

Revision

Question 1

- Young's modulus of steel = $2.1 \times 10^{11} \text{Nm}^{-2}$
- Two steel cables of length 40m cross sectional area $5.2 \times 10^{-3} \text{m}^2$ and mass 5.7kg/m hang from a crane jib
- A)How much does one cable weigh?
- B)If the cables break when lifting a load of $1.0 \times 10^6 \text{N}$, calculate the breaking stress of one cable
- C)When the crane supports a load on both cables, each cable experiences a stress of 400MNm^{-2}
- Assuming the cables obey Hooke's law and ignoring the weight of the cables:
- i) Calculate the weight of the load
- ii) Calculate the extension of each cable when supporting the load
- iii) Calculate the combined stiffness constant k for the two cables
- iv) Calculate the total energy stored in both stretched cables

Answers

$$\text{length} = 40\text{m}$$

$$\Delta s/\Delta = 5.2 \text{ kg/m}$$

$$40 \times 5.2 = 208$$

A) Weight of cable = 208kg

B) $F = ma = 208 \times 9.81 = 2036.68\text{N}$
 2 cables so half force $1 \times 10^6 / 2 = 0.5 \times 10^6$
 Breaking Stress = $\frac{F}{A}$
 $= \frac{0.5 \times 10^6 + (208 \times 9.81)}{5.2 \times 10^{-3}} = 9.645 \times 10^7 \text{ N/m}^2$

C) i) stress = $\frac{F}{A}$ so $F = \text{stress} \times A$
 $= 400 \times 10^6 \times 5.2 \times 10^{-3}$
 $= 2080000$
 2 cables = $2 \times 2080000 = 4160000 \text{ N}$
 $F = ma$ so $m = \frac{F}{a} = \frac{4160000}{9.81} = 4.24 \times 10^5$

ii) $\Delta L = \frac{1}{Y} \frac{F}{A} L_0 = \frac{1}{Y} \times \frac{2080000}{5.2 \times 10^{-3}} \times 40$
 $Y = 2.1 \times 10^{11}$
 $= \frac{1}{2.1 \times 10^{11}} \times 16 \times 10^9$

$\Delta L = 0.0762\text{m}$

iii) $F = kx$ so $k = \frac{F}{x}$ $k = \frac{2080000}{0.0762}$
 $= 27296587.93$
 $= 27.3 \text{ MN}$

iv) $W = \frac{1}{2} kx^2$
 $= \frac{1}{2} \times 27.3 \times 10^6 \times 0.0762^2 = 79.3 \text{ kJ}$
 $79.3 \text{ kJ} \times 2 = 1.58 \times 10^5 = 0.158 \text{ MJ}$

Question 2

- an 65kg climber hangs from a nylon rope and stretches it by 20cm. If the rope was originally 30m long and its diameter was 12mm. (*take $g = 9.81ms^{-2}$*)
- Calculate;
- (i) the tensile strain
- (ii) the tensile stress
- (iii) the Young's Modulus.

Answers

$$\text{i) Tensile strain} = \frac{x}{L} = \frac{0.2}{30} = \underline{\underline{0.0067}}$$

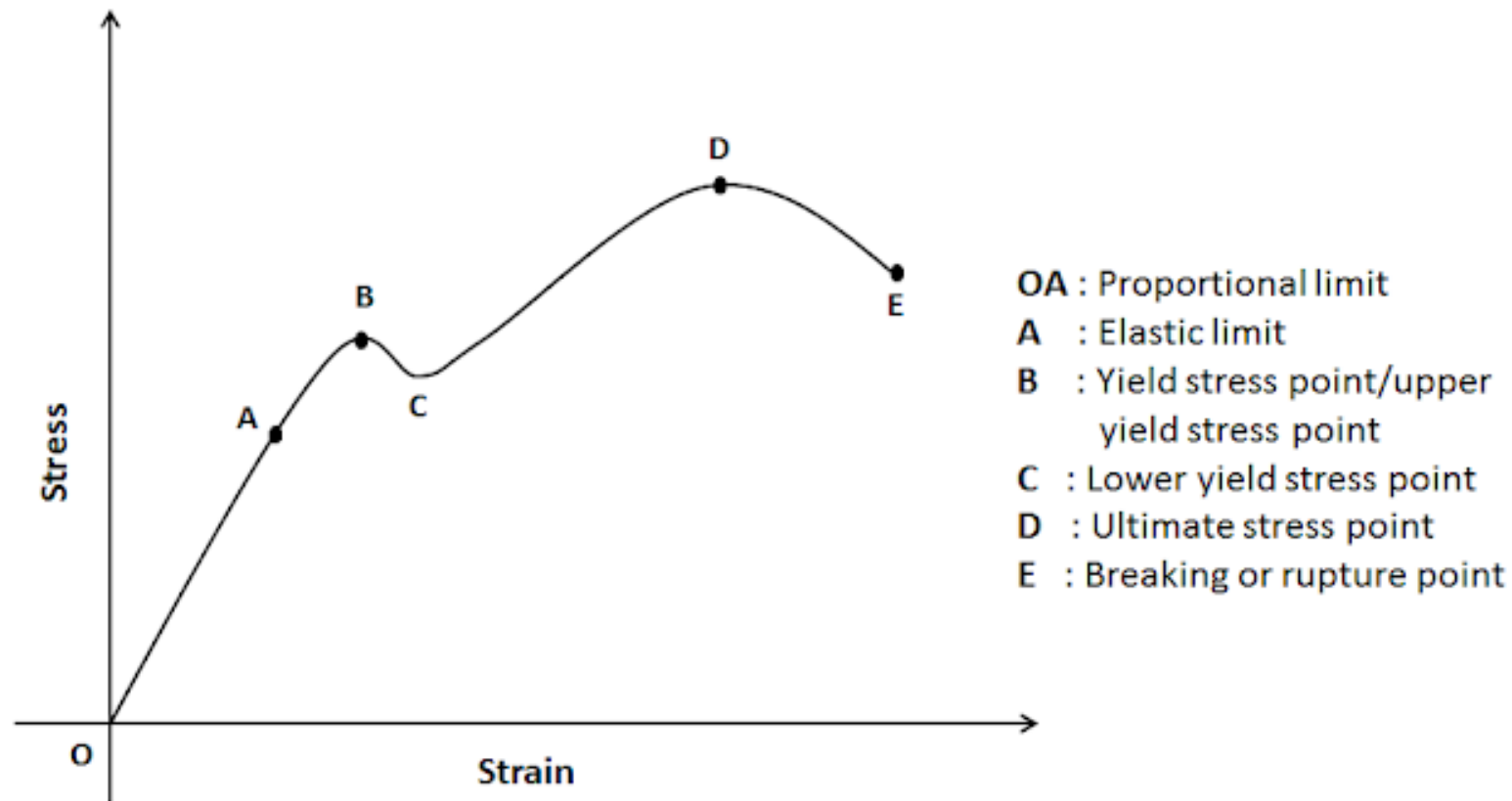
$$\text{ii) Tensile stress} = \frac{F}{A} = \frac{65 \times 9.81}{\pi \left(\frac{12 \times 10^{-3}}{2} \right)^2} \times$$
$$= \underline{\underline{5.64 \times 10^6 \text{ N/m}^2}}$$

$$\text{iii) } E = \frac{\sigma}{\epsilon} = \frac{5.64 \times 10^6}{0.0067}$$
$$= \underline{\underline{842 \text{ MN/m}^2}}$$

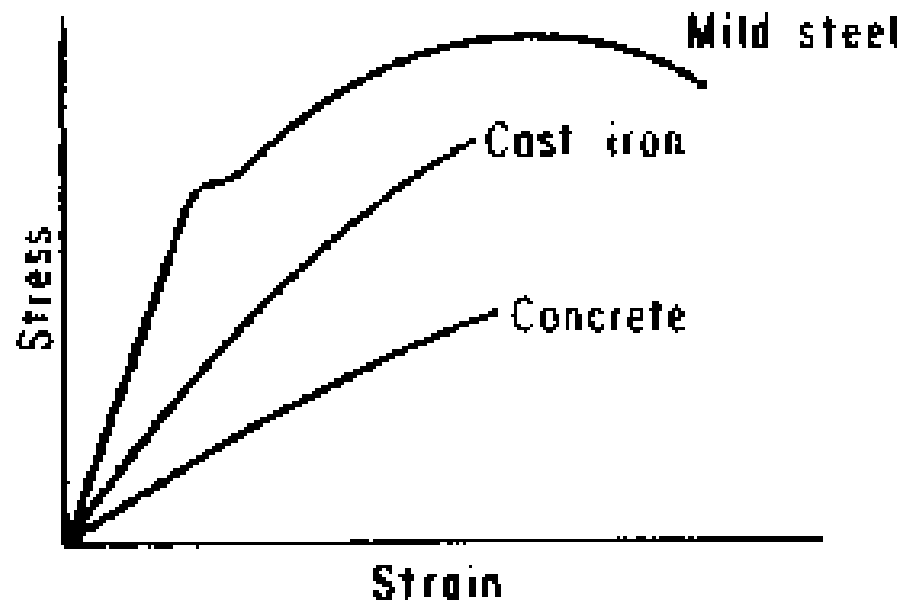
Question 3

- Sketch a stress strain graph for a ductile material and a brittle material
- Label graphs with upper and lower yield points, breaking point, UTS, Elastic limit, limit of proportionality

Typical stress strain trace for mild steel, a ductile material



Cast iron and concrete are brittle materials



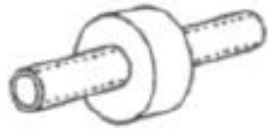
Question 4

- Draw and label a diagram showing how solidification takes place in sand casting
- What are the important quality factors in casting
- Using the diagrams explain the process

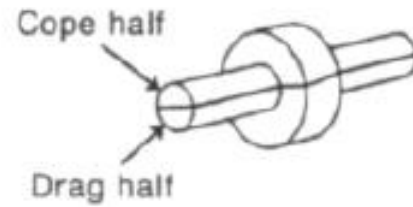
Rules for castings

1. Start with a good quality melt
2. Don't make the meniscus go too fast – max 0.5m/s for most metals
3. Don't stop the meniscus.
4. Avoid bubbles
5. Avoid core blows
6. Avoid shrinkage
7. Avoid convection
8. Reduce segregation
9. Reduce residual stress
10. Provide location points

Solidification and casting processes



Desired shape of finished casting

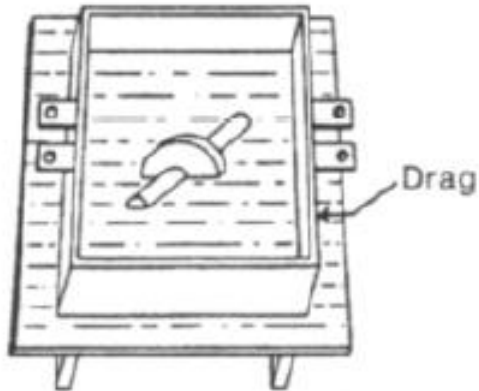


Wooden pattern



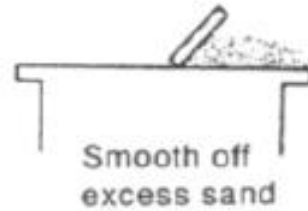
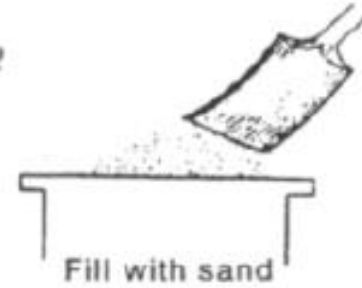
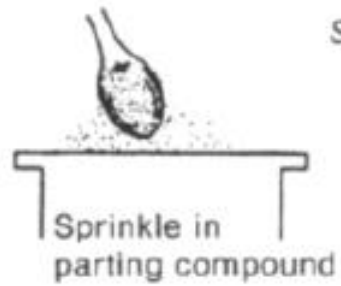
Sand core

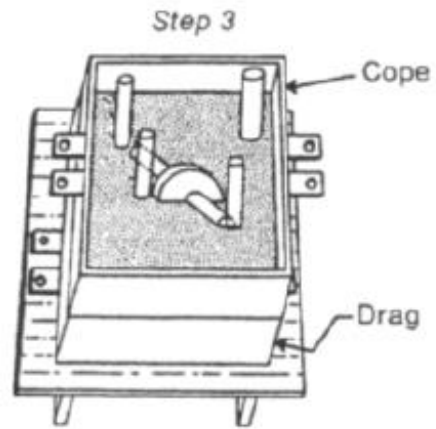
Step 1



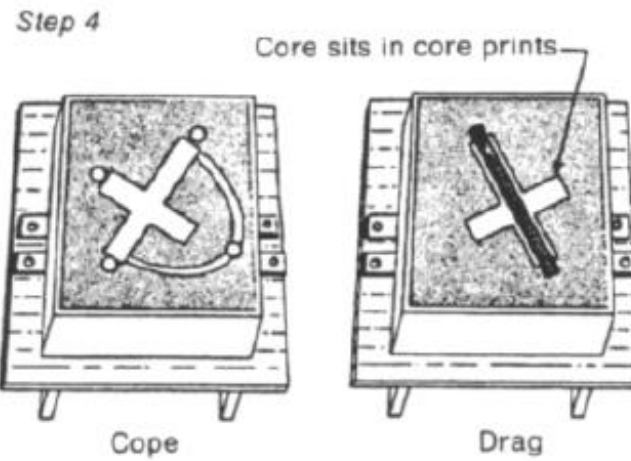
Drag half of pattern is placed in drag half of flask

Step 2

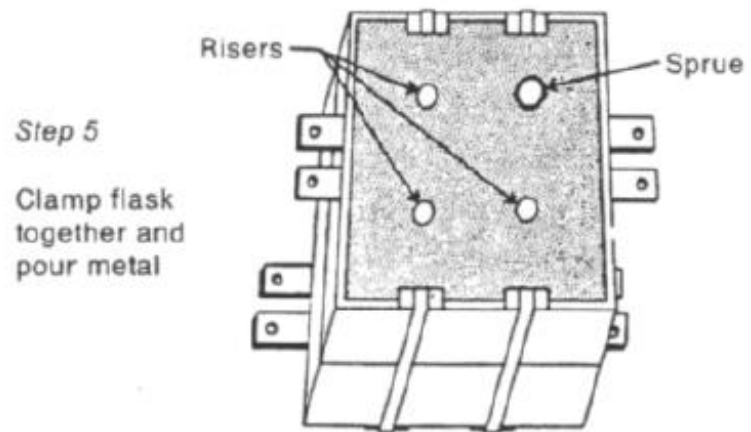




Invert drag and place cope half of pattern; position sprue and riser sticks



Separate the cope and drag; remove pattern, riser sticks and sprue plug; make gating system



Clamp flask together and pour metal



Solidification and casting processes

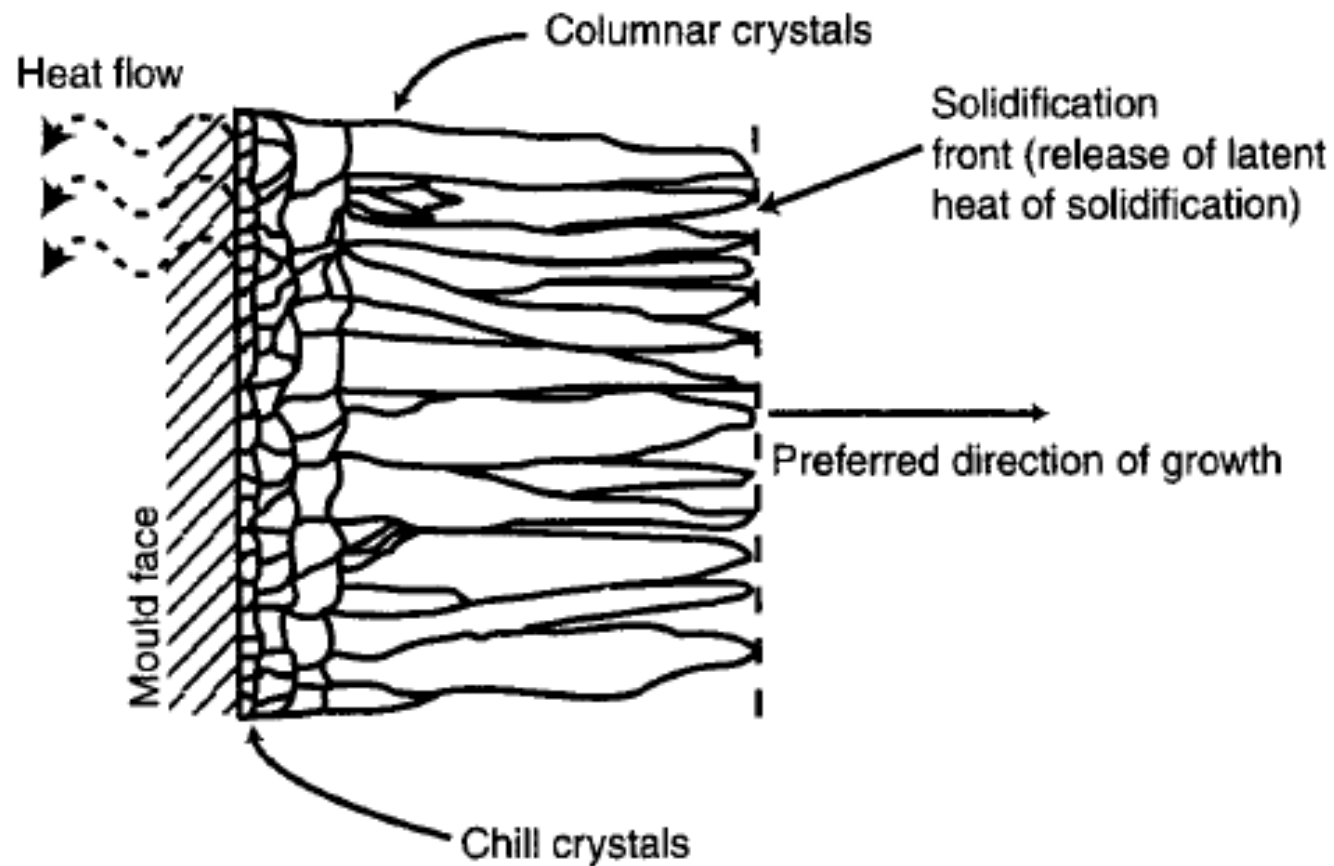


Fig. 2.12 Initial solidification of chill crystals and columnar crystals in a casting.

Question 5

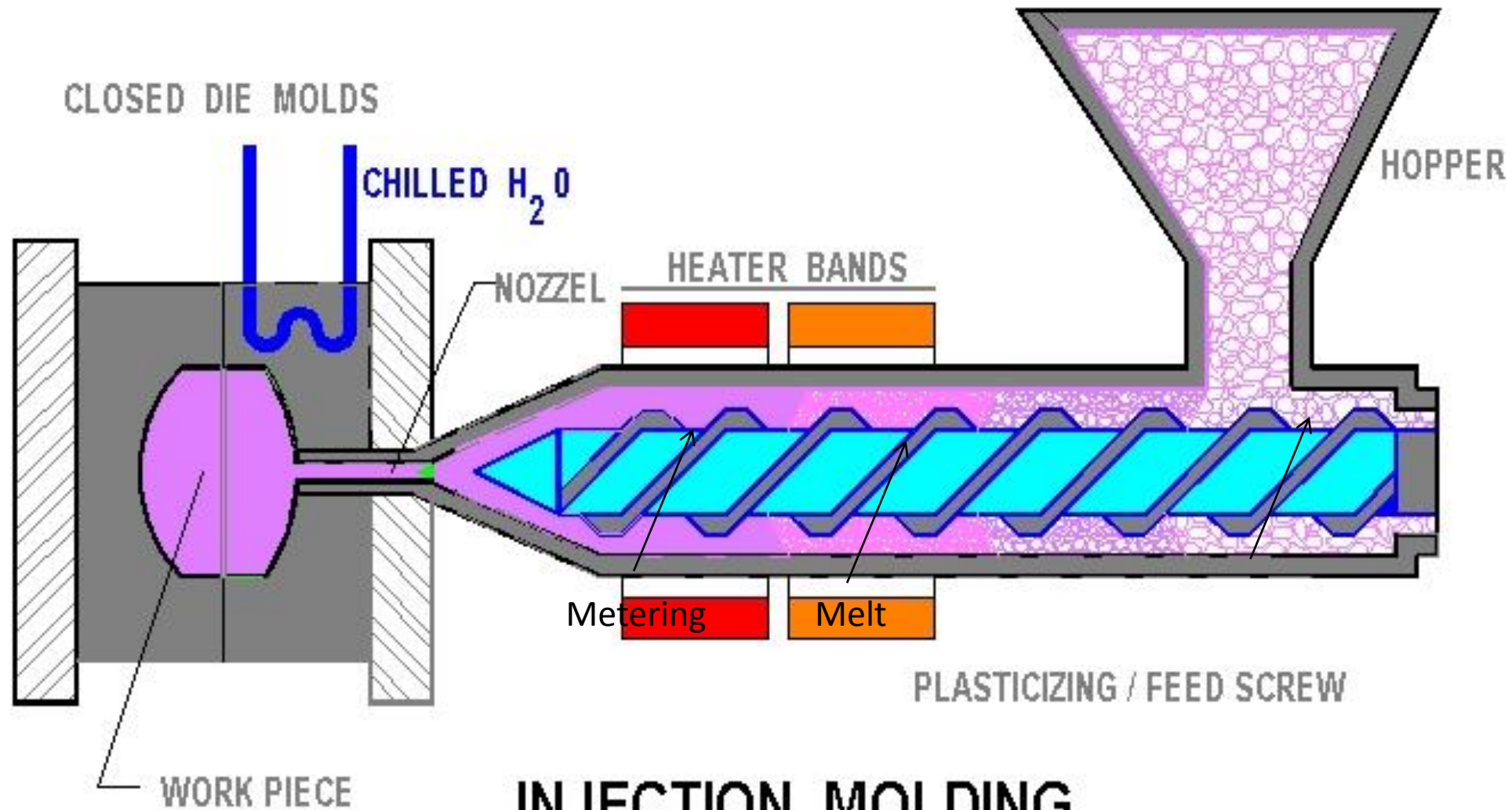
- What is a ceramic?
- Quartz and glass are both silica, what is the difference in their structure?
- What sort of bonds does graphite have?
- Give the properties that make it useful for use in batteries
- What are Frenkel and Schottky defects?

Answer 5

- **What is a ceramic?** Ceramics are inorganic and non-metallic materials that are commonly electrical and thermal insulators, brittle and composed of more than one element (e.g., two in Al_2O_3)
- **Quartz and glass are both silica, what is the difference in their structure?** Silica can be crystalline (e.g., quartz) or amorphous, as in glass.
- **What sort of bonds does graphite have?** Graphite has a layered structure with very strong hexagonal bonding within the planar layers (using 3 of the 3 bonding electrons) and weak, van der Waals bonding between layers using the fourth electron
- **Give the properties that make it useful for use in batteries** Graphite is a good electrical conductor and chemically stable even at high temperatures. Applications include furnaces, rocket nozzles, electrodes in batteries
- **What are Frenkel and Schottky defects?** Charge neutral defects include the Frenkel and Schottky defects. A Frenkel-defect is a vacancy- interstitial pair of cations (placing large anions in an interstitial position requires a lot of energy in lattice distortion). A Schottky-defect is the a pair of nearby cation and anion vacancies.

Question 6

- Draw and label a polymer injection mould
- Describe the process

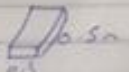


INJECTION MOLDING

Question 7 : Chvorinov's rule

- $T_s = C \frac{(V)^2}{(A)^2}$
- $(A)^2$
- T_s = solidification time, V = volume of casting, A = surface area of casting and C is the mould constant
- Using Chvorinov's rule where the constant is 5min/cm²
- How long would a flat plate of 0.5m x 0.3m x 30mm take to solidify?
- How long would a cylinder of length 25mm and diameter 4mm take?

$$T_s = C \left(\frac{V}{A} \right)^2$$

flat plate 

$$\begin{aligned} \text{Vol} &= l \times w \times d \\ &= 0.03 \times 0.3 \times 0.5 \\ &= 4.5 \times 10^{-3} \text{ m}^3 \end{aligned}$$

$$\text{Surface Area} = 2 \times \begin{array}{|c|} \hline 0.5 \\ \hline 0.3 \\ \hline \end{array} + 2 \times \begin{array}{|c|} \hline 0.03 \\ \hline 0.3 \\ \hline \end{array} + 2 \times \begin{array}{|c|} \hline 0.03 \\ \hline 0.5 \\ \hline \end{array}$$

$$\begin{aligned} &2((0.5 \times 0.3) + (0.3 \times 0.03) + (0.5 \times 0.03)) \\ &= 2 \times (0.15 + 0.009 + 0.015) \\ &= 0.348 \text{ m}^2 \end{aligned}$$

$$T_s = C \left(\frac{4.5 \times 10^{-3}}{0.348} \right)^2 = C(1.67 \times 10^{-4})$$

$$C = 5 \text{ min/cm}^2 = 3 \times 10^6 \text{ seconds/m}^2$$

conversion

$$1 \text{ cm}^2 = 0.0001 \text{ m}^2$$

$$100 \text{ cm} = 1 \text{ m}$$

$$1 \text{ m}^2 = 1 \text{ m} \times 1 \text{ m}$$

$$1 \text{ m}^2 = 100 \text{ cm} \times 100 \text{ cm}$$

$$1 \text{ m}^2 = 10,000 \text{ cm}^2 = 10^4 \text{ cm}^2$$

$$5 \text{ mins} = 5 \times 60 \text{ seconds}$$

$$= 300 \text{ seconds}$$

$$5 \text{ min/cm}^2 = 300 \times 10^4 \text{ secs/m}^2$$

$$= 3 \times 10^6 \text{ s/m}^2$$

$$T_s = 3 \times 10^6 (1.67 \times 10^{-4}) \text{ secs}$$

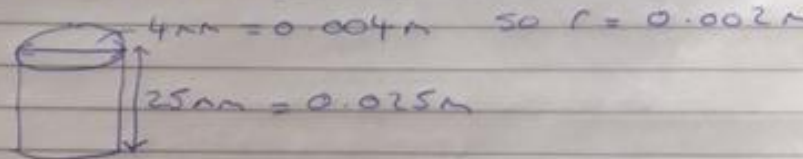
$$= 501 \text{ seconds}$$

$$= 8.35 \text{ minutes}$$

Volume of a cylinder = $\pi r^2 h$ 

Surface Area of a cylinder = $2\pi rh + 2\pi r^2$

$\bigcirc + \bigcirc + \text{rectangle}$



Volume = $\pi (0.002)^2 \times 0.025 \text{ m}^3$
 $= 3.142 \times 10^{-7} \text{ m}^3$

Surface Area = $2\pi r (h + r)$
 $= 2\pi (0.002) (0.025 + 0.002)$
 $= 3.393 \times 10^{-4}$

$T_s = C \left(\frac{V}{A} \right)^2 = 3 \times 10^6 \times \left(\frac{3.142 \times 10^{-7}}{3.393 \times 10^{-4}} \right)^2$

$= 2.572 \text{ seconds}$
 $= \underline{\underline{0.04288 \text{ minutes}}}$