CLASS TEST

S.No.: 01_SK_ME_JKLMN_170825

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Metal Cutting + Material Science

MECHANICAL ENGINEERING

Date of Test : 17/08/2025

ANSWER KEY

1.	(a)	7.	(d)	13.	(a)	19.	(b)	25.	(a)
2.	(d)	8.	(c)	14.	(c)	20.	(c)	26.	(a)
3.	(b)	9.	(d)	15.	(b)	21.	(b)	27.	(a)
4.	(c)	10.	(b)	16.	(b)	22.	(a)	28.	(d)
5.	(b)	11.	(a)	17.	(c)	23.	(d)	29.	(a)
6.	(b)	12.	(c)	18.	(d)	24.	(c)	30.	(c)

DETAILED EXPLANATIONS

1. (a)
Hadfield steel is used for making jaw crusher plate. Its composition is C 1.1 to 1.4%, Mn 11 to 14%, Rest Fe.

2. (d)
For FCC material:

Material	Slip plane	Slip direction	No. of slip system
Cu, Al, Ni, Ag, Au	{1 1 1}	< 1 1 0 >	12

3. (b)
In screw dislocation motion of dislocation is referred as climb and in edge dislocation movement of dislocation is referred as glide.
In edge dislocation Burger vector is perpendicular to the dislocation line while in screw dislocation Burger vector is parallel to the dislocation line.
Unit plastic deformation is called slip and it always appear in the direction of applied load. Direction of slip is represented by Burger vector.

4. (c)
Cu and Ni are completely soluble in the liquid as well as in solid state.
Ag + Cu and Pb + Sn → These are partially soluble in solid state but fully soluble in liquid state.

5. (b)

Peritectic reaction, $$\delta\text{-iron} + L \underset{0.18\%\,C}{\overset{1493°C}{\rightleftharpoons}} \gamma\text{-iron}$$

6. (b)
Diffusion annealing is performed for making the chemistry uniform throughout the material. Sample is heated to approximately 1150°C and then cooled slowly in the furnace. Higher temperature are selected to enable the diffusion phenomena more and more.

7. (d)
After hardening resulting microstructure is extremely hard and brittle. So, tempering is performed for reducing hardness and brittleness and for increasing ductility or toughness.

8. (c)
Austenite sample is quenched at a rate greater than or equal to critical cooling rate to a temperature below the nose but above martensite start line. This temperature is maintained for substantial period of time so that transformation line enters into TTT curve. This produces bainite. Bainite cannot be produced by continuous cooling. This process of producing bainite is called austempering.

9. (d)
Tools used in metrology like sine bar and precision ball are produced by low temperature tempering. Since the temperature in low temperature tempering is very low, so there is no diffusion. In low temperature tempering only thermal stresses are relieved.

10. (b)

At Jominy distance, there is 50% martensite and 50% pearlite, in Jominy end quench test.

11. (a)

1. Eutectic reaction:

$$L \underset{4.3\%\ C}{\overset{1150°C}{\rightleftharpoons}} \underbrace{\gamma - \text{iron} + Fe_3C}_{\text{Ledeburite}}$$

2. Eutectoid reaction:

$$\gamma - \text{iron} \underset{0.8\%\ C}{\overset{725°C}{\rightleftharpoons}} \underbrace{\alpha - \text{iron} + Fe_3C}_{\text{Pearlite}}$$

Pealite is having plate like structure of α-iron and Fe_3C. It is phase mixture of α-iron and Fe_3C. It is mainly produced by diffusion.

3. Peritectic reaction:

$$\underbrace{\delta - \text{iron}}_{\text{Solid}} + \underbrace{L}_{\text{Liquid}} \underset{0.18\%\ C}{\overset{1493°C}{\rightleftharpoons}} \underbrace{\gamma - \text{iron}}_{\text{solid}}$$

12. (c)

In 100 atoms of Cu-Ni alloy, there are 64 atoms of Cu and 36 atoms of Ni.

$$\text{Weight of 64 copper atoms} = \frac{64 \times 63.55}{6.023 \times 10^{23}} \text{gram} = 6.75278 \times 10^{-21} \text{ gram}$$

$$\text{Weight of 36 nickel atoms} = \frac{36 \times 58.69}{6.023 \times 10^{23}} \text{gram} = 3.507953 \times 10^{-21} \text{ gram}$$

$$\text{Weight fraction of copper} = \frac{W_{Cu}}{W_{Cu} + W_{Ni}} = \frac{6.75278 \times 10^{-21}}{6.75278 \times 10^{-21} + 3.507953 \times 10^{-21}}$$

$$= 0.65812$$

$$\text{Weight fraction of copper} = 65.81\%$$

13. (a)

Friction angle for dry cutting,

$$\tan\beta_{dry} = \frac{F_t + F_C \tan\alpha}{F_C - F_t \tan\alpha} = \frac{740 + (1330)\tan(-5°)}{1330 - 740\tan(-5°)}$$

$$\beta = 24.09°$$

for when coolant is used,

$$\tan\beta_{coolant} = \frac{710 + 1200\tan(-5°)}{1200 - 710\tan(-5°)}$$

$$\beta = 25.61°$$

$$\text{Change in friction angle} = 25.61° - 24.09° = 1.52°$$

14. (c)

$$t = f\sin\lambda = 0.4 \sin 60° = 0.346 \text{ mm}$$

$$r = \frac{t}{t_c} = \frac{0.346}{0.8} = 0.43$$

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} = \frac{0.43\cos 15°}{1 - 0.43\sin 15°} = 0.467$$

$$\phi = \tan^{-1}(0.467) = 25°$$

Shear strain, $\gamma = \tan(\phi - \alpha) + \cot\phi$

$= \tan(10°) + \cot 25°$

$= 2.321$

Shear strain rate, $\dot{\gamma} = \frac{\cos\alpha}{\cos(\phi - \alpha)} \times \frac{V}{\Delta y} = \frac{\cos 15°}{\cos 10°} \times \frac{150/60}{9 \times 10^{-6}}$

$= 2.7 \times 10^5 \text{ s}^{-1}$

15. (b)

0° - 10° - 6° - 6° - 8° - 75° – 1 (mm) ORS

$i = 0$, $\alpha = 10°$, λ = 75°

$$\tan\alpha_s = \sin\lambda \tan\alpha - \cos\lambda \tan i$$

$$\tan\alpha_s = \sin 75 \tan 10 - \cos 75 \tan 0$$

$$\tan\alpha_s = 0.170318$$

$$\alpha_s = 9.66°$$

16. (b)

$$\frac{C^{1/n} d_1^{-x/n} f_1^{-y/n}}{V_1^{1/n}} = \frac{C^{1/n} d_2^{-x/n} f_2^{-y/n}}{V_2^{1/n}}$$

$d_1 = d_2$

$$\left(\frac{V_2}{V_1}\right)^{1/n} = \left(\frac{f_2}{f_1}\right)^{-y/n}$$

$$\left(\frac{1.5V_1}{V_1}\right)^{2} = \left(\frac{f_1}{f_2}\right)^{1.2}$$

$$\frac{f_1}{f_2} = (1.5^2)^{1/1.2} = 1.96 \simeq 2$$

$\Rightarrow$ $f_2 = \frac{f_1}{2}$

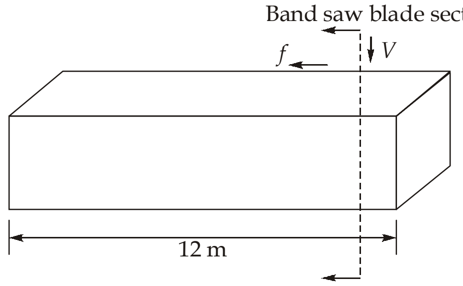
Feed has to be reduced by 50%.

17. (c)

Saw has 12 teeth per meter

$$\text{Saw speed} = 150 \text{ m/min}$$

So, Number of teeth engaging per minute $= \frac{12}{(\text{metre})} \times 150 \times \left(\frac{\text{metre}}{\text{min}}\right)$



$$= 1800 \text{ Teeth/minute}$$

$$\text{Feed per tooth} = 0.003 \text{ meter}$$

$$\text{Feed per minute} = 1800 \times 0.003$$

$$= 5.4 \text{ m/min}$$

Time taken to cut 12 m $= \frac{12}{5.4} = 2.223$ min

18. (d)

$$\text{X-ray wavelength} = \lambda$$

$$\text{Reflection angle, } \theta = 8° \text{ for } n = 1$$

$$\text{Interplanar distance, } d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

$$d_{200} = \frac{a}{\sqrt{2^2 + 0^2 + 0^2}}$$

$$d_{200} = \frac{a}{2}$$

As per Bragg's law,

$$2d \sin\theta = n\lambda$$

$$2 \times \left(\frac{a}{2}\right) \times \sin 8° = 1 \times \lambda$$

$$a = \frac{\lambda}{\sin 8°} = 7.1853\lambda$$

So, lattice parameter, $a = 7.1853\lambda$

19. (b)

$$\text{BHN number} = 450$$

$$\text{Load, } P = 500 \text{ kg}$$

$$\text{Indenter diameter, } D = 10 \text{ mm}$$

$$\text{Indentation diameter, } d = ?$$

$$\text{BHN} = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

$$450 = \frac{2 \times 500}{(10\pi)\left[10 - \sqrt{(10^2 - d^2)}\right]}$$

$$10-\sqrt{(100-d^2)} = \frac{1000}{450\times 10\pi}$$

$$9.92926447 = \sqrt{100-d^2}$$

$$98.5803 = 100 - d^2$$

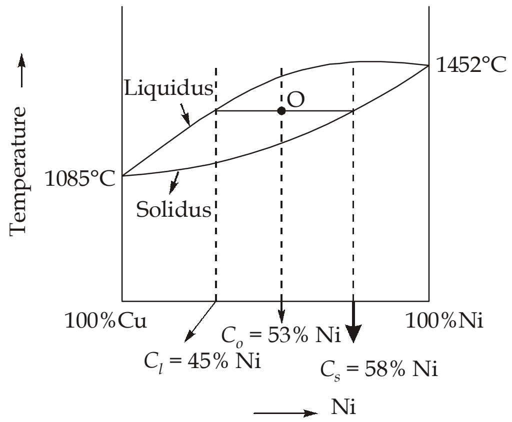
$$d^2 = 1.4097$$

$$d = 1.187 \text{ mm} \simeq 1.19 \text{ mm}$$

20. **(c)**

It is fastest case hardening process. Samples are passed through induction coil and heat will develop to the surface due to eddy current. Advantage of induction heating is that it can be localized. Samples are then immediately quenched into an oil bath to produce a thin layer of martensite over it.

21. **(b)**



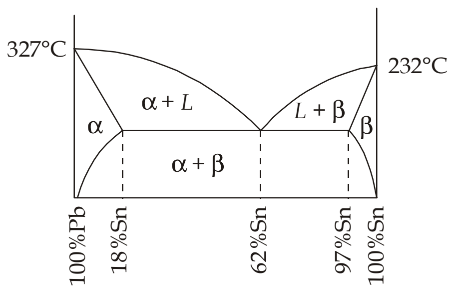
$$42\%\text{Cu} = (100-42)\%\text{ Ni} = 58\%\text{ Ni}$$

$$55\%\text{Cu} = (100-55)\%\text{ Ni} = 45\%\text{ Ni}$$

$$\%\text{liquid} = \left(\frac{C_s - C_o}{C_s - C_l}\right)\times 100$$

$$= \left(\frac{58-53}{58-45}\right)\times 100\% = 38.46\%$$

22. **(a)**



Terminal phases occur near the pure metal ends, e.g. α and β phases in the above eutectic system.

23. (d)

Sample size = 100 gram
Mass of iron atoms = 99.99 gram
Mass of carbon atoms = 0.01 gram
Molecular weight of iron = 56 g/mol
Molecular weight of carbon = 12 g/mol
Avogadro's number, N_A = 6.023×10^{23} atoms/mol

$$\text{Number of iron atoms} = \frac{99.99}{56} \times 6.023 \times 10^{23} = 10.7542816 \times 10^{23} \text{ atoms}$$

$$\text{Number of carbon atoms} = \left(\frac{0.01}{12}\right) \times 6.023 \times 10^{23} = 5.0191667 \times 10^{20} \text{ atoms}$$

Number of iron atoms per unit cell of BCC structure = 2
Number of iron atoms in 10000 unit lattices = 20000 atoms

$$\text{Number of carbon atom} = 20000 \times \left(\frac{5.0191667 \times 10^{20}}{10.7542816 \times 10^{23}}\right) = 9.33426 \simeq 10$$

24. (c)

In this problem, four alloys are assessed relative to the two criteria presented. The first criterion is that the material does not experience plastic deformation when the tensile load of 27.5 kN is applied, this means that the stress corresponding to this load should not exceed the yield strength of the material.

$$\text{Stress in member, } \sigma = \frac{F}{A} = \frac{27500}{\frac{\pi}{4} \times 10^2} = 350.14 \text{ MPa}$$

Among given alloys, steel and titanium alloy are having yield strength more than 350.14 MPa. According to second criteria, Δd should be less than 7.5×10^{-3} mm.

$$\text{We know that, } \mu = -\frac{\left(\frac{\Delta d}{d}\right)}{\left(\frac{\Delta l}{l}\right)} = -\frac{\left(\frac{\Delta d}{d}\right)}{\frac{\sigma}{E}} = -\left(\frac{E \Delta d}{\sigma d}\right)$$

$$\text{For steel alloy, } \Delta d = -\frac{\mu \sigma d}{E} = \frac{-0.30 \times 350.14 \times 10}{207 \times 10^3}$$

$$\Delta d = -5.07 \times 10^{-3} \text{ mm} \qquad \text{(Accepted)}$$

$$\text{For titanium alloy, } \Delta d = \frac{-0.34 \times 350.14 \times 10}{107 \times 10^3} = -11.12 \times 10^{-3} \text{ mm} \qquad \text{(Rejected)}$$

Hence, steel alloy is best material.

25. (a)

Full annealing: The objective of full annealing is to reduce hardness and brittleness or to increase ductility and toughness. Hypo-eutectoid sample are heated 50°C above the upper critical temperature and hyper eutectoid steel sample are heated 50°C above the lower critical temperature. We keep the sample at this temperature for certain time period and cool it slowly in the furnace. The resulting microstructure is coarse pearlite.

26. **(a)**

By Taylor's equation,

$$VT^n = C$$

$$65 \times (15 \times 60)^n = 300$$

$$\Rightarrow \quad n = 0.225$$

from second condition

$$(3 \times 65)\,(T)^{0.225} = 300$$

$$\Rightarrow \quad T = 6.784 \text{ min}$$

$$T = 0.113 \text{ hours}$$

27. **(a)**

$$\text{True strain, } \in \; = \ln\left(\frac{150}{100}\right) = 0.405$$

$$\text{Flow stress, } \sigma_f = 850(0.405)^{0.3} = 648.1 \text{ MPa}$$

$$\text{Average flow stress, } \sigma_{f,\,avg} = \frac{\sigma_f}{1+n} = \frac{648.1}{1.3} = 498.5 \text{ MPa}$$

28. **(d)**

Hole diameter, d = 20 mm

Sheet thickness, t = 4 mm

Clearance, C = 3% of t

Punch diameter, d = 20 mm

Die diameter = $d + 2C$

$$= 20 + 2 \times \frac{3}{100} \times 4 = 20.24 \text{ mm}$$

29. **(a)**

for maximum reduction

drawing stress, σ_d = flow stress, σ_f

$$\therefore \quad \frac{\sigma_f}{\sigma_f + B(\sigma_0 - \sigma_b)} = \ln\left(\frac{A_f}{A_i}\right)$$

$$B = \mu\cot\alpha$$

$$= 0.2\cot 2° = 5.727$$

$$\frac{A_f}{A_i} = \left[\frac{250}{250 + 5.727(250 - 50)}\right]^{1/5.727} = 0.7406$$

$$\%\text{redution} = \left(1 - \frac{A_f}{A_o}\right) \times 100 = 25.94\%$$

Alternate :

For wire drawing operation,

$$\sigma_d = \sigma_f\left(\frac{1+B}{B}\right)\left(1 - \left(\frac{d_f}{d_i}\right)^{2B}\right) + \sigma_b\left(\frac{d_f}{d_i}\right)^{2B}$$

$$B = \mu\cot\alpha$$

$$= 0.2\cot 2° = 5.727$$

As for maximum reduction,

$$\text{Drawing stress, } \sigma_d = \text{flow stress, } \sigma_f$$

$$\Rightarrow \quad 250 = 250\times\frac{6.727}{5.727}\left(1-\left(\frac{d_f}{d_i}\right)^{2\times5.727}\right)+50\left(\frac{d_f}{d_i}\right)^{2\times5.727}$$

$$250 = 293.653-293.653\left(\frac{d_f}{d_i}\right)^{2\times5.727} + 50\times\left(\frac{d_f}{d_i}\right)^{2\times5.727}$$

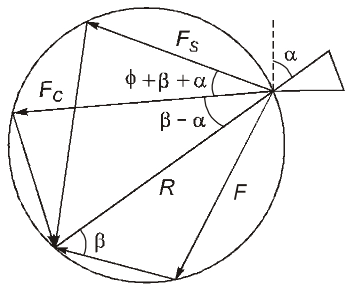
$$243.653\left(\frac{d_f}{d_i}\right)^{2\times5.727} = 43.653$$

$$\left(\frac{d_f}{d_i}\right)^{2} = (0.17916)^{1/5.727} = 0.7406$$

$$\%\text{reduction in wire area} = \left(\frac{A_i-A_f}{A_i}\right)\times100 = \left(1-\left(\frac{d_f}{d_i}\right)^2\right)\times100 = 25.94\% \simeq 26\%$$

30. (c)

By Merchant's theory



$$\frac{F_c}{F_s} = \frac{R\cos(\beta-\alpha)}{R\cos(\phi+\beta-\alpha)}$$

$$\alpha = 7°$$

$$\beta = ?$$

$$\phi = ?$$

$$\tan\phi = \frac{r\cos\alpha}{1-r\sin\alpha} = \frac{0.5\cos7°}{1-0.5\sin7°}$$

$$\phi = 27.8553°$$

$$2\phi = 90 + \alpha - \beta$$

$$2 \times 27.8553 = 90 + 7 - \beta$$

$$\beta = 41.2892°$$

$$F_s = \frac{\tau_s bt}{\sin\phi} = \frac{250\times3\times0.2}{\sin 27.8553°} = 321.0340 \text{ N}$$

$$F_c = 321.0340\times\frac{\cos(41.2892-7)}{\cos(41.2892+27.8553-7)}$$

$$F_c = 567.66 \text{ N}$$

■■■■