

# METALLURGY ENGINEERING

GATE 2009

EE25BTECH11027-INDHIRESH S

## I. Q1 - Q20 CARRY ONE MARK EACH

- 1) In a  $n \times n$  identity matrix, the trace equals: (GATE – MT2009)
- a) 0                      b) 1                      c)  $n$                       d)  $n^2$
- 2) Gibbs free energies of a system in states 1 and 2 are denoted by  $G_1$  and  $G_2$  respectively. The system will go spontaneously from state 1 to state 2, if and only if: (GATE – MT2009)
- a)  $G_1 - G_2 > 0$       b)  $G_1 - G_2 < 0$       c)  $G_1 - G_2 = 0$       d)  $G_1 < 0, G_2 < 0$
- 3) Flux in welding process acts as: (GATE – MT2009)
- a) catalyst                      c) filler  
b) protective agent              d) heat generator
- 4) In an ideal HCP packing, the  $\frac{c}{a}$  ratio is: (GATE – MT2009)
- a) 1.225                      b) 1.414                      c) 1.633                      d) 1.732
- 5) A property that CANNOT be obtained from a tensile test is (GATE – MT2009)
- a) Young's modulus                      c) ultimate tensile strength  
b) yield strength                      d) endurance limit
- 6) Intensive thermodynamic variables are (GATE – MT2009)
- a) independent of the number of moles in the system  
b) dependent on the volume of the system  
c) dependent on the volume of the system  
d) dependent on the volume of the system
- 7) In a sand casting, the last liquid to solidify is in the (GATE – MT2009)
- a) runner                      b) riser                      c) gate                      d) vent
- 8) An annealed plain carbon steel, showing fully pearlitic microstructure, has a carbon content of (GATE – MT2009)

- a) 0.001wt%      b) 0.20wt%      c) 0.77wt%      d) 1.20wt%

9) Superalloys are (GATE – MT2009)

- a) Al-based alloys      c) Ni-based alloys  
b) Cu-based alloys      d) Mg-based alloys

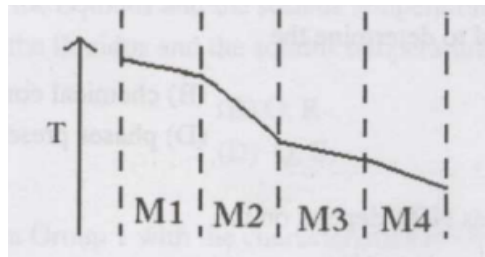
10) Wood is naturally occurring (GATE – MT2009)

- a) malleable material      c) ceramic material  
b) composite material      d) isotropic material

11) The function,  $f(x) = ax^2 + bx + c$  has a maximum only if (GATE – MT2009)

- a)  $a < 0$       b)  $a > 0$       c)  $a = 0$       d)  $a > 0$  and  $b < 0$

12) A furnace wall consists of four layers of different materials M1, M2, M3 and M4. If the layers are of equal thickness and the steady state temperature profile is, as shown below, then the material with the lowest thermal conductivity is (GATE – MT2009)



- a) M1      b) M2      c) M3      d) M4

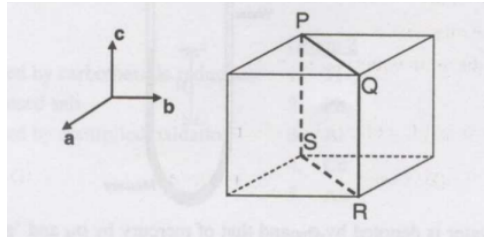
13) From the list given below

P.Cu  
Q.Mg  
R.Ni  
S.Zn

two metals which provide cathodic protection to steel are (GATE – MT2009)

- a) P,R      b) R,S      c) Q,R      d) Q,S

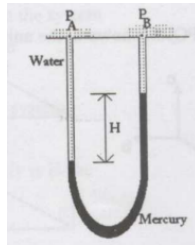
14) The Miller indices of the plane PQRS, shown in the unit cell are (GATE – MT2009)



- a) 111                      b) 121                      c) 110                      d) 100
- 15) A defect that is bounded by two mirror plane is (GATE – MT2009)
- a) twin                      b) stacking fault                      c) grain boundry                      d) edge dislocation
- 16)  $\lim_{x \rightarrow 0} \frac{\sin x}{x}$  is equal to (GATE – MT2009)
- a) 0                      b) 1                      c)  $\infty$                       d) undefined
- 17) Fick's first law relates (GATE – MT2009)
- a) flux of atoms and the concentration gradient
- b) amount of gas dissolved in the molten metal and the partial pressure
- c) applied normal stress and the orientation of slip system
- d) heat flux and the temperature gradient
- 18) X-ray radiography is used to determine the (GATE – MT2009)
- a) soundness of casting                      c) crystal structure
- b) chemical composition                      d) phase present
- 19) Hardenability of steel does NOT depend on the (GATE – MT2009)
- a) alloy content                      c) amount of carbon present
- b) grain size                      d) amount of cold work
- 20) p-type semiconductor can be obtained by doping silicon with (GATE – MT2009)
- a) antimony                      b) phosphorous                      c) arsenic                      d) boron

## II. Q21 - Q60 CARRY 2 MARKS EACH

- 21) The figure below shows water over mercury manometer. if the density of water is denoted by  $\rho_w$  and that of mercury by  $\rho_M$  and 'g' denotes the acceleration due to gravity, the pressure difference ( $P_A - P_B$ ) will be equal to (GATE – MT2009)



- a)  $-(\rho_M g H)$       b)  $(\rho_W - \rho_M)gH$       c)  $\rho_M g H$       d)  $(\rho_M - \rho_W)gH$

22) Match the processes given in Group 1 with the corresponding typical defects given in group 2 (GATE – MT2009)

Group 1	Group 2
P. Forging	1. Alligating
Q. Rolling	2. Cold shut
R. Deep drawing	3. Chevron cracks
S. Extrusion	4. wrinkles

- a)  $P - 1, Q - 2, R - 3, S - 4$       c)  $P - 2, Q - 1, R - 3, S - 4$   
 b)  $P - 2, Q - 1, R - 4, S - 3$       d)  $P - 3, Q - 1, R - 4, S - 2$

23) From the list given below, two factors that promote coring in cast alloys are (GATE – MT2009)

- P. slow cooling during solidification  
 Q. rapid cooling during solidification  
 R. small difference between the liquids and solidus temperatures  
 S. large difference between the liquidus and solidus temperatures

- a) P, R      b) Q, R      c) P, S      d) Q, S

24) Match the loading conditions in group 1 with the characteristics in group 2. (GATE – MT2009)

Group 1	Group 2
P. Tensile	1. barreling
Q. Compressive	2. Intergranular cracking
R. Fatigue	3. striations
S. Creep	4. Cup and cone
	5. Earing

- a)  $P - 4, Q - 5, R - 3, S - 1$       c)  $P - 5, Q - 1, R - 4, S - 2$   
 b)  $P - 4, Q - 1, R - 3, S - 2$       d)  $P - 1, Q - 2, R - 3, S - 5$

25) Match the extraction methods in group 1 with the metals in group 2 (GATE – MT2009)

Group 1	Group 2
P. roasting followed by carbothermic reduction	1. Ti
Q. electrolysis of fused salt	2. Pb
R. roasting followed by controlled oxidation	3. Al
S. halide process	4. Cu
	5. Au

- a)  $P - 2, Q - 3, R - 4, S - 1$                       c)  $P - 2, Q - 5, R - 1, S - 4$   
b)  $P - 5, Q - 4, R - 3, S - 1$                       d)  $P - 3, Q - 2, R - 5, S - 1$

26) The average molecular weight of high density polyethylene is found to be 56000. The degree of polymerization is (GATE – MT2009)

- a) 200                      b) 1000                      c) 2000                      d) 4000

27) A 0.2wt% C steel is carburized at 1200K for 4 hours to obtain 0.8wt% at a depth of 0.20mm. Instead, if the carburizing is performed for 8 hours at the same temperature, then 0.8wt% C will be achieved at a depth of (GATE – MT2009)

- a) 0.23mm                      b) 0.55mm                      c) 0.28mm                      d) 0.40mm

28) A unit dislocation with a Burgers vector  $\mathbf{b}_1$  will dissociate into two partial dislocations with burgers vectors  $\mathbf{b}_2$  and  $\mathbf{b}_3$ , if and only if (GATE – MT2009)

- P.  $\mathbf{b}_1^2 > \mathbf{b}_2^2 + \mathbf{b}_3^2$   
Q.  $\mathbf{b}_1^2 < \mathbf{b}_2^2 + \mathbf{b}_3^2$   
R.  $\mathbf{b}_1^2 = \mathbf{b}_2^2 + \mathbf{b}_3^2$   
S.  $\mathbf{b}_1^2 \neq \mathbf{b}_2^2 + \mathbf{b}_3^2$

- a) P,R                      b) P,S                      c) Q,R                      d) Q,S

29) The solution function  $y = f(x)$  for the ordinary differential equation,  $\frac{dy}{dx} = 3x^2 - 2x$ , passes through (1,1). The magnitude of y at  $x = 3$  is (GATE – MT2009)

- a) 0                      b) 18                      c) 19                      d) 21

30) What is the magnitude of the following integral using single step application of trapezoid rule? (GATE – MT2009)

$$\int_0^2 (3x^2 + 4x - 2) dx$$

- a) 9                      b) 16                      c) 18                      d) 36

31) During a sheet stamping operation, it is observed that sheet surface area triples. The true thickness strain is (GATE – MT2009)

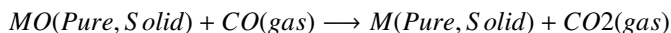
- a) -1.1                      b) -0.333                      c) +0.333                      d) +1.1

32) Match the practices in Group 1 with reactors in Group 2. (GATE – MT2009)

Group 1	Group 2
P. Layered charging of coke and ore	1. Ladle furnace
Q. Oxygen injection through supersonic nozzle	2. Electric arc furnace
R. Aluminium wire feeding	3. Blast furnace
S. Foamy slag practice	4. LD converter

- a) P-3, Q-1, R-2, S-4                      c) P-4, Q-3, R-2, S-1  
b) P-2, Q-4, R-3, S-1                      d) P-3, Q-4, R-1, S-2

33) For the reaction,



the equilibrium constant at 1000 K is 2.0. The oxide, MO, can be reduced to M at 1000 K, using a gas mixture containing (GATE – MT2009)

- a) 20%CO, 45%CO<sub>2</sub>, 35%N<sub>2</sub>                      c) 20%O<sub>2</sub>, 80%N<sub>2</sub>  
b) 20%CO, 10%CO<sub>2</sub>, 70%N<sub>2</sub>                      d) 50%N<sub>2</sub>, 50%Ar

34) Stacking fault energy (SFE) plays an important role in determining the work hardening ability of a metal. In this context, the correct logical sequence is (GATE – MT2009)

- a) High SFE → easy cross-slip → low work hardening  
b) High SFE → difficult cross-slip → high work hardening  
c) Low SFE → easy cross-slip → low work hardening  
d) Low SFE → difficult cross-slip → low work hardening

35) Match the joining processes in Group 1 with the filler materials in Group 2 (GATE – MT2009)

Group 1	Group 2
P. Soldering	1. Silver- Titanium alloy
Q. Welding	2. Silver- tin alloy
R. Brazing	3. Mild steel
	4. Lead fluoride

- a) P – 2, Q – 3, R – 1                      c) P – 3, Q – 1, R – 2  
b) P – 1, Q – 2, R – 3                      d) P – 2, Q – 4, R – 1

36) Match the properties in Group 1 with the metals in Group 2. (GATE – MT2009)

Group 1	Group 2
P. Ferromagnetism	1. Nb
Q. Superconductivity	2. Fe
R. Diamagnetism	3. Cu
S. antiferromagnetism	4. Cr

- a)  $P - 2, Q - 4, R - 3, S - 1$                       c)  $P - 3, Q - 4, R - 1, S - 2$   
 b)  $P - 2, Q - 1, R - 3, S - 4$                       d)  $P - 1, Q - 2, R - 3, S - 4$

37) Assertion a :During hardening of steel, the component to be heat treated is strongly agitated in the quenching medium.

Reason r: The agitation breaks down the vapour barrier allowing the quench to proceed at a more rapid rate. (GATE – MT2009)

- a) Both a and r are correct, but r is not the correct reason for a.  
 b) Both a and r are false.  
 c) a is true but r is false.  
 d) Both a and r are correct and r is the correct reason for a.
- 38) The activity of copper in the 'impure copper' is 0.5 at 298 K. The minimum voltage required to refine 'impure copper' to pure copper using an electrolyte having  $Cu^{2+}$  ions at 298K is (GATE – MT2009)

- a) 0.9mV                      b) 9mV                      c) 90mV                      d) 900mV

39) A 3.0mm diameter single crystal is loaded to 400N along [001] direction. The resolved shear stress on (111) [T01] slip system is (GATE – MT2009)

- a) 5.8MPa                      b) 11.5MPa                      c) 23.1MPa                      d) 46.2MPa

40) As per the TTT diagram, bainite will form in eutectoid plain carbon steel when heated to 850°C followed by (GATE – MT2009)

- a) air-cooling to room temperature  
 b) isothermal holding between eutectoid temperature and the nose  
 c) quenching to room temperature  
 d) isothermal holding between the nose and the M<sub>s</sub> temperature
- 41) The vapour pressure of pure liquid B at temperature  $T_0$  is 0.5atm. The partial pressure of B in the vapour phase that is in equilibrium with the liquid solution consisting of 30mol%A and 70mol% B at temperature  $T_0$  is (assume both liquid and vapour phases behave ideally) (GATE – MT2009)

- a) 0.35atm                      b) 0.50atm                      c) 0.70atm                      d) 1.00atm

42) During low temperature plastic deformation of an under-aged precipitation hardened alloy, dislocations (GATE – MT2009)

- a) climb to completely avoid the precipitate  
 b) loop around the precipitate  
 c) cross-slip to completely avoid the precipitate  
 d) cut through the precipitate
- 43) According to Hume-Rothery rules, extensive solid solubility between elements X and Y is promoted by the two factors in the following list: (GATE – MT2009)

- P. Same crystal structure of X and Y
- Q. Large atomic size difference (> 20%) between X and Y
- R. Same valence of X and Y
- S. Large difference in melting points of X and Y

- a) P, Q                      b) P, R                      c) Q, S                      d) P, S

44) At constant temperature and pressure, two phases  $\alpha$  and  $\beta$  will be in equilibrium when  
(GATE – MT2009)

- a) chemical potential of each component is the same in  $\alpha$  and  $\beta$
- b) partial molar free energy of each component is NOT the same in  $\alpha$  and  $\beta$
- c) Gibbs free energy of mixing is minimum
- d) enthalpy of mixing is zero

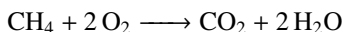
45) The stress applied on a material is (GATE – MT2009)

$$\sigma_{ij} = \begin{bmatrix} 21 & 0 & 0 \\ 0 & 21 & 0 \\ 0 & 0 & 21 \end{bmatrix} \text{ MPa.}$$

The maximum shear stress experienced by it is

- a) 0MPa                      b) 10.5MPa                      c) 21MPa                      d) 63MPa

46) For the following reaction at 300 K,



the heat of reaction is 803 kJ/mol of  $\text{CH}_4$ . At 300 K,  $\text{CH}_4$  - air gas mixture containing the required stoichiometric amount of oxygen is burnt to completion. Assuming, air contains 20 vol%  $\text{O}_2$  and 80 vol%  $\text{N}_2$  and the specific heats for  $\text{CO}_2$ ,  $\text{H}_2\text{O}$  (g) and  $\text{N}_2$  are 50, 40 and 40 J mol K- respectively the adiabatic flame temperature will be (GATE – MT2009)

- a) 1684K                      b) 1784K                      c) 2084K                      d) 2384K

47) Match the properties in Group 1 with the testing techniques in Group 2.  
(GATE – MT2009)

- Group 1
- P. Electrical conductivity
  - Q. Impact energy
  - R. Thermal expansion
  - S. Specific heat

- Group 2
- 1. Jominy test
  - 2. Izod test
  - 3. Dilatometry
  - 4. Four probe technique
  - 5. Differential scanning calorimetry



- a)  $P - 4, Q - 2, R - 5, S - 1$                       c)  $P - 2, Q - 1, R - 3, S - 4$   
 b)  $P - 5, Q - 3, R - 2, S - 1$                       d)  $P - 4, Q - 2, R - 3, S - 5$
- 48) A blast furnace is charged with pure  $Fe_2O_3$ . For each ton of Fe produced, it discharges 700 kg of  $CO_2$  and 450 kg of CO as top gas. The  $O_2$  consumed, per ton of Fe produced, is (GATE – MT2009)
- a) 138kg                      b) 238kg                      c) 338kg                      d) 438kg
- 49) Taylor series can be used to approximate the value of  $f(x) = \cos x$  by expanding around  $x = 0$ . If only the first three terms of the series are considered, the magnitude of deviation from the actual value of  $\cos(\pi/3)$  will be (GATE – MT2009)
- a) 0.01                      b) 0.03                      c) 0.05                      d) 0.07
- 50) A  $200mm \times 200mm$  cross-section bloom is continuously cast at a casting speed of 0.05 m/s. The amount of heat extracted from the 0.7 m long mould is 1.28 MW. Assume that the temperature of the steel is at its melting point while entering and leaving the mould. Latent heat of fusion for the steel is 278 kJ/kg and density of steel is  $7800 kg/m^3$ . The thickness of the solidified shell emerging from the mould will be (GATE – MT2009)
- a) 0.147mm                      b) 1.47mm                      c) 14.7mm                      d) 147mm

#### COMMON DATA QUESTIONS

*Common data for questions 51 and 52:*

A metallic rod with  $2mm \times 2mm$  square cross-section is being tested in tension and has the following mechanical properties:

Young's modulus = 100 GPa

Poisson's ratio = 0.30

Yield stress = 500 MPa

Work hardening exponent = 0.25

Ultimate tensile strength = 1000 MPa

- 51) The rod is loaded to 1000N, the magnitude of transverse strain is (GATE – MT2009)
- a) 0.025%                      b) ) 0.075%                      c) 0.15%                      d) 0.25%
- 52) The modulus of resilience of the material is (GATE – MT2009)
- a)  $0.25 MJ/m^3$                       b)  $0.50 MJ/m^3$                       c)  $0.75 MJ/m^3$                       d)  $1.25 MJ/m^3$

*Common data for Questions 53 and 54:*

Schematic of the Pb-Sn phase diagram at atmospheric pressure is shown below.

- 53) A Pb-Sn hypo-eutectic alloy is slowly cooled from the liquid state to room temperature. The composition of the alloy whose microstructure consists of 25wt% lamellar constituent is (GATE – MT2009)



- a)  $6 \times 10^{-8} \Omega$       b)  $6 \times 10^{-5} \Omega$       c)  $6 \times 10^{+5} \Omega$       d)  $6 \times 10^{+8} \Omega$

58) The time required to perform the weld is (GATE – MT2009)

- a) 0.6s      b) 6s      c) 60s      d) 600s

*Statement for Linked Answer Questions 59 and 60:*

Copper has FCC crystal structure with an atomic radius of  $0.128nm$ .

59) The interplanar spacing for (220) planes in copper is (GATE – MT2009)

- a)  $0.064nm$       b)  $0.128nm$       c)  $0.181nm$       d)  $0.256nm$

60) In an X-ray diffraction experiment, radiation of wavelength  $0.154nm$  is used. Assuming the order of reflection to be 1, the Bragg angle for the (220) set of planes in copper will be

(GATE – MT2009)

- a)  $12.56^\circ$       b)  $36.98^\circ$       c)  $48.98^\circ$       d)  $74.21^\circ$

\*END OF THE QUESTION PAPER\*