MT:METALLURGICAL ENGINEERING

Duration: Three Hours   *Maximum Marks*:100

Please read the following instructions carefully:

General Instructions:

1. Total duration of examination is 180 minutes (3 hours).

2. The clock will be set at the server. The countdown timer in the top right corner of screen will display the remaining time available for you to complete the examination. When the timer reaches zero, the examination will end by itself. You will not be required to end or submit your examination.

3. The Question Palette displayed on the right side of screen will show the status of each question using one of the following symbols:

| 1 | You have not visited the question yet. |

| 3 | You have not answered the question. |

| 5 | You have answered the question. |

| 7 | You have NOT answered the question, but have marked the question for review. |

| 9 | You have answered the question, but marked it for review. |

The Marked for Review status for a question simply indicates that you would like to look at that question again. *If a question is answered and Marked for Review, your answer for that question will be considered in the evaluation.*

Navigating to a Question

4. To answer a question, do the following:

   a. Click on the question number in the Question Palette to go to that question directly.
   b. Select an answer for a multiple choice type question. Use the virtual numeric keypad to enter a number as answer for a numerical type question.
   c. Click on **Save and Next** to save your answer for the current question and then go to the next question.
   d. Click on **Mark for Review and Next** to save your answer for the current question, mark it for review, and then go to the next question.
   e. **Caution: Note that your answer for the current question will not be saved, if you navigate to another question directly by clicking on its question number.**

5. You can view all the questions by clicking on the **Question Paper** button. Note that the options for multiple choice type questions will not be shown.

Answering a Question

6. Procedure for answering a multiple choice type question:
    a. To select your answer, click on the button of one of the options
    b. To deselect your chosen answer, click on the button of the chosen option again or click on the **Clear Response** button
    c. To change your chosen answer, click on the button of another option
    d. To save your answer, you MUST click on the **Save and Next** button
    e. To mark the question for review, click on the **Mark for Review and Next** button. *If an answer is selected for a question that is Marked for Review, that answer will be considered in the evaluation.*

7. Procedure for answering a numerical answer type question:
    a. To enter a number as your answer, use the virtual numerical keypad
    b. A fraction (eg.,-0.3 or -.3) can be entered as an answer with or without '0' before the decimal point
    c. To clear your answer, click on the **Clear Response** button
    d. To save your answer, you MUST click on the **Save and Next** button
    e. To mark the question for review, click on the **Mark for Review and Next** button. *If an answer is entered for a question that is Marked for Review, that answer will be considered in the evaluation.*

8. To change your answer to a question that has already been answered, first select that question for answering and then follow the procedure for answering that type of question.

9. Note that ONLY Questions for which answers are saved or marked for review after answering will be considered for evaluation.

Paper specific instructions:

1. There are a total of 65 questions carrying 100 marks. Questions are of multiple choice type numerical answer type. A multiple choice type question will have four choices for the answer with only **one** correct choice. For numerical answer type questions, the answer is a number and no choices will be given**. A number as the answer should be entered** using the virtual keyboard on the monitor.

2. Questions Q.1 – Q.25 carry 1mark each. Questions Q.26 – Q.55 carry 2marks each. The 2marks 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 not attempted, then the answer to the second question in the pair will not be evaluated.

3. Questions Q.56 – Q.65 belong to General Aptitude (GA) section and carry a total of 15 marks. Questions Q.56 – Q.60 carry 1mark each, and questions Q.61 – Q.65 carry 2marks each.

4. Questions not attempted will result in zero mark. Wrong answers for multiple choice type questions 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. There is no negative marking for questions of numerical answer type.

5. Calculator is allowed. Charts, graph sheets or tables are **NOT** allowed in the examination hall.

6. Do the rough work in the Scribble Pad provided.

USEFUL DATA
Universal gas constant, R: 8.314 J/mol/K
Acceleration due to gravity, g: 9.81 m/s^2
Faraday constant, F: 96500 C/mol
Bohr magneton, μ_B: 9.273×10^{-24} Am^2

Q. 1 – Q. 25 carry one mark each.

Q.1   Degree and order of the differential equation $\frac{d^2y}{dx^2} + 3\frac{dy}{dx} - 6y = 0$, respectively, are

(A) 1 and 2   (B) 2 and 1   (C) 1 and 1   (D) 2 and 2

Q.2   As the concentration of point defects in a crystal increases, its configurational entropy

(A) does not change   (B) decreases
(C) increases   (D) initially increases and then decreases

Q.3   In a binary system A-B, ε_{AA}, ε_{BB} and ε_{AB} correspond to A-A, B-B and A-B bond energies respectively. The miscibility gap will occur if

(A) $\varepsilon_{AB} > \frac{1}{2}(\varepsilon_{AA} + \varepsilon_{BB})$ (B) $\varepsilon_{AB} < \frac{1}{2}(\varepsilon_{AA} + \varepsilon_{BB})$
(C) $\varepsilon_{AB} = \frac{1}{2}(\varepsilon_{AA} + \varepsilon_{BB})$ (D) $\varepsilon_{AB} < \frac{1}{4}(\varepsilon_{AA} + \varepsilon_{BB})$

Q.4   Critical value of the Gibbs energy of nucleation at equilibrium temperature is

(A) zero   (B) infinite   (C) positive   (D) negative

Q.5   With respect to the matrix of Al-Cu alloys, G-P zones are

(A) coherent   (B) incoherent
(C) semi-coherent   (D) chemically indistinguishable

Q.6   Which one of the following techniques does **NOT** require quenching to obtain final case hardness?

(A) Flame hardening   (B) Induction hardening
(C) Nitriding   (D) Carburizing

Q.7   Which one of the following elements is an austenite stabilizer?

(A) Nitrogen   (B) Molybdenum
(C) Vanadium   (D) Tungsten

Q.8   A 0.2 wt.% plain carbon steel sheet is heated and equilibrated in the inter-critical region followed by instant water quenching. The microstructure of the quenched steel sheet consists of

(A) fully martensite   (B) proeutectoid ferrite + martensite
(C) martensite + pearlite   (D) martensite + austenite

Q.9   As compared to the engineering stress-engineering strain curve, the true stress-true strain curve for a given material

(A) lies above and to the left
(B) lies below and to the right
(C) crosses the engineering stress-engineering strain curve
(D) is identical

Q.10   Which one of the following does **NOT** improve fatigue life of a steel component?

(A) Nitriding   (B) Decarburization
(C) Improving surface finish   (D) Shot-peening

Q.11   When two phases α and β in an alloy are in thermodynamic equilibrium, then

(A) $c_p^\alpha = c_p^\beta$ (B) $V_m^\alpha = V_m^\beta$ (C) $G_m^\alpha = G_m^\beta$ (D) $\overline{G}_i^\alpha = \overline{G}_i^\beta$

Q.12   Isothermal compressibility of a material is given by

(A) $-\dfrac{1}{p}\left(\dfrac{\partial V}{\partial p}\right)_T$ (B) $\dfrac{1}{p}\left(\dfrac{\partial V}{\partial p}\right)_T$

(C) $-\dfrac{1}{V}\left(\dfrac{\partial V}{\partial p}\right)_T$ (D) $\dfrac{1}{V}\left(\dfrac{\partial V}{\partial p}\right)_T$

Q.13   In the Ellingham diagram for oxides, C-CO line cuts the M-MO line at temperature T_1 and the M′-M′O line at a higher temperature T_2. At a temperature greater than T_1 and less than T_2, carbon can reduce

(A) MO   (B) both MO and M′O
(C) M′O   (D) neither MO nor M′O

Q.14   Which one of the following can give information about the corrosion rate?

(A) Pourbaix diagram   (B) Polarization technique
(C) EMF series   (D) Galvanic series

Q.15   In a roasting process, the set of conditions that favour sulphate formation from metal sulphide concentrates are

P. high temperature
Q. high partial pressure of oxygen
R. use of excess air
S. high partial pressure of SO_3

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

Q.16   High top pressure in a blast furnace operation

(A) favours the solution-loss reaction
(B) suppresses the solution-loss reaction
(C) decreases gas-solid contact time
(D) increases coke rate

Q.17   In L-D steelmaking, the final slag can be best described as

(A) oxidizing   (B) basic
(C) oxidizing and basic   (D) reducing and basic

Q.18   The permeability of burden in an ironmaking blast furnace can be improved by using

(A) fine charge
(B) agglomerated charge
(C) oxygen enriched air blast
(D) pulverized coal injection through the tuyeres

Q.19   For a good quality brazing, the molten filler alloy should have

(A) low contact angle with the base metal   (B) low density
(C) high surface tension   (D) high viscosity

Q.20   Risers are **NOT** required for casting

(A) stainless steel   (B) plain carbon steel
(C) grey cast iron   (D) white cast iron

Q.21   For scalar fields ϕ and ψ, the value of $\nabla \cdot (\nabla \phi \times \nabla \psi)$ is _____

Q.22   The atomic packing fraction of diamond cubic structure is _____

Q.23   The total number of possible heat transfer mode(s) is _____

Q.24   If σ and ε are true stress and true strain, respectively, the maximum true uniform strain that can be imparted to a material obeying $\sigma = 1050\varepsilon^{0.25}$ is _____

Q.25   Arc welding is done using current, voltage and welding speed of 200 A, 20 V and 0.01 m/s, respectively. The heat input in kJ per unit length is _____

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

Q.26   Which one of the following series is divergent?

(A) $\sum_{n=1}^{\infty} \dfrac{1}{3^{n-1}}$ (B) $\sum_{n=1}^{\infty} \dfrac{1}{n}$ (C) $\sum_{n=0}^{\infty} \dfrac{1}{2^n}$ (D) $\sum_{n=1}^{\infty} \dfrac{1}{n^n}$

Q.27   Taylor series expansion of the function $f(x) = \dfrac{x}{1+x}$ around $x = 0$ will be

(A) $1 + x + x^2 + x^3 + \cdots$ (B) $1 - x + x^2 - x^3 + \cdots$
(C) $0 + x + \dfrac{x^2}{2} + \dfrac{x^3}{3} + \cdots$ (D) $0 + x - x^2 + x^3 - \cdots$

Q.28   Which one of the following attributes is **NOT** correct for the matrix?

$$\begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}, \text{ where } \theta = 60°$$

(A) orthogonal   (B) singular
(C) skew-symmetric   (D) positive-definite

Q.29   A unit cell of an element has maximum linear density along the [110] direction. The packing density of its (100) plane is

(A) 0.68   (B) 0.74   (C) 0.79   (D) 0.91

Q.30   For an FCC metal, the ratio of interplanar spacing obtained from the first two peaks of the X-ray diffraction pattern is

(A) 1.91   (B) 1.63   (C) 1.41   (D) 1.15

Q.31   There are 150 gearwheels in a box, out of which 112 are within the required tolerance, 21 a...
        and rest are above the required tolerance. If the selection is done without replaceme...
        combined probability of randomly selecting a gearwheel below the tolerance and then a second
        above the tolerance is

        (A) 0.016   (B) 0.032   (C) 0.492   (D) 0.984

Q.32   Match the metal in **Group I** with its corresponding ore in **Group II**

                        Group I   **Group II**
                        (P) Ni   (1) Monazite
                        (Q) Th   (2) Cassiterite
                        (R) Pb   (3) Penlandite
                        (S) Sn   (4) Galena

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

Q.33   The yield strength of a polycrystalline metal increases from 100 MPa to 145 MPa on decreasing the
        grain size from 64 μm to 25 μm. The yield strength of this metal (in MPa) having a grain size of 36
        μm is

        (A) 110   (B) 125   (C) 140   (D) 165

Q.34   In a brittle material, the maximum internal crack length is 8 μm. If Young's modulus is 400 GPa
        and surface energy is 3.14 J/m^2, the estimated theoretical fracture strength (in MPa) is

        (A) 375   (B) 412   (C) 327   (D) 447

Q.35   Saturation magnetization of an FCC metal with lattice parameter 0.2 nm is 600 kA/m. The net
        magnetic moment per atom is given by (in Bohr magneton)

        (A) 8.08×10^{57} (B) 2.02×10^{57} (C) 0.517   (D) 0.129

Q.36   A 480 mm thick slab is hot-rolled using a roll of 720 mm diameter. For a coefficient of friction of
        0.5, the maximum possible reduction (in mm) is

        (A) 90   (B) 180   (C) 240   (D) 360

Q.37   Match the defects listed in **Group I** with the corresponding manufacturing process listed in
        Group II

                        Group I   **Group II**
                        (P) Orange-peel effect   (1) Extrusion
                        (Q) Chevron cracking   (2) Deep drawing
                        (R) Flash   (3) Arc welding
                        (S) Undercut   (4) Forging

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

Q.38   Match the powder production technique given in **Group I** with the corresponding shape... **Group II**

Group I	**Group II**
(P) Reduction	(1) Flaky
(Q) Gas Atomization	(2) Spongy
(R) Milling	(3) Dendritic
(S) Electrolysis	(4) Spherical

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

Q.39   Match the suitability of non-destructive testing method in **Group I** for the detection of defects listed in **Group II**

Group I	**Group II**
(P) Magnetic particle inspection	(1) Surface crack in martensitic stainless steels
(Q) X-ray radiography	(2) Surface crack in austenitic stainless steels
(R) Dye penetrant test	(3) Hairline crack in aluminium
(S) Ultrasonic testing	(4) Inclusions in steels

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

Q.40   For the following electrochemical reaction $Sn + 2H^+ \rightleftharpoons Sn^{2+} + H_2$, if the solution has Sn^{2+} concentration 10^{-2} M and pH 5 at 298 K, which of the following is true?

Given: standard reduction potential for $Sn^{2+} + 2e^- \rightarrow Sn$ is -0.136 V *versus* SHE; $p_{H_2} = 1$ atm

(A) Sn undergoes oxidation   (B) H^+ undergoes reduction
(C) Sn^{2+} undergoes reduction   (D) No net reaction

Q.41   Match the unit operation in **Group I** with its corresponding principle in **Group II:**

Group I	**Group II**
(P) Jigging	(1) Modification of surface tension
(Q) Tabling	(2) Difference in density
(R) Heavy media separation	(3) Differential initial acceleration
(S) Flotation	(4) Differential lateral movement

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

Q.42   Determine the correctness or otherwise of the following **Assertion (a)** and **Reason (r)**.

Assertion: For the extraction of metal values from their sulphide concentrates by hydrometallurgical route, leaching with oxygen under high pressure is used.
Reason: Presence of oxygen under high pressure causes roasting of sulphides, which helps in leaching of the values.

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

Q.43   The aperture size (in μm) of a 200 mesh sieve having a wire diameter of 53 μm is _____

Q.44   From a 2 m × 1.2 m sheet, squares are cut out from each of the four corners as shown in the figu...
        and then the sides are bent to form an open box. The maximum possible volume (in m^3) of the box
        is _____
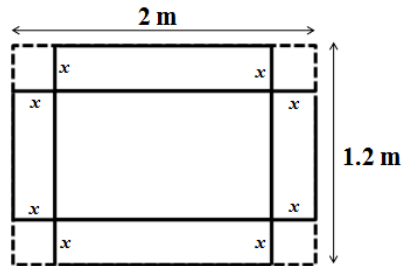
Q.45   Applying the secant method, the first approximation to the root of $f(x) = 1 + \ln x + \frac{x}{2}$, starting
        with function values at $x = 0.3$ and $x = 0.4$, is_____

Q.46   The critical internal crack length (in mm) in a steel having K_{Ic} of 45 MPa$\sqrt{m}$ to support a Mode-I
        stress of 400 MPa is _____

Q.47   Ladle deoxidation of liquid steel is done at 1600°C by adding ferro-aluminium. By assuming
        Stokes law behaviour, time (in s) required for alumina particles of 50 μm diameter to float to the
        surface from a depth of 2 m would be_____

        [Given: density of steel = 7000 kg/m^3, density of alumina = 3650 kg/m^3,
        viscosity of steel = 6×10^{-3} kg/m/s]

Common Data Questions

Common Data for Questions 48 and 49:

A steel specimen containing 0.2 wt.% C is carburized in an atmosphere that maintains a carbon content of
1.2 wt.% C at the surface of the specimen.

Given:
For carbon diffusion in austenite: $D_0 = 2.0 \times 10^{-5}$ m^2/s
Activation energy for diffusion, $Q = 142$ kJ/mol

y	erf(y)
0.85	0.7707
0.90	0.7970
0.95	0.8209

Q.48   What is the depth (in μm) from the surface of the specimen at which a composition of 0.4 wt.% C is
        obtained after carburizing at 870°C for 10 h?

        (A) 15   (B) 84   (C) 113   (D) 875

Q.49   How long (in h) will it take to double the depth at which 0.4 wt.% C is reached?

        (A) 40   (B) 20   (C) 18   (D) 14

Common Data for Questions 50 and 51:

Integral enthalpy of mixing (in J/mol) of liquid (Cu, Zn) solution can be approximated by
$$\Delta H_m^{mix} = -19250 x_{Cu} x_{Zn}$$

Q.50   The corresponding partial molar enthalpy of mixing (in J/mol) for Cu is

(A) $19250 x_{Zn}^2$
(B) $-19250 x_{Cu}^2$
(C) $38500 x_{Zn} - 19250 x_{Zn}^2 - 19250$
(D) $-19250 x_{Zn}^2$

Q.51   Assuming regular solution behaviour, the solution parameter (in J/mol) is

(A) -19250 (B) -9625 (C) 13.75   (D) 2315.4

Linked Answer Questions

Statement for Linked Answer Questions 52 and 53:

The density and associated crystallinity for two polypropylene samples are as follows:

density, g/cm^3	crystallinity, %
1.20	50
1.44	80

Q.52   Density of totally amorphous polypropylene is

(A) 0.64   (B) 0.74   (C) 0.84   (D) 0.94

Q.53   The percent crystallinity of polypropylene sample having a density of 1.3 g/cm^3 is

(A) 54   (B) 64   (C) 74   (D) 84

Statement for Linked Answer Questions 54 and 55:

An edge dislocation is present in α-Fe. Atomic diameter of iron atom is 0.25 nm and its shear modulus is 70 GPa.

Q.54   Modulus of the Burgers vector (in nm) is

(A) 0.125   (B) 0.25   (C) 0.50   (D) 0.625

Q.55   Energy (in J/m) of the dislocation is

(A) 0.5×10^{-9} (B) 1.1×10^{-9} (C) 2.2×10^{-9} (D) 4.4×10^{-9}

General Aptitude (GA) Questions

Q. 56 – Q. 60 carry one mark each.

Q.56 A number is as much greater than 75 as it is smaller than 117. The number is:

(A) 91   (B) 93   (C) 89   (D) 96

Q.57 <u>The professor</u> <u>ordered to</u> <u>the students to go</u> <u>out of the class</u>.
         I   II   III   IV
Which of the above underlined parts of the sentence is grammatically incorrect?

(A) I   (B) II   (C) III   (D) IV

Q.58 Which of the following options is the closest in meaning to the word given below:

Primeval

(A) Modern   (B) Historic
(C) Primitive   (D) Antique

Q.59 Friendship, no matter how _____ it is, has its limitations.

(A) cordial

(B) intimate

(C) secret

(D) pleasant

Q.60 Select the pair that best expresses a relationship similar to that expressed in the pair:
Medicine: Health

(A) Science: Experiment   (B) Wealth: Peace
(C) Education: Knowledge   (D) Money: Happiness

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

Q.61 X and Y are two positive real numbers such that $2X + Y \leq 6$ and $X + 2Y \leq 8$. For which of the following values of (X, Y) the function $f(X, Y) = 3X + 6Y$ will give maximum value?

(A) (4/3, 10/3)

(B) (8/3, 20/3)

(C) (8/3, 10/3)

(D) (4/3, 20/3)

Q.62 If $|4X - 7| = 5$ then the values of $2\,|X| - |-X|$ is:

(A) 2, 1/3   (B) 1/2, 3   (C) 3/2, 9   (D) 2/3, 9

Q.63   Following table provides figures (in rupees) on annual expenditure of a firm for two years
        and 2011.

Category	2010	2011
Raw material	5200	6240
Power & fuel	7000	9450
Salary & wages	9000	12600
Plant & machinery	20000	25000
Advertising	15000	19500
Research & Development	22000	26400

In 2011, which of the following two categories have registered increase by same percentage?

(A) Raw material and Salary & wages

(B) Salary & wages and Advertising

(C) Power & fuel and Advertising

(D) Raw material and Research & Development

Q.64   A firm is selling its product at Rs. 60 per unit. The total cost of production is Rs. 100 and firm is
        earning total profit of Rs. 500. Later, the total cost increased by 30%. By what percentage the price
        should be increased to maintained the same profit level.

(A) 5   (B) 10   (C) 15   (D) 30

Q.65   Abhishek is elder to Savar.
        Savar is younger to Anshul.

Which of the given conclusions is logically valid and is inferred from the above
statements?

(A) Abhishek is elder to Anshul

(B) Anshul is elder to Abhishek

(C) Abhishek and Anshul are of the same age

(D) No conclusion follows

END OF THE QUESTION PAPER

GATE 2013 : Answer keys for MT - Metallurgical Engineering

Paper	Q.No	Key(s)/Value(s)	Paper	Q.No	Key(s)/Value(s)
MT	1	A	MT	36	A
MT	2	D	MT	37	D
MT	3	A	MT	38	A
MT	4	B	MT	39	D
MT	5	A	MT	40	C
MT	6	C	MT	41	A
MT	7	A	MT	42	C
MT	8	B	MT	43	73 to 75
MT	9	A	MT	44	0.257 to 0.263
MT	10	B	MT	45	0.314 to 0.326
MT	11	D	MT	46	7.9 to 8.3
MT	12	C	MT	47	2626 to 2632
MT	13	A	MT	48	D
MT	14	B	MT	49	A
MT	15	C	MT	50	D
MT	16	B	MT	51	A
MT	17	C	MT	52	D
MT	18	B	MT	53	B
MT	19	A	MT	54	B
MT	20	C	MT	55	C
MT	21	0	MT	56	D
MT	22	0.339 to 0.341	MT	57	B
MT	23	3	MT	58	C
MT	24	0.25	MT	59	B
MT	25	400	MT	60	C
MT	26	B	MT	61	A
MT	27	D	MT	62	B
MT	28	Marks to All	MT	63	D
MT	29	C	MT	64	A
MT	30	D	MT	65	D
MT	31	A			
MT	32	C			
MT	33	B			
MT	34	D			
MT	35	D			