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MT : METALLURGICAL ENGINEERING

Duration: Three Hours *Maximum Marks*: 100

Read the following instructions carefully.

1. Do not open the seal of the Question Booklet until you are asked to do so by the invigilator.
2. Take out the **O**ptical **R**esponse **S**heet (**ORS)** from this Question Booklet **without breaking the seal** and read the instructions printed on the **ORS** carefully.
3. On the right half of the **ORS,** using ONLY a **black ink ball point pen**, (i) darken the bubble corresponding to your test paper code and the appropriate bubble under each digit of your registration number and (ii) write your registration number, your name and name of the examination centre and put your signature at the specified location.
4. This Question Booklet contains **16** pages including blank pages for rough work. After you are permitted to open the seal, please check all pages and report discrepancies, if any, to the invigilator.
5. There are a total of 65 questions carrying 100 marks. All these questions are of objective type. Each question has only **one** correct answer. Questions must be answered on the left hand side of the **ORS** by darkening the appropriate bubble (marked A, B, C, D) using ONLY a **black ink ball point pen** against the question number. **For each question darken the bubble of the correct answer**. More than one answer bubbled against a question will be treated as an incorrect response.
6. Since bubbles darkened by the black ink ball point pen **cannot** be erased, candidates should darken the bubbles in the **ORS very carefully**.
7. Questions Q.1 – Q.25 carry 1 mark each. Questions Q.26 – Q.55 carry 2 marks each. The 2 marks questions include two pairs of common data questions and two pairs of linked answer questions. The answer to the second question of the linked answer questions depends on the answer to the first question of the pair. If the first question in the linked pair is wrongly answered or is unattempted, then the answer to the second question in the pair will not be evaluated.
8. Questions Q.56 – Q.65 belong to General Aptitude (GA) section and carry a total of 15 marks. Questions Q.56 – Q.60 carry 1 mark each, and questions Q.61 – Q.65 carry 2 marks each.
9. Unattempted questions will result in zero mark and wrong answers will result in **NEGATIVE** marks. For all 1 mark questions, ⅓ mark will be deducted for each wrong answer. For all 2 marks questions, ⅔ mark will be deducted for each wrong answer. However, in the case of the linked answer question pair, there will be negative marks only for wrong answer to the first question and no negative marks for wrong answer to the second question.
10. Calculator is allowed whereas charts, graph sheets or tables are **NOT** allowed in the examination hall.
11. Rough work can be done on the question paper itself. Blank pages are provided at the end of the question paper for rough work.
12. Before the start of the examination, write your name and registration number in the space provided below using a black ink ball point pen.

Name								
Registration Number	**MT**							

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Useful Data

Universal gas constant R = 8.314 J/mol.K
Planck's constant h = 6.63×10^{-34} J.s
Acceleration due to gravity g = 9.8 m/s^2

Q. 1 – Q. 25 carry one mark each.

Q.1 **A** is a 2 × 2 matrix with det **A** = 2. The det (2**A**) is

(A) 4 (B) 8 (C) 32 (D) 16

Q.2 **A** is a 2 × 2 matrix given below:

$$\mathbf{A} = \begin{pmatrix} -3 & 1 \\ -1 & -1 \end{pmatrix}$$

The eigenvalues of **A** are

(A) –2, –2 (B) –3, –1 (C) 2, 2 (D) 3, 1

Q.3 In a production facility, iron rods are made with a mean diameter of 6 cm and standard deviation of 0.02 cm. If a large number of rods are tested, the approximate percentage of rods whose sizes fall in the range of 5.98 cm to 6.02 cm is

(A) 68 (B) 75 (C) 90 (D) 99.7

Q.4 Which one of the following methods is NOT used for numerical integration?

(A) Rectangular rule
(B) Trapezoidal rule
(C) Simpson's rule
(D) Cramer's rule

Q.5 How many boundary conditions are required to solve the following equation?

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

(A) Two in *r*-direction
(B) One in *r*-direction and one for time
(C) Two in *r*-direction and one for time
(D) Three in *r*-direction and one for time

Q.6 When a zinc metal rod is immersed in dilute hydrochloric acid, it results in

(A) Evolution of hydrogen
(B) Evolution of chlorine
(C) Evolution of oxygen
(D) No evolution of any gas

Q.7 A fluid is flowing with a velocity of 0.5 m/s on a plate moving with a velocity of 0.01 m/s in the same direction. The velocity at the interface of the fluid and plate is

(A) 0.0 m/s (B) 0.01 m/s (C) 0.255 m/s (D) 0.50 m/s

Q.8 Hot metal at 1700 K is poured in a sand mould that is open at the top. Heat loss from the liquid metal takes place by

(A) Radiation only
(B) Radiation and conduction only
(C) Radiation and convection only
(D) Radiation, conduction and convection

Q.9 Which one of the following is an equilibrium defect?

(A) Vacancies (B) Dislocations (C) Stacking faults (D) Grain boundaries

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Q.10 Floatation beneficiation is based on the principle of

(A) Mineral surface hydrophobicity
(B) Gravity difference
(C) Chemical reactivity
(D) Particle size difference

Q.11 Copper can be reduced from acidic copper sulphate solution by

(A) Silver (B) Iron
(C) Carbon (D) Lead

Q.12 Which one is NOT an agglomeration process?

(A) Nodulizing (B) Briquetting (C) Roasting (D) Pelletizing

Q.13 During LD blow in steelmaking the impurity that gets removed first is

(A) Carbon (B) Phosphorous (C) Manganese (D) Silicon

Q.14 During the solidification of a pure metal, it was found that dendrites are formed. Assuming that the liquid-solid interface is at the melting temperature, the temperature from the interface into the liquid

(A) Decreases
(B) Increases
(C) Remains constant
(D) Increases and then decreases

Q.15 A peak in the X-ray diffraction pattern is observed at $2\theta = 78°$, corresponding to {311} planes of an fcc metal, when the incident beam has a wavelength of 0.154 nm. The lattice parameter of the metal is approximately

(A) 0.6 nm (B) 0.4 nm (C) 0.3 nm (D) 0.2 nm

Q.16 If d is the inter-planar spacing of the planes {h k l}, the inter-planar spacing of the planes {nh nk nl}, n being an integer, is

(A) d (B) d/n (C) nd (D) d/n^2

Q.17 As temperature increases, the electrical resistivities of pure metals (ρ_m) and intrinsic semiconductors (ρ_s) vary as follows

(A) Both ρ_m and ρ_s increase
(B) Both ρ_m and ρ_s decrease
(C) ρ_m increases and ρ_s decreases
(D) ρ_m decreases and ρ_s increases

Q.18 At equilibrium spacing in a crystalline solid, which of the following is true for net inter-atomic force (F) and potential energy (U)

(A) F is zero and U is zero (B) F is zero and U is minimum
(C) F is minimum and U is zero (D) F is minimum and U is minimum

Q.19 The property of a material that CANNOT be significantly changed by heat treatment is

(A) Yield strength (B) Ultimate tensile strength
(C) Ductility (D) Elastic modulus

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Q.20 A unit dislocation splits into two partial dislocations. The correct combination of the Burgers vectors of the partial dislocations for a given unit dislocation having Burgers vector $\frac{a}{2}[1\bar{1}0]$ is

(A) $\frac{a}{6}[2\bar{1}1]$ and $\frac{a}{6}[1\bar{2}\bar{1}]$

(B) $\frac{a}{6}[1\bar{1}2]$ and $\frac{a}{6}[\bar{1}\bar{2}1]$

(C) $\frac{a}{6}[11\bar{2}]$ and $\frac{a}{6}[2\bar{1}\bar{1}]$

(D) $\frac{a}{6}[211]$ and $\frac{a}{6}[12\bar{1}]$

Q.21 A polymer matrix composite is reinforced with long continuous ceramic fibres aligned in one direction. The Young's moduli of the matrix and fibres are E_m and E_f respectively, and the volume fraction of the fibres is f. Assuming iso-stress condition, Young's modulus of the composite E_C in a direction perpendicular to the length of fibres, is given by the expression

(A) $E_C = (1-f)E_m + f\,E_f$

(B) $E_C = f\,E_m + (1-f)E_f$

(C) $\frac{1}{E_C} = \frac{(1-f)}{E_m} + \frac{f}{E_f}$

(D) $\frac{1}{E_C} = \frac{f}{E_m} + \frac{(1-f)}{E_f}$

Q.22 Which of the following is NOT a fusion welding process?

(A) Arc welding
(B) Gas welding
(C) Resistance welding
(D) Friction stir welding

Q.23 Tungsten filament used in electric bulb is processed by

(A) Extrusion
(B) Wire drawing
(C) Casting
(D) Powder metallurgy

Q.24 The riser is designed such that the melt in the riser solidifies

(A) Before casting solidifies
(B) At the same time as casting solidifies
(C) After casting solidifies
(D) Irrespective of the solidification of the casting

Q.25 Radiography technique of detecting defects is based on the principle of

(A) Diffraction
(B) Reflection
(C) Interference
(D) Absorption

Q. 26 to Q. 55 carry two marks each.

Q.26 At x = 0.5, the polynomial $x^2(1-x)^2$ has

(A) No extrema (B) A saddle point (C) A minima (D) A maxima

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Q.27 Given that v is a vector field and f is a scalar field, match the equations in **Group I** with their physical meaning in **Group II**

Group I	**Group II**
P. $\text{div}(v) = 0$	1. Irrotational
Q. $\text{curl}(\text{grad}(f)) = 0$	2. Incompressible
R. $\text{div}(\text{grad}(f)) = 0$	3. Potential
S. $v = \text{grad}(f)$	4. Laplace equation

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

Q.28 The temperature field of a slab is given by $T = 400 - 50z \exp(-t - x^2 - y^2)$. The temperature gradient in y-direction is

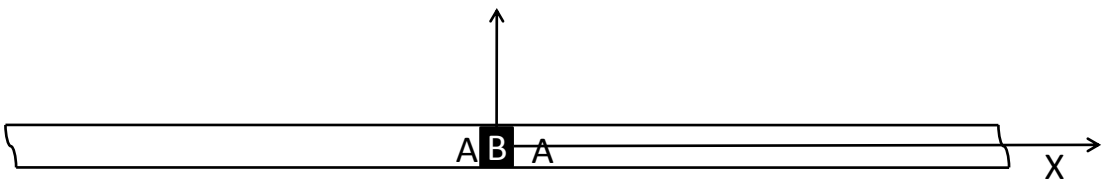
(A) $100yz \exp(-t - x^2 - y^2)$
(B) $-100yz \exp(-t - x^2 - y^2)$
(C) $100xz \exp(-t - x^2 - y^2)$
(D) $-100xz \exp(-t - x^2 - y^2)$

Q.29 What does the solution of the following ordinary differential equation represent?

$$y\frac{dy}{dx} + x = 0$$

(A) A parabola (B) A circle (C) An ellipse (D) A hyperbola

Q.30 A thin layer of material B (of total amount m) is plated on the end faces of two long rods of material A. These are then joined together on the plated side (see the figure below) and heated to a high temperature. Assuming the diffusion coefficient of B in A is D, the composition profile c_B along the rod axis x after a time t is described by



(A) $c_B = \frac{m}{2\sqrt{\pi Dt}} \exp\left[-\frac{x^2}{4Dt}\right]$

(B) $c_B = \frac{m}{2\sqrt{\pi Dt}} \text{erf}\left[-\frac{x^2}{4Dt}\right]$

(C) $c_B = \frac{m}{2\sqrt{\pi Dt}}\left[1 - \text{erf}\left(-\frac{x^2}{4Dt}\right)\right]$

(D) $c_B = \frac{m}{2\sqrt{\pi Dt}} t$

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Q.31 Match the principles given in **Group I** with corresponding corrosion terminology in **Group II**

Group I	**Group II**
P. Electrode polarization	1. Dezincification
Q. Passivity	2. Intergranular attack
R. Selective leaching	3. Over voltage
S. Grain boundary precipitation	4. Surface oxide film

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

Q.32 Identify the correct combination of the following statements

P. Hydrogen electrode is a standard used to measure redox potentials
Q. Activation polarization refers to electrochemical processes controlled by reaction sequence at metal-solution interface
R. Potential-pH diagrams can be used to predict corrosion rates of metals
S. Cathodic protection can use sacrificial anodes such as magnesium

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

Q.33 Consider a reaction with activation energy of 8.314 kJ/mol that takes place at 300 K. If the reaction rate is to be tripled, the temperature of the reaction should be

(A) 174.5 K (B) 447.5 K (C) 600.5 K (D) 847.5 K

Q.34 Match the processes in **Group I** with the objectives in **Group II**

Group I	**Group II**
P. Vacuum Arc Degassing (VAD)	1. Primary iron making
Q. LD	2. Secondary steel making
R. COREX	3. Direct smelting
S. Blast Furnace	4. Primary steel making

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

Q.35 The reduction of FeO with CO gas in co-current flow is given by the following equation:

$$FeO + CO = Fe + CO_2 \qquad \Delta G^o = 8120 \text{ J at } 1173 \text{ K}$$

The ratio of p_{CO}/p_{CO2} for this reaction at 1173 K is

(A) 0.0 (B) 0.25 (C) 0.44 (D) 2.3

Q.36 The sulphide capacity (C_S) of liquid slag of composition 55 wt.% CaO, 20 wt.% SiO_2, 15 wt.% Al_2O_3, and 10 wt.% MgO is given by the following equation

$$\log C_S = 3.44\,(X_{CaO} + 0.1\,X_{MgO} - 0.8\,X_{Al_2O_3} - X_{SiO_2}) - (9894/T) + 2.05$$

where, X is mole fraction of the respective components. Atomic weights of Ca, Mg, Si, Al and O are 40, 24, 28, 27 and 16 respectively.

The value of C_S at 1900 K is

(A) 0.0009 (B) 0.009 (C) 0.09 (D) 0.9

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Q.37 Match the processes given in **Group I** with the corresponding metals in **Group II**

Group I	**Group II**
P. Matte smelting	1. Lead
Q. Cyanide leaching	2. Copper
R. Carbothermic reduction	3. Gold
S. Fused salt electrolysis	4. Aluminium

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

Q.38 Identify the correct combination of the following statements

P. Bessemer converter can be used in copper smelting
Q. The Mond process for nickel involves reaction of metal with H_2 gas
R. Roasted ZnS concentrates can be smelted in a blast furnace
S. Magnesium metal can be produced by electrolysis of sea water

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

Q.39 Match the phases of steel in **Group I** with the crystal structures in **Group II**

Group I	**Group II**
P. Martensite	1. bcc
Q. Cementite	2. fcc
R. Austenite	3. bct
S. Ferrite	4. Orthorhombic

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

Q.40 Arrange the following in terms of increasing severity of quench

P. Oil quenching
Q. Water quenching
R. Water quenching with agitation
S. Brine quenching

(A) P<Q<R<S (B) Q<R<P<S
(C) P<Q<S<R (D) Q<P<R<S

Q.41 Regarding recrystallization, which one of the following statements is NOT correct?

(A) Higher the amount of cold work, lower is the recrystallization temperature
(B) Higher the recovery, higher is the recrystallization temperature
(C) Higher the temperature of cold work, higher is the recrystallization temperature
(D) Finer the initial grain size, higher is the recrystallization temperature

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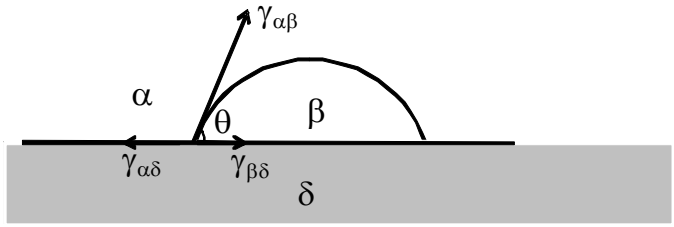
Q.42 A liquid droplet (β) is on a substrate (δ) and is surrounded by air (α), as shown below. The angle of contact (θ) is determined using the following expression:



(A) $\theta = \cos^{-1}\left(\frac{\gamma_{\alpha\delta} - \gamma_{\beta\delta}}{\gamma_{\alpha\beta}}\right)$

(B) $\theta = \cos^{-1}\left(\frac{\gamma_{\alpha\delta} - \gamma_{\alpha\beta}}{\gamma_{\alpha\beta}}\right)$

(C) $\theta = \cos^{-1}\left(\frac{\gamma_{\alpha\delta} - \gamma_{\beta\delta}}{\gamma_{\alpha\delta}}\right)$

(D) $\theta = \cos^{-1}\left(\frac{\gamma_{\alpha\delta} - \gamma_{\beta\delta}}{\gamma_{\beta\delta}}\right)$

Q.43 Match the phenomena listed in **Group I** with the possible mechanisms in **Group II**

Group I	**Group II**
P. Fatigue	1. Grain boundary sliding
Q. Creep	2. Slip band extrusion and intrusion
R. Strain hardening	3. Cottrell atmosphere
S. Yield point phenomenon	4. Dislocation interaction

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

Q.44 Fracture stress for a brittle material having a crack length of 1 μm is 200 MPa. Fracture stress for the same material having a crack length of 4 μm is

(A) 200 MPa (B) 150 MPa (C) 100 MPa (D) 50 MPa

Q.45 The flow stress ($\bar{\sigma}$) of an alloy varies with strain rate $(\dot{\varepsilon})$ as $\bar{\sigma} = 100\ (\dot{\varepsilon})^{0.1}$ MPa. When the alloy is hot extruded from 10 cm diameter to 5 cm diameter at a speed of 2 cm/s, the flow stress is

(A) 1000 MPa (B) 105 MPa (C) 150 MPa (D) 1050 MPa

Q.46 Determine the correctness or otherwise of the following **Assertion (a)** and **Reason (r)**.

Assertion : During rolling, front tension and (or) back tension are (is) employed to decrease rolling load.
Reason : Roll pressure decreases due to lowering of flow stress as a result of front tension/back tension.

(A) **a** is false but **r** is true
(B) **a** is true and **r** is also true, but **r** is not the reason for **a**
(C) **a** is true and **r** is also true, and **r** is the reason for **a**
(D) **a** is true but **r** is false

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Q.47 Match the defects listed in **Group I** with the processes listed in **Group II**

Group I	**Group II**
P. Cold shut	1. Rolling
Q. Earing	2. Forging
R. Alligatoring	3. Deep drawing
S. Shrinkage porosity	4. Fusion welding

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

Common Data Questions

Common Data for Questions 48 and 49:

A steel ball (density ρ_{steel} = 7200 kg/m^3) is placed in an upward moving liquid Al (density ρ_{Al} = 2360 kg/m^3, viscosity $\mu_{Al} = 1\times10^{-3}$ Pa.s and Reynolds number = 5×10^5). The force (F) exerted on the steel ball is expressed as

$$F = f\,\pi\,R^2\,(\rho_{Al}v^2/2)$$

where, f is friction factor (=0.2), v is the velocity of liquid Al and R is the radius of steel ball.

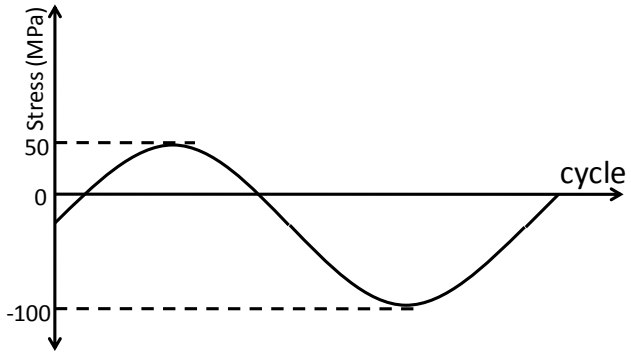
Q.48 The force exerted on the steel ball is

(A) 8.32 N (B) 6.70 N (C) 1.67 N (D) 0.52 N

Q.49 The terminal velocity of a fine spherical steel particle having diameter d_p, in μm range, if allowed to fall in a quiescent liquid Al bath, is

(A) $5.2\times10^6\ d_p^2$ m/s (B) $2.6\times10^6\ d_p^2$ m/s (C) $1.3\times10^6\ d_p^2$ m/s (D) $6.6\times10^5\ d_p^2$ m/s

Common Data for Questions 50 and 51:



For the above stress cycle

Q.50 Stress ratio is

(A) 4 (B) 2 (C) -2 (D) -4

Q.51 Amplitude ratio is

(A) 3 (B) 1/3 (C) -1/3 (D) -3

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Linked Answer Questions

Statement for Linked Answer Questions 52 and 53:

A material with grain size of ASTM No. 6 has a lattice frictional stress 100 MN/m^2 and locking parameter (Hall-Petch constant) 0.10 MN/m$^{3/2}$

Q.52 Grain size of the material is approximately

(A) 45 μm (B) 35 μm (C) 4.5 μm (D) 3.5 μm

Q.53 Yield strength of the material is approximately

(A) 100 MPa (B) 115 MPa (C) 165 MPa (D) 215 MPa

Statement for Linked Answer Questions 54 and 55:

The strain hardening behaviour of an annealed rod during cold rolling is given by $\bar{\sigma} = 700\ (\varepsilon)^{0.2}$ MPa, where $\bar{\sigma}$ is the flow stress at strain ε.

Q.54 Flow stress after 50% reduction in area of the annealed rod on cold rolling is approximately

(A) 750 MPa (B) 650 MPa (C) 609 MPa (D) 559 MPa

Q.55 If a wire of 5 mm diameter is drawn from the above cold rolled rod of 10 mm diameter, the drawing stress, neglecting the effect of friction and redundant work, is approximately

(A) 650 MPa (B) 550 MPa (C) 450 MPa (D) 400 MPa

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General Aptitude (GA) Questions (Compulsory)

Q. 56 – Q. 60 carry one mark each.

Q.56 Which one of the following options is the closest in meaning to the word given below?

Latitude

(A) Eligibility (B) Freedom (C) Coercion (D) Meticulousness

Q.57 Choose the most appropriate word from the options given below to complete the following sentence:

Given the seriousness of the situation that he had to face, his ___ was impressive.

(A) beggary (B) nomenclature (C) jealousy (D) nonchalance

Q.58 Choose the most appropriate alternative from the options given below to complete the following sentence:

If the tired soldier wanted to lie down, he ___ the mattress out on the balcony.

(A) should take
(B) shall take
(C) should have taken
(D) will have taken

Q.59 If $(1.001)^{1259} = 3.52$ and $(1.001)^{2062} = 7.85$, then $(1.001)^{3321} =$

(A) 2.23 (B) 4.33 (C) 11.37 (D) 27.64

Q.60 One of the parts (A, B, C, D) in the sentence given below contains an ERROR. Which one of the following is **INCORRECT**?

I requested that he should be given the driving test today instead of tomorrow.

(A) requested that
(B) should be given
(C) the driving test
(D) instead of tomorrow

Q. 61 - Q. 65 carry two marks each.

Q.61 The data given in the following table summarizes the monthly budget of an average household.

Category	Amount (Rs.)
Food	4000
Clothing	1200
Rent	2000
Savings	1500
Other expenses	1800

The approximate percentage of the monthly budget **NOT** spent on savings is

(A) 10% (B) 14% (C) 81% (D) 86%

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Q.62 There are eight bags of rice looking alike, seven of which have equal weight and one is slightly heavier. The weighing balance is of unlimited capacity. Using this balance, the minimum number of weighings required to identify the heavier bag is

(A) 2 (B) 3 (C) 4 (D) 8

Q.63 Raju has 14 currency notes in his pocket consisting of only Rs. 20 notes and Rs. 10 notes. The total money value of the notes is Rs. 230. The number of Rs. 10 notes that Raju has is

(A) 5 (B) 6 (C) 9 (D) 10

Q.64 **One of the legacies of the Roman legions was discipline. In the legions, military law prevailed and discipline was brutal. Discipline on the battlefield kept units obedient, intact and fighting, even when the odds and conditions were against them.**

Which one of the following statements best sums up the meaning of the above passage?

(A) Thorough regimentation was the main reason for the efficiency of the Roman legions even in adverse circumstances.
(B) The legions were treated inhumanly as if the men were animals.
(C) Discipline was the armies' inheritance from their seniors.
(D) The harsh discipline to which the legions were subjected to led to the odds and conditions being against them.

Q.65 A and B are friends. They decide to meet between 1 PM and 2 PM on a given day. There is a condition that whoever arrives first will not wait for the other for more than 15 minutes. The probability that they will meet on that day is

(A) 1/4 (B) 1/16 (C) 7/16 (D) 9/16

END OF THE QUESTION PAPER

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Space for Rough Work

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