BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)

CLASS: B.TECH. **SEMESTER : VI**
BRANCH: PIE/MECH **SESSION : SP/2023**

SUBJECT: PE324 SURFACE ENGINEERING AND LASER ADDITIVE MANUFACTURING
TIME: 3 Hours **FULL MARKS: 100**

INSTRUCTIONS:

- This paper has 10 questions each having FIVE (5) parts comprising 2-3 of them only multiple-choice type objective questions with only one correct option, and the remaining requiring a short answer (< 20-25 words) in text or with a schematic diagram.
- Each part is of equal marks (2 x 5 x 10 = 100).
- All questions/parts are compulsory.
- There is no negative marking.
- **All answers for multiple-choice type objective questions** must be answered by marking the only correct option on this **question paper itself**.
- Answers for **short answer type questions (part 'a' and/or 'b')** and **schematic diagram (part e)** of each 10 questions must be written on blank answer book provided to you.
- Please **return both the marked question paper and answer book** at the end of the examination to the Invigilator in Charge before leaving the examination hall.

Roll No. …… Name ……

Question 1: (2 marks x 5 = 10 marks) CO1BL2

(a) What is surface engineering? Cite one example of how surface engineering can improve the life of an engineering component in a specific industrial application.

(b) Name the most common engineering failure or damage encountered in the: (i) powder injection nozzle of plasma spray gun, and (ii) turbine blade of jet engine.

(c) Choose the only CORRECT statement about the genesis of surface energy of a solid: (i) Presence of large numbers of broken bonds at the surface, (ii) Higher absorptivity of the surface, (iii) Structural change at the surface, (iv) Composition of surface

(d) Hydrophobic surface usually possesses a very:

i) High surface energy with a high contact angle showing poor wettability

ii) High surface energy with low contact angle showing good wettability

iii) Low surface energy with a high contact angle showing poor wettability

iv) Low surface energy with a low contact angle showing good wettability

(e) Draw a typical stress-strain diagram of a metallic alloy subjected to tensile deformation until fracture to mark (on the diagram) qualitatively the (i) yield point, (ii) tensile strength, (iii) toughness and (iv) fracture stress.

Question 2: (2 marks x 5 = 10 marks) CO1,2 BL4

(a)What is wear of an engineering solid? How is it different than erosion?

(b)How can you differentiate between: (i) Abrasive and adhesive wear, and (ii) 2-body and 3-body wear?

(c) The contact angle of a super hydrophilic surface is expected to be: (i) greater than 150^o, (ii) equal to 45^o, (iii) nearly equal to 0^o, (iv) higher than 90^o.

(d)Arrange the following engineering solids in order of increasing electrical resistivity: (i) germanium, (ii) polyvinyl chloride (PVC), (iii) hardened steel, (iv) pure silver

(e)Draw a schematic diagram of face centered cubic unit cell and show the relationship between the lattice parameter and atomic radius

Question 3: (2 marks x 5 = 10 marks) CO3 BL2,3

(a)Why metals are prone to aqueous corrosion? Between Mg and Cu, who should corrode in a typical galvanic cell and why?

(b)Both rusting of iron and sensitization of AISI 304 stainless steel occur due to corrosion, but more specifically due to: (i) uniform and pitting corrosion, (ii) pitting and erosion corrosion, (iii) crevice and galvanic corrosion, (iv) general and intergranular corrosion, respectively.

(c)Seizure is a special type of surface degradation which occurs due to: (i) corrosion caused by hardness difference, (ii) oxidation owing to the presence of excess lubricant, (iii) adhesive wear caused by temporary cold welding, (iv) fatigue due to oscillatory motion of high amplitude

(d)The laws of friction state that the frictional force: (i) is directly proportional to the applied load, (ii) depends on the sliding velocity, (iii) depends on the duration of the applied load, (iv) is independent of the elastic modulus of the solid

(e)Draw a schematic electrodeposition cell and show the three main parts or components

Question 4: (2 marks x 5 = 10 marks) CO2,3 BL2

a) Why is flame or induction hardening not applicable to 18-8 stainless steel?

b) Galvanic cell and electrolytic cell appear very similar in arrangement and operation. yet they differ in function and mechanism involved. Identify the only CORRECT statement related to comparison of these two cells from the following:

i) Galvanic Cell produces current by non-spontaneous ionic dissociation, but Electrolytic Cell consumes current by spontaneous dissociation of ions.

ii) Galvanic Cell is used for electroplating on the cathode, but Electrochemical Cell is used for electrolytic polishing of the cathode.

iii) The anode is negative, and cathode is positive in Galvanic Cell to support a spontaneous reaction; but cathode is negative, and anode is positive in Electrochemical Cell to conduct a non-spontaneous reaction.

iv) Galvanic cells convert electrical energy to chemical energy by externally applied potential difference, but Electrolytic Cell allows chemical energy to be stored as electrical energy by spontaneous chemical potential difference.

c) Pick up the only CORRECT set of equilibrium allotropic forms of pure iron (Fe) at normal pressure:

i) α-Fe (BCC), β-Fe (BCC), γ-Fe (FCC) and ε-Fe (HCP)

ii) α-Fe (BCC), β -Fe (BCC), γ-Fe (FCC) and δ-Fe (BCC)

iii)α-Fe (BCC), γ-Fe (FCC), θ-Fe (Hexagonal) and η-Fe (Tetragonal)

iv)α-Fe (BCC), α'-Fe (BCT), γ-Fe (FCC) and δ-Fe (BCC)

d) Cathodic protection refers to the protection technique where:

i) The component to be protected is made cathode in an electrochemical cell.

ii) The component to be protected is made anode in an electrochemical cell.

iii) Component is connected to the metal which is more noble

iv) None of the above.

e) Draw a binary eutectic phase diagram showing complete solubility in the liquid state but in the solid state, B has no solubility in A and A has partial solubility in B

Question 5: (2 marks x 5 = 10 marks) CO2,3 BL2,4

a) Nitrided components can be used at elevated temperature but not the carburized components – why? Name the most important mechanism of strengthening associated with carburizing and nitriding of steel.

b) Fe-Fe_3C phase diagram contains a number of invariant changes. Select the only CORRECT set of invariant changes present in the Fe-Fe_3C phase diagram concerning pure metal or alloys from below:

i) Martensitic, peritectic, eutectic and eutectoid

ii) Allotropic, peritectic, eutectic and eutectoid

iii) Monotectic, peritectic, eutectic and eutectoid

iv) Allotriomorphic, massive, peritectoid and monotectoid

c) Carburizing is carried out above AC3 and not below because:

i) Diffusivity of carbon in austenite is faster in austenite than that in ferrite

ii) Martensite can form during carburizing

iii) Transformation kinetics of carburizing is faster above AC3

iv) Solubility of carbon is significantly higher in austenite than that in ferrite

d) The hard and wear resistant 'white layer' formed on the surface of steel after nitriding consists of mainly three types of nitrides. Identify the group listing such nitrides in order of highest to lowest probable volume fraction of occurrence as a function of depth:

i) Fe_2N, $Fe_{2-3}N$, Fe_4N

ii) $Fe_{2-3}N$, Fe_2N, Fe_4N

iii) Fe_2N, Fe_4N, $Fe_{2-3}N$

iv) Fe_4N, $Fe_{2-3}N$, Fe_2N

e) A heat treatment cycle for induction hardening of a medium carbon taper roller bearing (schematic temperature-time plot showing/citing reference temperatures)

Question 6: (2 marks x 5 = 10 marks) CO2,3 BL2,4

a) Name any two elements that are very common in diffusion coating of metallic alloys for improving oxidation resistance at high temperature in air and state why?

b) Which of the following techniques may be considered as chemical conversion coating for the stated purpose:

i) Phosphatizing as a primer for spray painting

ii) Plasma spray deposition for surface hardening

iii) Laser surface alloying for improving emissivity

iv) Cathodic protection by galvanizing for improving wear resistance

c) Which of the following ingredients are used in pack carburizing process?

i) Charcoal, barium carbonate and air

ii) Sodium cyanide salt, charcoal, and carbon dioxide

iii) Carbonaceous gas like methane, ethane, and acetylene

iv)A mixture of coke, charcoal, and sodium chloride

d) In immersion deposition:

i) Low voltage and high current are applied between anode and cathode

ii) Anion in deposited on anode from solid electrolyte without catalyst

iii) Ni-cation is deposited on Ni-anode in presence of Ni catalyst

iv) Cu-cation in deposited on Cu-cathode without catalyst or current

e) Draw the schematic microstructures of a low alloy steel in fully annealed and hardened conditions.

Question 7 (2 marks x 5 = 10 marks) CO3,5 BL2,4

a) How can laser irradiation bend a sheet metal of finite thickness? Why is laser cutting usually conducted using oxygen shroud gas?

b) Ion implantation refers to the process of:

i) Ionization of atoms and its deposition as a thin film on the substrate in air

ii) Injection of high energy ions up to a depth of several mm to nm from the surface in high vacuum

iii) Displacement of atoms from the surface by high energy ions to form metastable compounds up to mm depth

iv) Deposition of cations on cathode without electrical current in low vacuum

c) The advantages of chemical vapour deposition (CVD) over physical vapour deposition (PVD) is:

i) The deposited thin film is harder than any other method

ii) CVD is faster and cheaper than PVD as it can be done in air

iii) Composition of the thin film deposited by CVD can be different than the species admitted in the chamber in the vapor state

iv) CVD can be conducted at room temperature while PVD needs high temperature

d) Which of the following sets comprise all thermal spray deposition techniques?

i) HVOF coating, Electrodeposition, Galvanizing

ii) HVOF coating, Cold spray, Detonation gun coating

iii) Physical vapor deposition, Sputtering, Electro-less deposition

iv) Flame spray coating, Plasma ion implantation, Ultrasonic peening

e) Draw a schematic diagram to show the difference in Cr-distribution or deposition-profile as a function of depth after (i) diffusion coating and (ii) electroplating

Question 8 (2 marks x 5 = 10 marks) CO2,4 BL2,4

a) Why is a bond coat applied before thermal spray deposition of ceramic oxide or thermal barrier coating (TBC) on superalloy-based turbine engine blades? Why controlled porosity in such TBC is beneficial?

b) Identify the set consisting of all characteristic features of cold spray:

i) Sub-sonic velocity, Coating of mixed powders, Diffused coating-substrate interface, Fused particles

ii) High velocity, Coating of elemental powders, Sharp coating-substrate interface, Incipient melting of powders

iii) Supersonic velocity, Coating of compound powders, Fused coating-substrate

interface, Reaction in solid state

iv) Supersonic velocity, Coating of same or mixed powders, Sharp coating-substrate interface, No melting

c) Identify the ONLY correct statement about thermal spray coating from below:

i) Plasma transferred arc deposition is not a thermal spray coating technique

ii) Velocity of particles during spraying in HVOF coating reaches supersonic level

iii) Thermal energy of particles in D-gun spray is derived from electrical arcing

iv) Atmospheric plasma spray is conducted at high vacuum and high temperature

d) Arrange the following thermal spray techniques in the sequence of gradually increasing (low to high) particle velocity:

i) HVOF spray > Cold spray > Air plasma spray > Wire arc spray

ii) Wire arc spray > Cold spray > Air plasma spray > HVOF spray

iii) Air plasma spray > Wire arc spray > Cold spray >, HVOF spray

iv) Wire arc spray > Air plasma spray > HVOF spray > Cold spray

e) Draw a schematic line diagram to show linear, parabolic, and logarithmic oxidation kinetic curves to show why linear kinetics is ultimately the most damaging nature of isothermal oxidation of metals.

Question 9 (2 marks x 5 = 10 marks) CO2 BL2,3

a) Surface melting and surface hardening of steel may both improve hardness but not fatigue strength – why?

b) Which one of the following conditions should produce the highest fatigue strength

i) Shot peening after bulk hardening and machining

ii) Electroplating followed by shot peening

iii) Laser shock peening after machining and transformation hardening

iv) Surface deformation by skin pass rolling and shot peening

c) Select the CORRECT combination of characteristics about martensite:

i) Interstitial compound, bears random relationship with the matrix, grows with low angle coherent interface, and contains large point defect density

ii) Intermetallic phase, bears orientation relationship with the matrix, grows with random incoherent boundary, and contains large dislocation density

iii) Invariant phase transformation product, maintains orientation relationship with the matrix, grows with coherent boundary, and contains large dislocation density

iv) Supersaturated solid solution, maintains orientation relationship with matrix, grows with a glissile coherent interface, and contains large dislocation density

d) Energy or species deposition profile in directed energy (ion, laser, or electron) beam

assisted surface engineering as a function of depth varies as follows:

i) Ion beam (IB): exponential, Laser beam (LB): exponential, Electron beam (EB): Gaussian

ii) IB: Linear, LB: Gaussian, EB: exponential

iii) IB: Logarithmic, LB: exponential, EB: sinusoidal

iv) IB: Gaussian, LB: exponential, EB: Gaussian

e) Draw a schematic diagram showing the 'straggle' created during ion implantation.

Question 10 (2 marks x 5 = 10 marks) CO2,5 BL4

a) Mention two reasons each where laser additive manufacturing is advantageous and not advantageous over conventional manufacturing

b) The origin of stress during laser assisted bending is:

i) Differential thermal stress generated during the heating and cooling cycle following laser irradiation across the thickness of the sheet metal

ii) Phase transformation stress arrested during laser heating/cooling

iii) Application of stress during laser processing

iv) Stress introduced during the expansion of plasma during high energy density laser–matter interaction.

c) Carbon exists in diamond like coating (DLC) in the following form of hybridized state of bonding:

i)Partially crystalline or non-crystalline $sp^2 + sp^3$

ii)Non-crystalline sp^2

iii)Crystalline sp^3

iv)Amorphous sp^4

d)Select the CORRECT list of combination of properties and units from Column A and B:

Column A		Column B
i.	Viscosity	(A) W/m.K
ii.	Fracture toughness	(B) MPa.s
iii.	Thermal conductivity	(C) m^2/s
iv.	Volume diffusivity of solute	(D) MPa√m

The CORRECT combination is:

I) i + A, ii + B, iii + C, iv + D

II) i + B, ii + D, iii + A, iv + C

III) i + B, ii + A, iii + D, iv + C

IV) i + C, ii + D, iii + A, iv + B

e) The advantages of Plasma Immersion ion implantation over conventional Ion Implantation lies in the former being a:

i) A line-of-sight process with exponentially increasing solute distribution profile

ii) A non-line-of-sight process with Gaussian distribution profile of species

iii) A process with high chemical reactivity to produce a thin compound layer

iv) A process under high vacuum with sinusoidally varying ion distribution profile

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