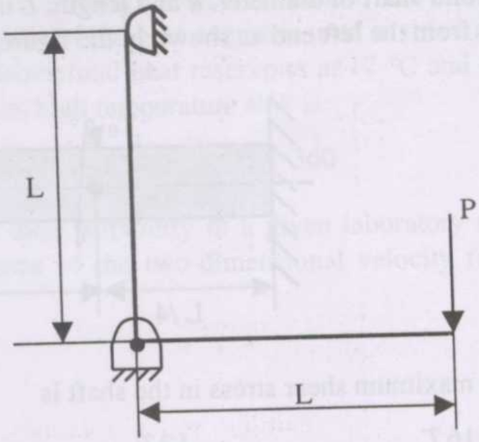
Q.38 An automotive engine weighing 240 kg is supported on four springs with linear characteristics. Each of the front two springs have a stiffness of 16 MN/m while the stiffness of each rear spring is 32 MN/m. The engine speed (in rpm), at which resonance is likely to occur, is

(A) 6040 (B) 3020 (C) 1424 (D) 955

Q.39 A vehicle suspension system consists of a spring and a damper. The stiffness of the spring is 3.6 kN/m and the damping constant of the damper is 400 Ns/m. If the mass is 50 kg, then the damping factor (d) and damped natural frequency (f_n), respectively, are

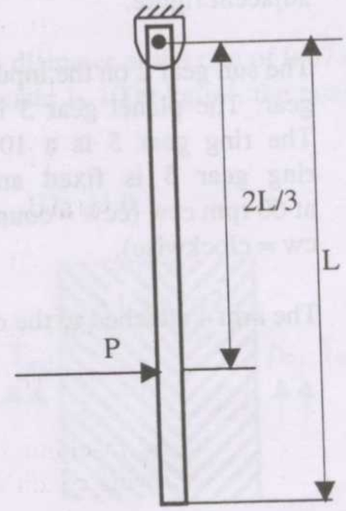
(A) 0.471 and 1.19 Hz (B) 0.471 and 7.48 Hz
(C) 0.666 and 1.35 Hz (D) 0.666 and 8.50 Hz

Q.40 A frame of two arms of equal length L is shown in the adjacent figure. The flexural rigidity of each arm of the frame is EI. The vertical deflection at the point of application of load P is



(A) $\frac{PL^3}{3EI}$ (B) $\frac{2PL^3}{3EI}$ (C) $\frac{PL^3}{EI}$ (D) $\frac{4PL^3}{3EI}$

Q.41 A uniform rigid rod of mass M and length L is hinged at one end as shown in the adjacent figure. A force P is applied at a distance of $2L/3$ from the hinge so that the rod swings to the right. The reaction at the hinge is



(A) –P (B) 0 (C) P/3 (D) 2P/3

Q.42 Match the approaches given below to perform stated kinematics / dynamics analysis of machine.

Analysis	Approach
P. Continuous relative rotation	1. D'Alembert's principle
Q. Velocity and acceleration	2. Grubler's criterion
R. Mobility	3. Grashoff's law
S. Dynamic-static analysis	4. Kennedy's theorem

(A) P-1, Q-2, R-3, S-4 (B) P-3, Q-4, R-2, S-1
(C) P-2, Q-3, R-4, S-1 (D) P-4, Q-2, R-1, S-3

Q.43 A company uses 2555 units of an item annually. Delivery lead time is 8 days. The reorder point (in number of units) to achieve optimum inventory is

(A) 7 (B) 8 (C) 56 (D) 60

Q.44 Consider the following Linear Programming Problem (LPP) :

$$\begin{aligned} &\text{Maximize } z = 3x_1 + 2x_2 \\ &\text{Subject to} \quad x_1 \le 4 \\ &\qquad x_2 \le 6 \\ &\qquad 3x_1 + 2x_2 \le 18 \\ &\qquad x_1 \ge 0, x_2 \ge 0 \end{aligned}$$

(A) The LPP has a unique optimal solution.
(B) The LPP is infeasible.
(C) The LPP is unbounded.
(D) The LPP has multiple optimal solutions.

Q.45 Six jobs arrived in a sequence as given below:

Jobs	Processing Time (days)
I	4
II	9
III	5
IV	10
V	6
VI	8

Average flow time (in days) for the above jobs using Shortest Processing Time rule is

(A) 20.83 (B) 23.16 (C) 125.00 (D) 139.00

Q.46 Minimum shear strain in orthogonal turning with a cutting tool of zero rake angle is

(A) 0.0 (B) 0.5 (C) 1.0 (D) 2.0

Q.47 Electrochemical machining is performed to remove material from an iron surface of 20 mm × 20 mm under the following conditions:

Inter electrode gap	= 0.2 mm
Supply voltage (DC)	= 12 V
Specific resistance of electrolyte	= 2 Ω cm
Atomic weight of Iron	= 55.85
Valency of Iron	= 2
Faraday's constant	= 96540 Coulombs

The material removal rate (in g/s) is

(A) 0.3471 (B) 3.471 (C) 34.71 (D) 347.1

Q.48 Match the following :

NC Code	Definition
P. M05	1. Absolute coordinate system
Q. G01	2. Dwell
R. G04	3. Spindle stop
S. G90	4. Linear interpolation

(A) P-2,Q-3,R-4,S-1 (B) P-3,Q-4,R-1,S-2
(C) P-3,Q-4,R-2,S-1 (D) P-4,Q-3,R-2,S-1

Q.49 What are the upper and lower limits of the shaft represented by 60 f_8 ?

Use the following data:

Diameter 60 lies in the diameter step of 50-80 mm.

Fundamental tolerance unit, i, in μm = $0.45\,D^{1/3} + 0.001\,D$, where D is the representative size in mm;

Tolerance value for IT8 = $25i$. Fundamental deviation for 'f' shaft = $-5.5D^{0.41}$

(A) Lower limit = 59.924 mm, Upper Limit = 59.970 mm

(B) Lower limit = 59.954 mm, Upper Limit = 60.000 mm

(C) Lower limit = 59.970 mm, Upper Limit = 60.016 mm

(D) Lower limit = 60.000 mm, Upper Limit = 60.046 mm

Q.50 Match the items in Column I and Column II.

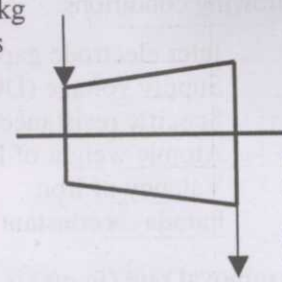
Column I	Column II
P. Metallic Chills	1. Support for the core
Q. Metallic Chaplets	2. Reservoir of the molten metal
R. Riser	3. Control cooling of critical sections
S. Exothermic Padding	4. Progressive solidification

(A) P-1, Q-3, R-2, S-4
(B) P-1, Q-4, R-2, S-3
(C) P-3, Q-4, R-2, S-1
(D) P-4, Q-1, R-2, S-3

Common Data Questions

Common Data for Questions 51 and 52 :

The inlet and the outlet conditions of steam for an adiabatic steam turbine are as indicated in the figure. The notations are as usually followed.



Q.51 If mass flow rate of steam through the turbine is 20 kg/s, the power output of the turbine (in MW) is

(A) 12.157 (B) 12.941 (C) 168.001 (D) 168.785

Q.52 Assume the above turbine to be part of a simple Rankine cycle. The density of water at the inlet to the pump is 1000 kg/m^3. Ignoring kinetic and potential energy effects, the specific work (in kJ/kg) supplied to the pump is

(A) 0.293 (B) 0.351 (C) 2.930 (D) 3.510

Common Data for Questions 53 and 54:

Radiative heat transfer is intended between the inner surfaces of two very large isothermal parallel metal plates. While the upper plate (designated as plate 1) is a black surface and is the warmer one being maintained at 727 °C, the lower plate (plate 2) is a diffuse and gray surface with an emissivity of 0.7 and is kept at 227 °C. Assume that the surfaces are sufficiently large to form a two-surface enclosure and steady-state conditions to exist. Stefan-Boltzmann constant is given as 5.67×10^{-8} W/m^2K^4.

Q.53 The irradiation (in kW/m^2) for the upper plate (plate 1) is

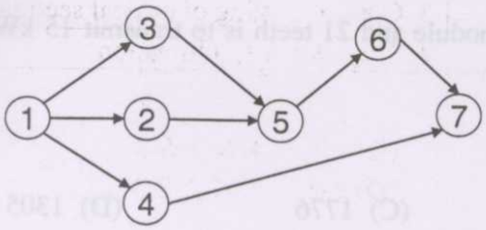
(A) 2.5 (B) 3.6 (C) 17.0 (D) 19.5

Q.54 If plate 1 is also a diffuse and gray surface with an emissivity value of 0.8, the net radiation heat exchange (in kW/m^2) between plate 1 and plate 2 is

(A) 17.0 (B) 19.5 (C) 23.0 (D) 31.7

Common Data for Questions 55 and 56 :

Consider the following PERT network :



The optimistic time, most likely time and pessimistic time of all the activities are given in the table below :

Activity	Optimistic time (days)	Most likely time (days)	Pessimistic time (days)
1-2	1	2	3
1-3	5	6	7
1-4	3	5	7
2-5	5	7	9
3-5	2	4	6
5-6	4	5	6
4-7	4	6	8
6-7	2	3	4

Q.55 The critical path duration of the network (in days) is

(A) 11 (B) 14 (C) 17 (D) 18

Q.56 The standard deviation of the critical path is

(A) 0.33 (B) 0.55 (C) 0.77 (D) 1.66

Linked Answer Questions

Statement for Linked Answer Questions 57 and 58 :

In a machining experiment, tool life was found to vary with the cutting speed in the following manner:

Cutting speed (m/min)	Tool life (minutes)
60	81
90	36

Q.57 The exponent (n) and constant (k) of the Taylor's tool life equation are

(A) $n = 0.5$ and $k = 540$
(B) $n = 1$ and $k = 4860$
(C) $n = -1$ and $k = 0.74$
(D) $n = -0.5$ and $k = 1.155$

Q.58 What is the percentage increase in tool life when the cutting speed is halved ?

(A) 50% (B) 200% (C) 300% (D) 400%

Statement for Linked Answer Questions 59 and 60 :

A 20° full depth involute spur pinion of 4 mm module and 21 teeth is to transmit 15 kW at 960 rpm. Its face width is 25 mm.

Q.59 The tangential force transmitted (in N) is

(A) 3552 (B) 2611 (C) 1776 (D) 1305

Q.60 Given that the tooth geometry factor is 0.32 and the combined effect of dynamic load and allied factors intensifying the stress is 1.5; the minimum allowable stress (in MPa) for the gear material is

(A) 242.0 (B) 166.5 (C) 121.0 (D) 74.0

END OF THE QUESTION PAPER