SECTION - A

1. This question consists of TWENTY-FIVE sub-questions (1.1 – 1.25) of ONE mark each. For each of these sub-questions, four possible alternatives (A, B, C and D) are given, out of which ONLY ONE is correct. Indicate the correct answer by darkening the appropriate bubble against the question number on the left hand side of the Objective Response Sheet (ORS). You may use the answer book provided for any rough work, if needed.

1.1 Two dice are thrown. What is the probability that the sum of the numbers on the two dice is eight?

(a) $\frac{5}{36}$ (b) $\frac{5}{18}$ (c) $\frac{1}{4}$ (d) $\frac{1}{3}$

1.2 Which of the following functions is not differentiable in the domain [-1,1]?

(a) $f(x)=x^2$ (b) $f(x)=x-1$

(c) $f(x)=2$ (d) $f(x)=\text{maximum}(x,-x)$

1.3 A regression model is used to express a variable Y as a function of another variable X. this implies that

(a) there is a causal relationship between Y and X

(b) a value of X may be used to estimate a value of Y

(c) values of X exactly determine values of Y

(d) there is no causal relationship between Y and X

1.4 The principles of motion economy are mostly used while conducting

(a) a method study on an operation

(b) a time study on an operation

(c) a financial appraisal of an operation

(d) a feasibility study of the proposed manufacturing plant

1.5 The standard time of an operation while conducting a time study is

(a) mean observed time + allowances

(b) normal time + allowances

(c) mean observed time × rating factor + allowances

(d) normal time × rating factor + allowances

1.6 In carrying out a work sampling study in a machine shop, it was found that a particular lathe was down for 20% of the time. What would be the 95% confidence interval of this estimate if 100 observations were made?

(a) (0.16,0.24) (b) (0.12,0.28) (c) (0.08,0.32) (d) none of these

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1.7 An item can be purchased for Rs.100. The ordering cost is Rs.200 and the inventory carrying cost is 10% of the item cost per annum. If the annual demand is 4000 units, the economic order quantity (in units) is

(a) 50 (b) 100 (c) 200 (d) 400

1.8 The minimum number of teeth on the pinion to operate without interference in standard full height involute teeth gear mechanism with 20° pressure angle is

(a) 14 (b) 12 (c) 18 (d) 32

1.9 The minimum number of links in a single degree-of-freedom planar mechanism with both higher and lower kinematic pairs is

(a) 2 (b) 3 (c) 4 (d) 5

1.10 The Coriolis component of acceleration is present in

(a) 4-bar mechanisms with 4 turning pairs (b) shape mechanism
(c) slider-crank mechanism (d) Scotch Yoke mechanism

1.11 The total area under the stress-strain curve of a mild steel specimen tested up to failure under tension is a measure of

(a) ductility (b) ultimate strength
(c) stiffness (d) toughness

1.12 The number of components in a stress tensor defining stress at a point in three dimensions is

(a) 3 (b) 4 (c) 6 (d) 9

1.13 A lead-screw with half nuts in a lathe, free to rotate in both directions has

(a) V-threads (b) Whitworth threads
(c) Buttress threads (d) Acme threads

1.14 the primary purpose of a sprue in a casting mould is to

(a) feed the casting at a rate consistent with the rate of solidification
(b) act as a reservoir for molten metal
(c) feed molten metal from the pouring basin to the gate
(d) help feed the casting until all solidification takes place

1.15 Hot rolling of mild steel is carried out

(a) at re-crystallization temperature (b) between 100 C to 150 C
(c) between re-crystallization temperature
(d) above re-crystallization temperature

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1.16 Which of the following arc welding processes does not use consumable electrodes

(a) GMAW (b) GTAW

(c) Submerged Arc Welding (d) none of these

1.17 Trepanning is performed for

(a) finishing a drilled hole

(b) producing a large hole without drilling

(c) truing a hole for alignment (d) enlarging a drilled hole

1.18 The hardness of a grinding wheel is determined by the

(a) hardness of abrasive grains

(b) ability of the bond to retain abrasives

(c) hardness of the bond

(d) ability of the grinding wheel to penetrate the work piece

1.19 A positive value of Joule-Thomson coefficient of a fluid means

(a) temperature drops during throttling

(b) temperature remains constant during throttling

(c) temperature rises during throttling

(d) none of these

1.20 If there are m physical quantities and n fundamental dimensions in a particular process, the number of non-dimensional parameters is

(a) $m+n$ (b) $m \times n$ (c) $m-n$ (d) m/n

1.21 If x is the distance measured from the leading edge of a flat plate, the laminar boundary layer thickness varies as

(a) $\frac{1}{x}$ (b) $x^{\frac{4}{5}}$ (c) x^2 (d) $x^{\frac{1}{2}}$

1.22 Flow separation in flow past a solid object is caused by

(a) a reduction of pressure to vapour pressure

(b) a negative pressure gradient

(c) a positive pressure gradient

(d) the boundary layer thickness reducing to zero

1.23 A correctly designed convergent-divergent nozzle working at a designed load is

(a) always isentropic (b) always choked

(c) never choked (d) never isentropic

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1.24 The value of Biot number is very small (less than 0.01) when

(a) the convective resistance of the fluid is negligible

(b) the conductive resistance of the fluid is negligible

(c) the conductive resistance of the solid is negligible

(d) none of these

1.25 For the same inlet and outlet temperatures of hot and cold fluids, the Log Mean Temperature Difference (LMTD) is

(a) greater for parallel flow heat exchanger than for counter flow heat exchanger.

(b) greater for counter flow heat exchanger than for parallel flow heat exchanger.

(c) same for both parallel and counter flow heat exchangers.

(d) dependent on the properties of the fluids.

2. This question consists of TWENTY-FIVE sub-questions (2.1 – 2.25) of TWO marks each. For each of these sub-questions, four possible alternatives (A, B, C and D) are given, out of which ONLY ONE is correct. Indicate the correct answer by darkening the appropriate bubble against the question number on the left hand side of the Objective Response Sheet (ORS). You may use the answer book provided for any rough work, if needed.

2.1 The following set of equations has

$$3x + 2y + z = 4$$
$$x - y + z = 2$$
$$-2x + 2z = 5$$

(a) no solution

(b) a unique solution

(c) multiple solutions

(d) an inconsistency

2.2 The function $f(x, y) = 2x^2 + 2xy - y^3$ has

(a) only one stationary point at (0,0)

(b) two stationary points at (0,0) and $\left(\frac{1}{6}, \frac{1}{3}\right)$

(c) two stationary points at (0,0) and (1,-1)

(d) no stationary point

2.3 Manish has to travel from A to D changing buses at stops B and C enroute. The maximum waiting time at either stop can be 8 minutes each, but any time of waiting up to 8 minutes is equally likely at both places. He can afford up to 13 minutes of total waiting time if he is to arrive at D on time. What is the probability that Manish will arrive late at D?

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(a) $\frac{8}{13}$ (b) $\frac{13}{64}$ (c) $\frac{119}{128}$ (d) $\frac{9}{128}$

2.4 Arrivals at a telephone booth are considered to be Poisson, with an average time of 10 minutes between successive arrivals. The length of a phone call is distributed exponentially with mean 3 minutes. The probability that an arrival does not have to wait before service is

(a) 0.3 (b) 0.5 (c) 0.7 (d) 0.9

2.5 The supply at three sources is 50, 40 and 60 units respectively whilst the demand at the four destinations is 20, 30, 10 and 50 units. In solving this transportation problem

(a) a dummy source of capacity 40 units is needed

(b) a dummy destination of capacity 40 units is needed

(c) no solution exists as the problem is infeasible

(d) none solution exists as the problem is degenerate

2.6 A project consists of three parallel paths with mean durations and variances of (10,4), (12,4) and (12,9) respectively. According to the standard PERT assumptions, the distribution of the project duration is

(a) Beta with mean 10 and standard deviation 2

(b) Beta with mean 12 and standard deviation 2

(c) Normal with mean 10 and standard deviation 3

(d) Normal with mean 12 and standard deviation 3

2.7 The coupling used to connect two shafts with large angular misalignment is

(a) a Flange coupling (b) an Oldham's coupling

(c) a Flexible bush coupling (d) a Hooke's joint

2.8 A static load is mounted at the center of a shaft rotating at uniform angular velocity. This shaft will be designed for

(a) the maximum compressive stress (static)

(b) the maximum tensile (static)

(c) the maximum bending moment (static)

(d) fatigue loading

2.9 Large speed reductions (greater than 20) in one stage of a gear train are possible through

(a) Spur gearing (b) Worm gearing

(c) Bevel gearing (d) Helical gearing

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2.10 If the wire diameter of a closed coil helical spring subjected to compressive load is increased from 1 cm to 2 cm, other parameters remaining same, the deflection will decrease by a factor of

(a) 16 (b) 8 (c) 4 (d) 2

2.11 The relationship between Young's modulus (E), Bulk modulus (K) and Poisson's ratio (μ) is given by

(a) $E = 3K(1-2\mu)$ (b) $K = 3E(1-2\mu)$ (c) $E = 3K(1-\mu)$ (d) $K = 3E(1-\mu)$

2.12 The ratio of Euler's buckling loads of columns with the same parameters having (i) both ends fixed, and (ii) both ends hinged is

(a) 2 (b) 4 (c) 6 (d) 8

2.13 If the length of the cantilever beam is halved, the natural frequency of the mass M at the end of this cantilever beam of negligible mass is increased by a factor of

(a) 2 (b) 4 (c) $\sqrt{8}$ (d) 8

2.14 In centrifugal casting, the impurities are

(a) uniformly distributed (b) forced towards the outer surface
(c) trapped near the mean radius of the casting
(d) collected at the center of the casting

2.15 The ductility of a material with work hardening

(a) increases (b) decreases
(c) remains unaffected (d) unpredictable

2.16 The temperature of a carburising flame in gas welding is _____ that of a neutral or an oxidizing flame.

(a) lower than (b) higher than (c) equal to (d) unrelated to

2.17 In a blanking operation, the clearance is provided on

(a) the die (b) both the die and the punch equally
(c) the punch (d) neither the punch nor the die

2.18 A built-up-edge is formed while machining

(a) ductile materials at high speed (b) ductile materials at low speed
(c) brittle materials at high speed (d) brittle materials at low speed

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2.19 The time taken to drill a hole though a 25 mm thick plate with the drill rotating at 300 rpm and moving at a feed rate of 0.25 mm/revolution is

(a) 10 sec (b) 20 sec (c) 60 sec (d) 100 sec

2.20 The properties of mercury at 300 K are: density = 13529 kg/m^3, specific heat at constant pressure = 0.1393 kJ/kg-K, dynamic viscosity =0.1523×10^{-2} N.s/m^2 and thermal conductivity =8.540 W/m-K. The Prandtl number of the mercury at 300 K is

(a) 0.0248 (b) 2.48 (c) 24.8 (d) 248

2.21 What is the value of the view factor for two inclined flat hving common edge of equal width, and with an angle of 20 degrees?

(a) 0.83 (b) 1.17 (c) 0.66 (d) 1.34

2.22 A Carnot cycle is having an efficiency of 0.75. If the temperature of the high temperature reservoir is 727 C, what is the temperature of low temperature reservoir?

(a) 23 C (b) -23 C (c) 0 C (d) 250 C

2.23 An ideal air standard Otto cycle has a compression ratio of 8.5. If the ratio of the specific heats of air (γ) is 1.4, what is the thermal efficiency (in percentage) of the Otto cycle?

(a) 57.5 (b) 45.7 (c) 52.5 (d) 95

2.24 What is the speed of sound in Neon gas at a temperature of 500K (Gas constant of Neon is 0.4210 kJ/kg-K)?

(a) 492 m/s (b) 460 m/s (c) 592 m/s (d) 543 m/s

2.25 The efficiency of superheat Rankine cycle is higher than that of simple Rankine cycle because

(a) the enthalpy of main steam is higher for superheat cycle
(b) the mean temperature of heat addition is higher for superheat cycle
(c) the temperature of steam in the condenser is high
(d) the quality of steam in the condenser is low

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SECTION – B

This section consists of TWENTY questions of FIVE marks each. Attempt ANY FIFTEEN questions. Answers must be given in the answer book provided.

3. Using Laplace transform, solve

$$d^2y/dt^2 + 4y = 12t$$

given that y = 0 and $dy/dt = 9$ at t = 0.

4. A tube of 35 mm outside diameter was turned on a lathe and the following data was obtained:

Rake angle = 35°	Cutting speed	= 15 m/min
Feed rate = 0.1mm/rev	Length of continuous chip in one revolution	=60 mm
Cutting force = 2000 N	Feed force	= 800 N

Calculate the chip thickness, shear plane angle, velocity of chip along tool face and coefficient of friction.

5. While measuring the effective diameter of an external metric screw thread gauge of 3.5mm pitch, a 30.5 mm diameter cylindrical standard and 2 mm diameter wires were used. The micrometer reading over the standard and wires was 13.3768 mm. The corresponding reading over the thread gauge and wires was 12.2428 mm.

Calculate the thread gauge effective diameter.

6. The arc length-voltage characteristic of a D.C. arc is given by the equation V =24+4L where V is the arc voltage in volts and L is the arc length in mm. The static volt-ampere characteristic of the power source is approximated by a straight line with a no load voltage of 80 Volts and short circuit current of 600 Amperes. Determine the optimum arc length for maximum power.

7. Estimate the metal removal rate (in cc/hr) of an alloy containing 18% Cobalt, 62% Nickel and 20% Chromium during Electro-Chemical Machining (ECM) with a current of 500 Amperes. The density of the alloy is 8.28 gm/cc. The following data is available:

Metal	Gram Atomic Weight	Valency
Cobalt	58.93	2
Nickel	58.71	2
Chromium	51.99	6
Assume Faraday's constant as 96,500 Coulombs/mole		

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8. A chalk stick is twisted to failure by applying opposite torques T at the two ends. Take a square elements ABCD with two sides parallel to the longitudinal axis of the stick.

(a) Show the free body diagram with principal stresses.

(b) Find out the principal stresses σ_1 and σ_2 and the principal planes.

(c) Show the plane on which failure/fracture will take place.

9. A cantilever AB of length 'L' has fixed end A and free end B. It is loaded by applying a concentrated load W at the mid point C of the cantilever.

(a) Determine the deflection and slope at points C and B.

(b) Show deflections and slopes on the cantilever.

10. In a single degree-of-freedom, 4-link, revolute jointed Grashoff mechanism, 'l' is the longest link, 's' is the shortest link and p,q are the two remaining links. These links may be in any order.

(a) Write down the condition for feasibility of Grashoff mechanism.

(b) When will you get crank-crank, crank-rocker and rocker-rocker type of mechanisms by fixing links s,l,p or q respectively?

(c) Draw these mechanisms showing motions of crank and rocker links.

11. A toy cylinder of weight w, length l, and radius r rolls without slipping on the inner cylindrical surface of radius R, which is fixed.

(a) Determine the differential equation of motion of the toy for large oscillation about its lowest point using energy method.

(b) Write down the equation of motion and circular frequency of oscillation of the toy for small oscillations.

The center of gravity of the toy is assumed to be at the center of the toy cylinder.

12. A hollow mild steel shaft is subjected to torsional and bending moments T and M respectively. The outside and inside diameters of the shaft are D and d respectively.

(a) Derive the expressions for the maximum shear stress, and the maximum normal stress induced due to combined T and M.

(b) Name any one theory of failure, which may be used to design this shaft using these stresses.

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13. A company has introduced a new product with fixed cost of Rs.200 per week and unit variable cost of Rs.7. The product is sold to a retailer with a quantity discount as per the following schedule:

Quantity	Unit price
0 – 99 units	Rs.10
100 units onwards	Rs.8

(a) Determine the profit as a function of quantity sold.

(b) In what range of quantities sold does the company earn profit?

14. A furniture manufacturer produces chairs and tables. The wood-working department is capable of producing 200 chairs or 100 tables or any proportionate combinations of these per week. The weekly demand for chairs and tables is limited to 150 and 80 units respectively. The profit from a chair is Rs.100 and that from a table is Rs.300.

(a) Set up the problem as a Linear Program

(b) Determine the optimum product mix for maximizing the profit.

(c) What is the maximum profit?

(d) If the profit of each table drops to Rs.200 per unit, what is the optimal mix and profit?

15. The precedence relations and durations of jobs in a project are given below:

Job	Predecessor(s)	Duration (in days)
A	-	2
B	-	4
C	A	6
D	A	8
E	B,C	6
F	B,C	4
G	F	2
H	F	8
I	D,E,G	6

(a) Draw the activity-on-arc project network

(b) Determine all critical path(s) and their duration(s).

(c) What is the total float for jobs B and D?

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16. A copper tube of 20 mm outer diameter, 1 mm thickness and 20 m long (Thermal conductivity = 400 W/m-K) is carrying saturated steam at 150 C (Convective heat transfer coefficient = 150 W/m^2-K). The tube is exposed to an ambient temperature of 27 C. The convective heat transfer coefficient of air is 5 W/m^2-K. Glass wool is used for insulation (Thermal conductivity = 0.075 W/m-K). If the thickness of the insulation used is 5 mm higher than the critical thickness of insulation, calculate the rate of heat lost by the steam and the rate of steam condensation in kg/hr (The enthalpy of condensation of steam = 2230 kJ/kg).

17. Air at 327 C and 400 kPa with a volume flow rate of 5 m^3/s flows through a turbine and exits at 100 kPa and 182 C.

    If the expansion process is polytropic, calculate power output, rate of heat transfer and rate of change in entropy (specific heat at constant pressure of air = 1.0035 kJ/kg-K, and Gas Constant of air = 0.287 kJ/kg-K).

18. An ideal, air standard regenerative Brayton cycle is working between minimum and maximum temperatures of 300 K and 1200 K respectively.

    (a) Find out the value of critical pressure ratio where the degree of regeneration becomes zero.

    (b) Calculate the efficiency of the cycle when the operating pressure ratio is 60% of the critical pressure ratio.

19. A centrifugal pump has an efficiency of 80%. The specifications of the pump are: discharge = $70m^3/hr$, Head = 7m, speed = 1450 rpm and diameter = 200mm. If the speed of this pump is increased to 1750 rpm, calculate the discharge, heat developed and power input required without loss in efficiency.

20. The Willan's line measured for a four-stroke, four-cylinder is expressed as:

    FC = 0.15 + 0.03 × B.P., where FC is the rate of fuel consumption in gm/s and B.P. is the brake power in kW. The bore of each cylinder is 75 mm and stroke is 90 mm and the speed is 3000 rpm.

    Calculate indicated power, mechanical efficiency and indicated mean effective pressure, when the engine is developing a brake power of 20 kW.

21. An ice making plant using refrigerant R-12 is having an evaporator saturation temperature of −25C and the condenser saturation temperature of 35C. The vapour is leaving the compressor at 65C. Following table shows the properties of the refrigerant.

Temperature C	Pressure, kPa	Saturation Enthalpy kJ/kg	
		Liquid	Vapour
25	123.7	13.3	176.5
35	850.0	69.6	201.5
Enthalpy of superheated refrigerant at 850 kPa and 65C = 225.5 kJ/kg.			

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(a) Calculate the Coefficient Of Performance (COP) of this system

(b) If the capacity of the plant is 5 kW, calculate mass flow rate of refrigerant and Power consumption.

22. A reciprocating compressor is to be designed to compress 4.5 kg/min of air from 100 kPa and 27C through an overall pressure ratio of 9. The law of compression is $pV^{1.3} = \text{constant}$. Calculate the savings in power consumption and gain in isothermal efficiency, when a two-stage compressor with complete inter-cooling is used in place of a single stage compressor. Assume equal pressure ratio in both the stages of the two stage compressor. (Gas Constant = 0.287 kJ/kg-K).

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