MADE EASY PUBLICATIONS

POSTAL BOOK PACKAGE 2027

MECHANICAL ENGINEERING

CONVENTIONAL PRACTICE SETS VOLUME - IV

CONTENTS

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ENGINEERING MECHANICS

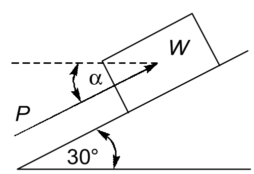
CONVENTIONAL PRACTICE SETS

Page No. 1 - 35

1 CHAPTER Equilibrium of Forces and Moment

Practice Questions

Q.1 Determine the magnitude and direction of the smallest force P, which will maintain the body of weight W = 300 N on an inclined smooth plane as shown in figure is in equilibrium.



Solution:

The body is acted upon by three forces, namely the action of gravity force W, the applied force P and the reaction R. Since these three forces are in equilibrium, the vectors representing them must build a closed triangle, we begin with the known vector $\overline{bc}$ representing to a certain scale, the weight of the body, and then draw the line aa parallel to the R.

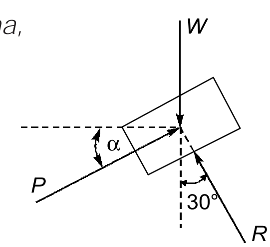
The side $\overline{cd}$ will be minimum if it is perpendicular to line aa,

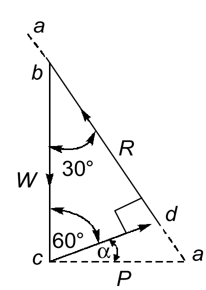
that is P will be minimum, if it is perpendicular to aa.

From the triangle bcd, $\angle c = 90° - 30° = 60°$

$\therefore \quad \alpha = 90° - 60° = 30°$

and using the triangle bcd, we obtain,





$$P = W\sin 30° = \frac{W}{2} = 150 \text{ N}$$

Alternate solution: After drawing the free-body diagram of the body of above, then applying the Lami's theorem to the free-body diagram of the body as shown in figure we get

$$\frac{W}{\sin(90° - \alpha + 30°)} = \frac{P}{\sin(\pi - 30°)} = \frac{R}{\sin(90° + \alpha)}$$

Using the first two of the equation we obtain

$$\frac{W}{\cos(30° - \alpha)} = \frac{P}{\sin 30°}$$

$$P = \frac{W\sin 30°}{\cos(30° - \alpha)}$$

From equation, P will be minimum, if the denominator is maximum, i.e.

$$\cos(30° - \alpha) = 1$$

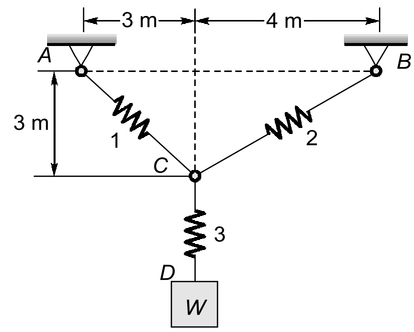
$\Rightarrow \quad 30° - \alpha = 0$

$\Rightarrow \quad \alpha = 30°$

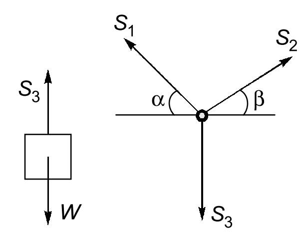
and substituting this value into equation, we get the value of

$$P = W \sin 30° = 150 \text{ N, as before}$$

Q.2 Determine the stretch in each spring for equilibrium of the weight W = 40 N block as shown in figure. The springs are in equilibrium position. The stiffness of each spring is given as: k_1 = 40 N/m, k_2 = 50 N/m, and k_3 = 60 N/m



Solution:



Draw the free-body diagram of the body as shown in figure.

Only two forces are acting on the body, gravity force W and the reactive force caused by the spring S_3. Since the body is in equilibrium, from the law of equilibrium of two forces,

$$S_3 = W$$

Now, draw the free-body diagram of the point C. At the joint, C three forces are acting all are reactive forces caused by the springs. The angles that springs S_1 and S_2 make with the horizontal are calculated as below:

$$\tan\alpha = \frac{3}{3} = 1 \Rightarrow \alpha = 45°$$

$$\tan\beta = \frac{3}{4} \Rightarrow \beta = 36.87°$$

Since the joint C is in equilibrium, applying Lami's theorem, we obtain

$$\frac{S_1}{\sin\left(\frac{\pi}{2}+\beta\right)} = \frac{S_2}{\sin\left(\frac{\pi}{2}+\alpha\right)} = \frac{S_3}{\sin(\pi-\alpha-\beta)}$$

From equation we get

$\Rightarrow$
$$S_1 = \frac{S_3\cos\beta}{\sin(\alpha+\beta)} = \frac{W\cos\beta}{\sin(\alpha+\beta)}$$

$$S_2 = \frac{S_3\cos\alpha}{\sin(\alpha+\beta)} = \frac{W\cos\alpha}{\sin(\alpha+\beta)}$$

$$EF = EC + CF = r_1 + r_2 = 100 + 50 = 150 \text{ mm}$$

and
$$EH = OI - OG - BI$$

$$OI = a = 200 \text{ mm}$$

and
$$OG = r_2 = 50 \text{ mm}$$

$$BI = EI\sin\frac{\alpha}{2}\left[\because EI = \frac{BE}{\cos\frac{\alpha}{2}} = \frac{r_1}{\cos 30°} = \frac{100}{\cos 30°} = 115.47 \text{ mm}\right]$$

$\therefore$
$$BI = 115.47\sin 30° = 57.74 \text{ mm and}$$

$\therefore$
$$EH = 200 - 50 - 57.74 = 92.26 \text{ mm}$$

$$\cos\beta = \frac{EH}{EF} = \frac{92.26}{150} = 0.615$$

$\therefore \quad \beta = 52.05°$

$$R_c \cos\beta = R_d$$

$$R_c \sin\beta = Q$$

Substituting the values for β and Q in the above equations and solving for R_c and R_d, we obtain

$$R_c = \frac{Q}{\sin\beta} = \frac{800}{\sin 52.05} = 1014.52 \text{ N}$$

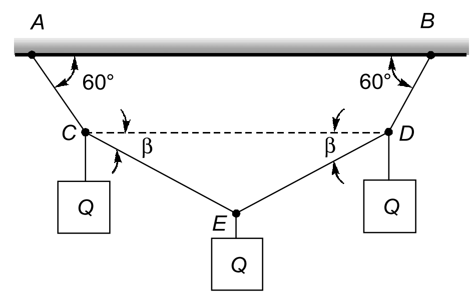
$$R_d = R_c \cos\beta = 1014.52 \times \cos 52.05° = 623.9 \text{ N}$$

$$R_a = R_c \frac{\cos\beta}{\sin\alpha} = 1014.52 \times \frac{\cos 52.05}{\sin 60} = 720.42 \text{ N}$$

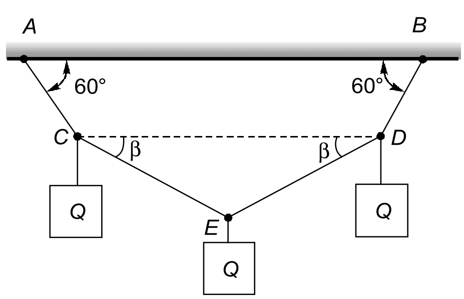
$$R_b = R_c \sin\beta + P - R_a \cos\alpha$$

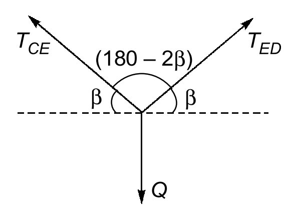
$$= 1014.52 \times \sin 52.05° + 2000 - 720.42 \cos 60° = 2439.79 \text{ N}$$

Q.3 On the string *ACEDB* are hung three equal weights *Q* symmetrically placed with respect to the vertical line through the mid-point *E*. Determine the value of the angles *b* if the other angles are as shown in the figure.



Solution:





At point *E*,

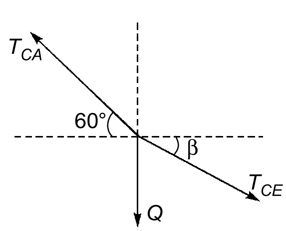
By symmetry,

$$T_{CE} = T_{ED}$$

Lami's theorem
$$\frac{T_{CE}}{Sin(90+\beta)} = \frac{T_{ED}}{\sin(90+\beta)} = \frac{Q}{\sin(180-2\beta)}$$

$$T_{CE} = \frac{Q\cos\beta}{\sin 2\beta} = \frac{Q}{2\sin\beta} \quad \text{...(i)}$$

At point *C*:



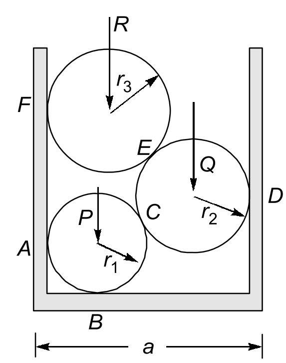
Lami's theorem
$$\frac{T_{CA}}{\sin(90-\beta)} = \frac{T_{CE}}{\sin 150} = \frac{Q}{\sin(120+\beta)}$$

Now,
$$T_{CE} = \frac{Q \times \sin 150}{\sin(120+\beta)} \quad \text{...(ii)}$$

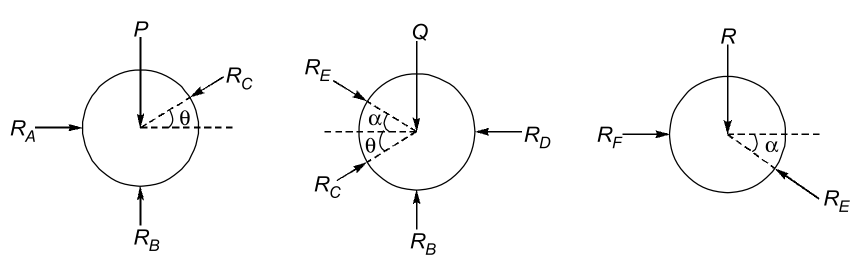
By equation (i) and (ii)
$$\frac{Q}{2\sin\beta} = \frac{Q\times 1/2}{\sin(120+\beta)}$$
$$\sin(120+\beta) = \sin\beta$$
$$\sin[90+(30+\beta)] = \sin\beta$$
$$\cos\beta\cdot\cos 30 - \sin\beta\cdot\sin 30 = \sin\beta$$
$$\cos\beta\times\frac{\sqrt{3}}{2} = \sin\beta+\frac{1}{2}(\sin\beta)$$
$$\frac{\cos\beta}{\sin\beta} = \frac{\frac{3}{2}}{\left(\frac{\sqrt{3}}{2}\right)}$$
$$\left(\frac{\cos\beta}{\sin\beta}\right) = \sqrt{3}$$
$$\tan\beta = \frac{1}{\sqrt{3}}$$
$$\beta = 30^\circ$$

Alternate:
$$\sin[180-(120+\beta)] = \sin\beta$$
comparing on both sides
$$180-120-\beta = \beta$$
$$60 = 2\beta$$
$$\beta = 30^\circ$$

Q.4 The smooth cylinders rest in a horizontal channel having vertical walls, the distance between which is a. Find the pressures exerted on the walls and floor at the points of contact *A*, *B*, *D* and *F*. the following numerical data are given: P = 200 N, Q = 400 N, R = 300 N, r_1 = 120 mm, r_2 = 180 mm, r_3 = 150 mm and a = 540 mm.



Solution:



Cylinder 1 **Cylinder 2** **Cylinder 3**

For cylinder 2:
$$\cos\alpha = \frac{540-180-150}{180+150}$$
$$\alpha = 50.47^\circ$$
$$\frac{R}{\sin(180-50.47)^\circ} = \frac{R_E}{\sin 90^\circ} = \frac{R_F}{\sin(90+50.47)^\circ}$$

MATERIAL SCIENCE

CONVENTIONAL PRACTICE SETS

Page No. 36 - 73

1 CHAPTER Basic Crystallography

Practice Questions : Level-I

Q.1 Aluminium has an FCC crystal structure. Its atomic weight equals 26.98 amu. The approximate atom radius equals 1.431 Å (Å = 10^{-10} m). Determine the weight density of aluminum.

Solution:

$$\rho = \frac{(\text{number of atoms/ unit cell}) \times (\text{atomic weight/ } A_0)}{\text{volume of unit cell}}$$

$$\rho_{Al} = \frac{(4 \text{ atoms})(26.98 \text{ amu/ } 6.02 \times 10^{23} \text{ amu/ g})}{a^3}$$

From table, $a_{fcc}^3 = 66.314 \times 10^{-24}$ cm^3 [$\because$ For FCC $\sqrt{2}\,a = 4r$]

Therefore, $$\rho_{Al} = \frac{4 \times 26.98}{66.3314 \times 10^{-24} \times 6.02 \times 10^{23}} = 2.703 \text{ g/cm}^3$$

Q.2 In a body centered cubic crystal of lattice parameter 3.6 Å, a positive edge dislocation of 1 mm long climbs up by 1 μm. How many vacancies are created?

Solution:

When a dislocation of 1 mm long climbs up by 1 μm.

Area affected = $1 \times 10^{-3} \times 1 \times 10^{-6} = 10^{-9}$ m^2

Area of unit cell, $a^2 = (3.6 \times 10^{-10})^2 = 12.96 \times 10^{-20}$ m^2

Number of atoms per unit cell in BCC structure = 2

For an area of 12.96×10^{-20} m^2, 2 atoms gets affected (destroyed).

For an area of 10^{-9} m^2, the number of atoms destroyed

$$= \frac{2 \times 10^{-9}}{12.96 \times 10^{-20}} = 1.5432 \times 10^{10} \text{ atoms}$$

Number of vacancies created = 1.5432×10^{10} atoms

Q.3 In an orthogonal crystal structure with lattice parameters $a \neq b \neq c$, draw the direction $[2\bar{1}2]$.

Solution:

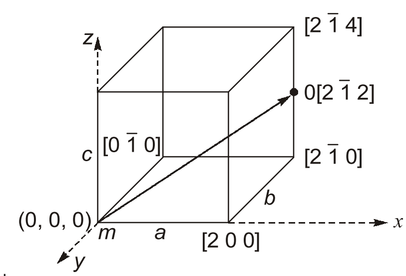
Orthogonal Crystal Structure ($a \neq b \neq c$, $\alpha = \beta = \gamma = 90°$)

Direction $[2\,\bar{1}\,2]$

Here, $x = 2$

$y = -1$

$z = 2$



Joining the point $0[2\,\bar{1}\,2]$ with the origin m [0 0 0] gives the crystal direction.

Q.4 Silver is face-centred cubic with lattice constant 4.086 Å. Calculate the planar density of atoms (a) on the (100) plane, (b) on the (111) plane and (c) the linear density of atoms along the [110] direction.

Solution:

Silver is FCC with lattice constant 4.086 Å.

$$\text{Planar density} = \frac{\text{Number of atoms}}{\text{Area of plane}}$$

(i) On the (100) Plane

$$\rho_{(100)} = \frac{2}{a^2} = \frac{2}{(4.086\times10^{-10})^2} = 1.1979 \times 10^{19}\ \text{atoms/m}^2$$

(ii) On the (111) plane

$$\rho_{(111)} = \left(\frac{2}{\frac{\sqrt{3}}{2}a^2}\right) = \frac{4}{\sqrt{3}\times(4.086\times10^{-10})^2}$$

$$\rho_{pl} = 1.3832 \times 10^{19}\ \text{atoms/m}^2$$

(iii) Linear density of atoms along the [110] direction

$$\rho_l = \frac{\text{Number of atoms on the direction vector}}{\text{Length of the direction vector}}$$

$$= \frac{2}{\sqrt{2}a} = \frac{2}{\sqrt{2}\times(4.086\times10^{-10})} = 3.4611 \times 10^{9}\ \text{atoms/m}$$

Q.5 Calculate the number of atoms per unit cell of a metal having lattice parameter of 0.29 nm, density of 7.868 g/cc, atomic weight is 55.85 g/mol and Avogadro's number is 6.023×10^{23}. What is the crystal structure of metal?

Solution:

Given data: Avogadro's number, $N_A = 6.023 \times 10^{23}$; Lattice parameter; $a = 0.29$ nm $= 0.29 \times 10^{-7}$ cm

Density, $\rho = 7.868$ g/cm^3; Atomic weight, $A = 55.85$ g/mol

Number of atoms/unit cell $= n$

Volume of one unit cell, $V_C = (a)^3 = (0.29 \times 10^{-7})^3$ cm^3

$$\rho = \left(\frac{nA}{V_c N}\right)$$

$$\Rightarrow \quad 7.868 = \frac{n\times55.85}{(0.29\times10^{-7})^3\times6.023\times10^{23}}$$

$$n = \frac{7.868\times(0.29\times10^{-7})^3\times6.023\times10^{23}}{55.85} = 2.06 \simeq 2$$

Crystal structure of the atoms is BCC.

Q.6 Define unit cell of a space lattice. Derive the effective number of lattice points in the unit cell of cubic lattices. Calculate the packing efficiency and density of silicon which has diamond cubic structure. Use the following properties for silicon :

Atomic Number = 14

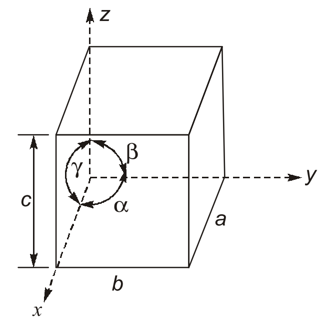
Atomic mass unit = 1.66×10^{-27} kg

Lattice parameter = 5.431×10^{-10} m

Assume radius of Si atom in diamond cubic structure to be $\left(\frac{\sqrt{3}}{8}\right)$ times the lattice parameter.

Solution:

Unit cell: The atomic order in crystalline solids, indicates that small group of atoms that form a repetitive pattern.



$$a, b, c = \text{Lattice parameters}$$

$$\alpha, \beta, \gamma = \text{Interfacial angles}$$

Effective number of lattice points/ atoms in the unit cell of cubic lattices.

1. **Simple cubic structure:** In simple cubic structure, with atoms located at each of the corners of a unit cell.

$$\text{Number of atoms} = \text{Number of corner atoms } (N_C) \times \frac{1}{8}$$

$$= 8 \times \frac{1}{8} = 1 \text{ atoms}$$

2. **Body centered cubic structure (BCC):** In this crystal structure a cubic unit cell with atoms located at all eight corner and a single atom at the cube center.

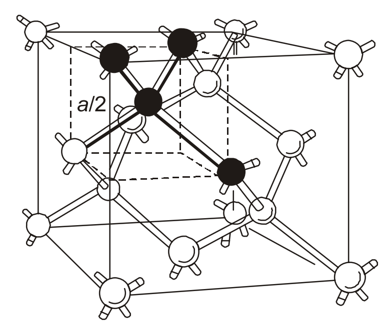
$$\text{Number of atoms} = \text{Number of corner atoms } (N_C) \times \frac{1}{8} + \text{Body centered atom } (N_B)$$

$$= 8 \times \frac{1}{8} + 1 = 2 \text{ atoms}$$

3. **Face centered cubic structures (FCC):** In face centered cubic structure a unit cell with atoms located at each of the corners and the centers of all the cube faces.

$$\text{Number of atoms} = \text{Number of corner atoms } (N_C) \times \frac{1}{8} + \text{Number of face centered atom} \times \frac{1}{2}$$

$$= 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 1 + 3 = 4 \text{ atoms}$$



Diamond cubic structure (Si)

Si has a diamond cubic structure. In this structure 8 atoms are arranged at corners and 6 atoms are arranged at face centers and 4 atoms are arranged inside cell on 4 body diagonal.

Average number of atoms in the diamond cubic unit cell = $\frac{1}{8} \times 8$ (Corner atoms) + $\frac{1}{2} \times 6$ (Face centered atoms) + 1 × 4 (Atoms inside the cell)

$$= 1 + 3 + 4 = 8$$

Relations between atomic radius (R) and lattice parameter (a)

$$R = \frac{a\sqrt{3}}{8}$$

$$\text{Lattice parameter (a)} = 5.431 \times 10^{-10} \text{ m}$$

$$\text{Atomic radius (R)} = \frac{5.431 \times 10^{-10}\sqrt{3}}{8} = 1.1758 \times 10^{-10} \text{ m}$$

$$\text{Volume unit cell} = a^3 = (5.431 \times 10^{-10})^3$$

$$\text{Atomic packing factor} = \frac{N_{av} \times \frac{4}{3}\pi R^3}{a^3} = \frac{8 \times \frac{4}{3} \times \pi (1.1758 \times 10^{-10})^3}{(5.431 \times 10^{-10})^3} = 0.3400$$

$$\% \text{ APF} = 34.00\%$$

$$\text{Density} = \frac{N_{av} \times \text{Atomic weight}}{\text{Avagadro number} \times \text{Volume of unit}} = \frac{8 \times (2 \times \text{atomic number})}{6.023 \times 10^{23} \times (5.431 \times 10^{-10})^3}$$

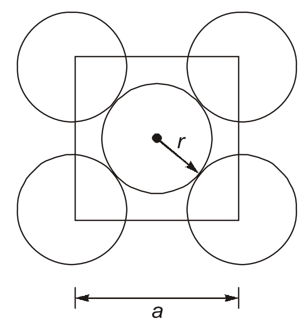
$$= \frac{8 \times 2 \times 14 \times 10^{-3}}{9.64833 \times 10^{-5}} = 2321.645 \text{ kg/m}^3$$

Practice Questions : Level-II

Q.7 Prove that the packing fraction for F.C.C. structure is 0.74. Draw the phase diagram of Pb-Sn alloy and from this diagram draw cooling curve for eutectic alloy. How many atoms per mm^2 are there on the (100) planes of lead (Pb) radius 0.1750 nm? What is deformation by twinning?

Solution:

Atomic Packing Fraction,



$$APF = \frac{N_{avg} \times V_{molecule}}{V_{unit\ cell}}$$

$N_{avg.}$ = Average number of atoms in a unit cell

$V_{molecule}$ = Volume of one atom/molecule

For FCC structure, $\left(\sqrt{2}a = 4r\right)$

$$APF = \frac{4 \times \frac{4}{3}\pi r^3}{a^3} = \frac{16}{3}\frac{\pi r^3}{a^3} = \frac{16}{3}\pi \frac{\left(\frac{\sqrt{2}}{4}a\right)^3}{a^3} = 0.74$$

Assuming lead (Pb) forms FCC structure.

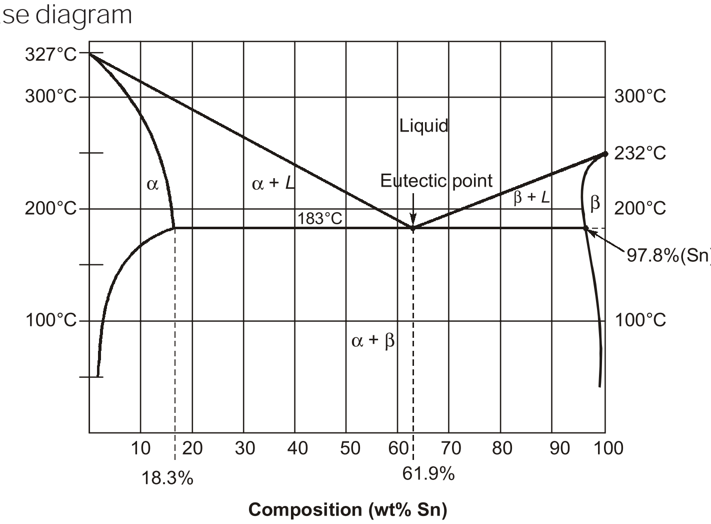
$$\text{Planar Density (100)} = \frac{\text{Number of atoms}}{\text{Area of plane}} = \frac{2}{a^2}$$

and, $\sqrt{2}a = 4r$

$$a = \frac{4r}{\sqrt{2}} = \frac{4 \times 0.1750 \times 10^{-9}}{\sqrt{2}} \text{m} = 0.495 \times 10^{-9} \text{ m} = 0.495 \times 10^{-6} \text{ mm}$$

$$\text{Planar density(100)} = \frac{2}{(0.495 \times 10^{-9} \times 10^3)^2} = 8.1624 \times 10^{12} \text{ atoms/mm}^2$$

The Lead-Tin phase diagram



The other mechanism of plastic deformation is twinning, in which a portion of the crystal forms a mirror image of itself across the plane of twinning. Twins forms abruptly and are the cause of the cracking sound (" tin cry") that occurs when tin or zinc rod is bent at room temperature. Twinning usually occurs in HCP metals.

PRODUCTION AND MAINTENANCE ENGINEERING

CONVENTIONAL PRACTICE SETS

Page No. 74 - 145

Metal Casting

Practice Questions : Level-I

Q.1 A pressure die casting set-up was testing by injecting water (density 1000 kg/m^3) are pressure of 200 bar. Mould filling time was found to be 0.05 s. Afterwards, the actual casting is made by injecting the liquid metal (density 2000 kg/m^3) at an injection pressure of 400 bar. Neglecting all losses (friction, viscous etc). Determine the approximate mould filling time.

Solution:

Let us injection velocity of liquid V_1 from Bernoulli equation,

$$V_1 = \sqrt{\frac{2p_0}{\rho}} = \sqrt{\frac{2 \times 200 \times 10^5}{1000}} = 200 \text{ m/s}$$

Volume flow rate through unit cross-section,

$$Q_1 = A_1 \times V_1 = 1 \times 200 = 200 \text{ m}^3/\text{s}$$

Volume of liquid flow in 0.05 sec = $Q \times t_{f1}$ = 200 × 0.05 = 10 m^3

When liquid metal injected.

The injection velocity of liquid metal (V_2) from Bernoulli equation,

$$V_2 = \sqrt{\frac{2p_2}{\rho}} = \sqrt{\frac{2 \times 400 \times 10^5}{2000}} = 200 \text{ m/s}$$

Q.2 A cylinder riser is used for casting steel cube of 10 cm side. It freezing constant for the metal is 0.1, contraction ratio from liquid to solid is 0.03 and same mould material is used around casting and riser. Determine the dimension of the riser (side riser), for the freezing ratio of 1.25.

Solution:

By Caine's method

$$x = \frac{a}{y-b} + c$$

where, a = freezing constant, b = contraction ratio, c = relative freezing rate of riser and casting = 1, if same mould material is used around casting and riser.

$$x = \text{freezing ratio} \left(\frac{(A/V)_c}{(A/V)_r}\right)$$

$$y = \text{volume ratio } (V_r/V_c)$$

Put the values of a, b and c

$$x = \frac{0.1}{y-0.03} + 1$$

At $x = 1.25$

$$1.25 = \frac{0.1}{y-0.03}+1$$

$$y = 0.43$$

$$y = \frac{V_r}{V_c} = 0.43$$

For side riser, $h = d$

$$V_r = \frac{\pi}{4}d^2 \times h = \frac{\pi}{4}d^3$$

$$V_c = 1000 \text{ cm}^3$$

$$\frac{\pi}{4}\times\frac{d^3}{1000} = 0.43$$

$$d = 8.180 \text{ cm}$$

Q.3 Calculate the time required for filling the mould of a sand casting of dimension 40 mm × 10 mm × 10 mm using top gating with metal flow rate of 25 cm^3/min (design should be such that the pressure anywhere in sprue should not be less than atmospheric pressure).

Solution:

Time taken for filling mold, $t_f = \dfrac{V}{A_g v_g}$

$$A_g v_g = \text{Volumetric flow rate} = 25 \text{ cm}^3/\text{min}$$

$$V = \text{Volume} = \frac{40\times10\times10}{1000} = 4 \text{ cm}^3$$

$$t_f = \frac{4}{25}\text{ min} = 0.16 \text{ min}$$

Q.4 A sand core having volume 2500 cm^3 is used in the casting of a cast iron machine part. The density of core sand and cast iron is 1500 kg/m^3 and 6000 kg/m^3, respectively. What is the net force acting on the core during pouring?(Take acceleration due to gravity, g = 10 m/s^2)

Solution:

$$\text{Buoyancy force} = V_{core}(\rho_m - \rho_c)g$$

$$= 2500 \times 10^{-6}(6000 - 1500) \times 10 = 112.5 \text{ N}$$

Q.5 The dimensions of a cylindrical top riser (h/d = 1), to feed steel casting 30 cm × 30 cm × 10 cm are to be determined. Casting is poured horizontally into the mould. Determine the dimension of the riser using modulus method.

Solution:

Using modulus method,

$$m_r = 1.2\, m_c$$

and for cylindrical top riser, $m_r = \dfrac{D}{5}$

$\therefore$ $D = 6\, M_c$

$$= 6\left(\frac{V}{SA}\right)_C = 6\times\left(\frac{30\times30\times10}{2(30\times30+30\times10+10\times30)}\right) = 18 \text{ cm}$$

Q.6 The dimensions of a steel slab casting is 25 cm × 25 cm × 5 cm. What is the shape factor of the slab according to the Naval Research Laboratory method?

Solution:

According to Naval Research Laboratory method,

$$\text{Shape factor of casting} = \frac{L+W}{t}$$

Where,

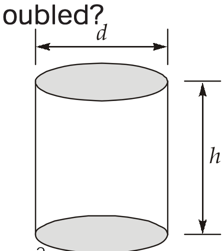
$$L = \text{Length of casting} = 25 \text{ cm}$$

$$W = \text{Width of casting} = 25 \text{ cm}$$

$$t = \text{Thickness of casting} = 5 \text{ cm}$$

$$\text{Shape factor} = \frac{25+25}{5} = \frac{50}{5} = 10$$

Q.7 In a sand casting operation, a solid cylinder having a diameter of 10 cm and a height of 5 cm takes four minutes to solidify. What will be the solidification time, if the cylinder height is doubled?



Solution:

$$t_s = k\left(\frac{V}{SA}\right)^2 = k\left(\frac{\frac{\pi}{4}d^2h}{2\times\frac{\pi}{4}d^2+\pi dh}\right) = k\left(\frac{dh}{2d+4h}\right)^2$$

$$\frac{t_{s,2}}{t_{s,1}} = \left[\frac{d_2h_2}{2d_2+4h_2}\times\frac{2d_1+4h_1}{d_1h_1}\right]^2 = \left(\frac{10\times10}{2\times10+4\times10}\times\frac{2\times10+4\times5}{10\times5}\right)^2$$

$$t_{s,2} = \frac{16}{9}\times 4$$

$$t_{s,2} = 7.1 \text{ minutes}$$

Q.8 A casting process is performed to make 0.5 m long hollow cylindrical copper pipes having external diameter 0.3 m and wall thickness 20 mm. If the liquid metal shrinkage, solidification shrinkage and solid contraction in terms of volume for the copper are 0.5%, 5% and 8%, respectively. Determine the required amount of molten metal that must be poured into the mould.

Solution:

$$\text{Volume to be poured} = \frac{\text{Final volume}}{(1-0.005)(1-0.05)(1-0.08)}$$

$$= \frac{\frac{\pi}{4}\left(0.3^2-0.26\right)^2\times0.5}{(1-0.005)(1-0.05)(1-0.08)}\times10^6 \text{ cm}^3 = 10115.1 \text{ cm}^3$$

Q.9 Solidification time of a spherical casting is 15 seconds. Determine the solidification time of a cubical casting of same volume as the spherical casting and casted under identical conditions.

Solution:

$$\frac{4}{3}\pi r^3 = a^3$$

(where, r is the radius of sphere and a is the side of cube)

$$\therefore \quad a = \left(\frac{4}{3}\pi\right)^{1/3} r$$

$$\frac{(t_s)_{cube}}{(t_s)_{sphere}} = \frac{\left(\frac{V}{SA}\right)^2_{cube}}{\left(\frac{V}{SA}\right)^2_{sphere}} = \frac{(a/6)^2}{(r/3)^2} = \left(\frac{a}{2r}\right)^2 = \left(\frac{\left(\frac{4}{3}\pi\right)^{1/3}}{2}\right)^2 = 0.6496$$

$$(t_s)_{cube} = 0.6496 \times 15 = 9.74 \text{ seconds}$$

Practice Questions : Level-II

Q.10 What are different methods of casting inspection? Explain each method briefly.

Solution:

Non destructive inspection techniques are necessary for creating a confidence when using a cast product. Some techniques used for testing the various kinds of defects are listed below.

1. Visual inspection: Common defects such as rough surfaces (fused sand), obvious shifts, omission of cores, and surface cracks can be detected by a visual inspection of casting. Cracks may also be detected by hitting the casting with a mallet and listening to the quality of the tone.
2. Pressure test: The pressure test is conducted on a casting to be used as a pressure vessel. In this, first all the flanges and ports are blocked. Then, the casting is filled with water, oil or compressed air. Thereafter, the casting is submerged in a soap solution when any leak will be evident by the bubbles that come out.
3. Magnetic particle inspection: The magnetic particle test is conducted to check for very small voids and cracks at or just below the surface of a casting of a ferromagnetic material. The test involves inducing a magnetic field through the section under inspection. The powdered ferromagnetic material is spread out onto the surface. The presence of voids or cracks in the section results in a change in the permeability of the surface; this, in turn, cause a leakage in the magnetic field. The powdered particles offer a low resistance path to the leakage. Thus, the particles accumulate on the disrupted magnetic field, outlining the boundary of discontinuity.
4. Dye penetrant inspection: The dye-penetrant method is used to detect invisible surface defects in a nonmagnetic casting. The casting is brushed with, sprayed with, or dipped into a dye containing a fluorescent material. The surface to be inspected is then wiped, dried and viewed in darkness. The discontinuities in the surface will then be readily visible.
5. Radiographic examination: The radiographic method is expensive and is used only for subsurface exploration. In this, both *X*- and γ-ray are used. With γ-rays, more than one film can be exposed simultaneously; however, *X*-ray pictures are more distinct. Various defects, e.g., voids, nonmetallic inclusions, porosity, cracks and tears can be detected by this method. On the exposed film, the defects, being less dense, appear darker in contrast to the surrounding.
6. Ultrasonic inspection: In the ultrasonic method, an oscillator is used to send an ultrasonic signal through the casting. Such a signal is readily transmitted through a homogeneous medium. However, on encountering a discontinuity, the signal is reflected back. This reflected signal is then detected by an ultrasonic detector. The time interval between sending the signal and receiving its reflection determines the location of the discontinuity. The method is not very suitable for a material with a high damping capacity (e.g., cast iron) because in such a case the signal gets considerably weakened over some distance.

Q.11 What is aspiration effect? Design a sprue for avoiding aspiration to deliver liquid iron at a rate of 20 kg/sec. Neglecting frictional and orifice effects. Take density of molten iron as 7800 kg/m^3. The height of pouring basin is 9 cm and height of sprue as 25 cm.

Solution:

Aspiration Effect: When molten metal passes through a passage in sand mould, the gases originated in the sand due to high temperature of metal may mix in metal and cause porous casting. This mixing of generated gases in mould with molten metal is called aspiration effect.

INDUSTRIAL ENGINEERING

CONVENTIONAL PRACTICE SETS

Page No. 146 - 256

1 CHAPTER Break Even Analysis

Practice Questions : Level-I

Q.1 A company manufactures pocket transistors. The details of its monthly expenditure are as follow:

Direct material - ₹10000

Direct labour - 200 hours at the rate of ₹5 per hour

125 hours at the rate of ₹4 per hour

Applied overheads (factory overheads) = 10% of prime cost

Other overheads = 10% of works cost

Profit = 20% of total cost

Number of units manufactured per month = 200

Estimate the selling price unit.

Solution:

Prime cost = Cost of direct material + Cost of direct labour + Direct expenses

$= 10000 + 200 \times 5 + 125 \times 4 = ₹11500$

$$\text{Factory overheads} = \frac{10}{100} \times 11500 = ₹1150$$

Works cost (Factory cost) = Prime cost + Factory overheads

$= 11500 + 1150 = ₹12650$

$$\text{Other overheads} = \frac{10}{100} \times 12650 = ₹1265$$

Total cost = ₹12650 + ₹1265 = ₹13915

$$\text{Profit} = \frac{20}{100} \times 13915 = ₹2783$$

Selling price for 200 units = 13915 + 2783 = ₹16698

$$\text{Selling price per unit} = \frac{16698}{200} = ₹83.49$$

Q.2 A standard machine tool and an automatic machine tool are being compared for the production of a component. Following data refers to the two machines.

	Standard Machine tool	Automatic Machine tool
Setup time	30 min.	2 hours
Machining time per piece	22 min.	5 min
Machine rate	Rs. 200 per hour	Rs. 800 per hours

What is the breakeven production batch size above which the automatic machine tool will be economical to use?

Solution:

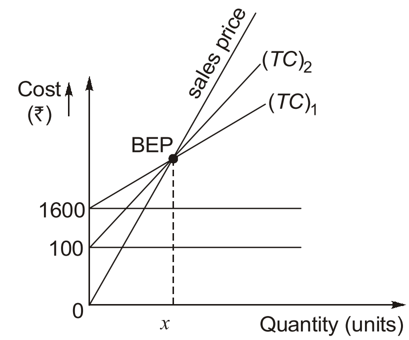
Total cost of x_1 component by using standard machine tool

$$(TC)_1 = \left(\frac{30}{60} + \frac{22x_1}{60}\right) \times 200 = 100 + \frac{2200}{30} x_1$$

Total cost x_2 component by using automatic machine tool.

$$(TC)_2 = \left(2 + \frac{5}{60} \times x_2\right) \times 800$$

$$= 1600 + \frac{2000}{30} x_2$$



Let break even quantity be x.

At break even point,

$$(TC)_1 = (TC)_2$$

$$\therefore \quad 100 + \frac{2200}{30} x = 1600 + \frac{2000}{30} x$$

or $$6.667x = 1500$$

$$\therefore \quad x = 225$$

Q.3 A factory producing only one item of selling price ₹ 13.5 per piece and has fixed cost equal to ₹ 80,000 and variable cost ₹ 8.5 per piece find:

(i) Break even-point

(ii) Number of pieces to be produced to earn the profit of ₹ 15,000.

(iii) The profit, if 30,000 pieces are produced and sold.

Solution:

Given data: Selling prices, S = ₹ 13.5 per unit fixed cost, FC = ₹ 80000; Variable cost, V = ₹ 8.5 per unit

Let the quantity produced is Q

$$\therefore \quad \text{Total cost, } TC = FC + VC$$

$$= 80{,}000 + 8.5\,Q$$

$$\text{Sales, } S = Q \times 13.5 = 13.5\,Q$$

(i) At Break even point

$$\text{Sales} = \text{Total cost}$$

$$13.5\,Q = 80{,}000 + 8.5\,Q$$

$$5\,Q = 80{,}000$$

$$Q_{BE} = 16{,}000 \text{ Units}$$

(ii) No. of units for ₹ 15,000 profit

$$\text{Profit} = \text{Sales} - \text{Total cost}$$

$$15000 = 13.5\,Q - 80{,}000 - 8.5\,Q$$

$$5\,Q = 15{,}000 + 80{,}000$$

$$Q = 19{,}000 \text{ units}$$

(iii) Profit when 30000 units produced

$$\text{Profit} = \text{Sales} - \text{Total cost}$$

$$= 13.5 \times 30{,}000 - 80{,}000 - 8.5 \times 30{,}000$$

$$= 150{,}000 - 80{,}000 = ₹\ 70{,}000$$

Q.4 The fixed cost of ₹24000 and a break-even-quantity of 34000 unit are estimated for a productions. Draw profit graph and calculate profit at a sales volume of 50000 units.

Solution:

As we know, $S = F + V + P$

At BEP, $P = 0$

$$x_{BEP} = 34000 \text{ unit}$$

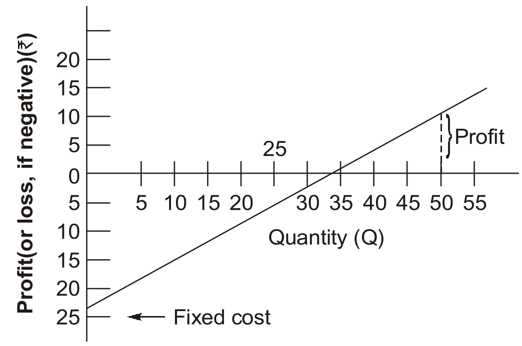
$$Sx_{BEP} - Vx_{BEP} = F$$

$$s - v = \frac{F}{x_{BEP}} = \frac{24000}{34000} = 0.706$$

Profit, when $x = 50000$, $P = (s - v)x - F$

$$= 0.706 \times 50000 - 24000$$

$$= ₹11300$$



Q.5 Following is information regarding a manufacturing enterprises:

Total fixed cost = ₹ 4,500

Total variable cost = ₹ 7,500

Total sales = ₹ 15,000

Units Sold = 5000

Find out :

(i) Break even point in units

(ii) Margin of safety

(iii) Profit

(iv) Volume of sales to earn a profit of ₹ 6000.

Solution:

(i) Break even points in units

$$\text{Sale price, } S = \frac{15000}{5000} = ₹\ 3 \text{ per unit}$$

$$\text{Variable price, } V = \frac{7500}{5000} = ₹\ 1.5 \text{ per unit}$$

Let Q is units of break even point

$$S.Q. = F.C. + V.Q. \text{ at BEP}$$

$$3\,Q = 4500 + 1.5\,Q$$

$$1.5\,Q = 4500$$

$$Q = 3000 \text{ units}$$

(ii) Margin of safety

(a) In terms of unit produced = 5000 – 3000 = 2000 units

(b) In terms of money = 15000 – 3000 × 3 = ₹ 6000

(iii) Profit = Total Sales– Total cost

$$= 15000 - (4500 + 1.5 \times 5000)$$

$$= 15000 - 12000 = ₹\ 3{,}000$$

(iv) Volume of sales to earn profit of ₹ 6000

$$\therefore \quad 6000 = Q \times 3 - (4500 + 1.5\,Q)$$

$$10500 = 1.5\,Q$$

$$Q = 7000 \text{ Units}$$