# Materials Questions – OCR A Level Physics

Praneel Physics

**1.** Define stress and give its SI unit. **(P)**

*Working and Answer:*

Stress is force per unit area.

$$\sigma = \frac{F}{A}$$

SI unit: pascal (Pa), where 1 Pa = 1 N/m$^2$. *Answer:* Stress = force/area, unit Pascal (Pa).

**2.** Calculate the stress on a wire with cross-sectional area 2 $\text{mm}^2$ when a force of 10 N is applied. **(P)**

*Working and Answer:*

Convert area to $\text{m}^2$: $2 \times 10^{-6}$ $\text{m}^2$.

$$\sigma = \frac{F}{A} = \frac{10}{2 \times 10^{-6}} = 5 \times 10^6 \text{ Pa}$$

*Answer:* 5 MPa

**3.** Define strain. **(P)**

*Working and Answer:*

Strain is the fractional extension (change in length per original length).

$$\text{strain} = \frac{\Delta L}{L_0}$$

Strain is dimensionless. *Answer:* Strain = extension/original length (no units).

**4.** Calculate the strain of a wire stretched from 1.00 m to 1.01 m. **(P)**

*Working and Answer:*

$$\text{strain} = \frac{\Delta L}{L_0} = \frac{1.01 - 1.00}{1.00} = 0.01$$

*Answer:* 0.01 (dimensionless)

**5.** What is Young's modulus? **(P)**

*Working and Answer:*

Young's modulus $E$ is the ratio of stress to strain in the elastic region:

$$E = \frac{\text{stress}}{\text{strain}} = \frac{\sigma}{\epsilon}$$

It is a measure of stiffness. *Answer:* Ratio of stress to strain, unit Pascal (Pa).

**6.** Calculate the Young's modulus of a wire with length 2 m, diameter 0.5 mm, stretched by 1 mm under a 50 N load. **(PP)**

*Working and Answer:*

Diameter $d = 0.5$ mm $= 5 \times 10^{-4}$ m.
Cross-sectional area $A = \pi r^2 = \pi \times (2.5 \times 10^{-4})^2 = 1.96 \times 10^{-7}$ m$^2$.
Strain $= \frac{\frac{1 \times 10^{-3}}{2}}{50} = 5 \times 10^{-4}$.
Stress $= \frac{50}{1.96 \times 10^{-7}} = 2.55 \times 10^{8}$ Pa.

$$E = \frac{\text{stress}}{\text{strain}} = \frac{2.55 \times 10^{8}}{5 \times 10^{-4}} = 5.1 \times 10^{11} \text{ Pa}$$

*Answer:* $5.1 \times 10^{11}$ Pa

**7.** Explain the difference between elastic and plastic deformation. **(PP)**

*Working and Answer:*

Elastic deformation: material returns to original shape when force is removed.
Plastic deformation: permanent shape change after force is removed. *Answer:*
Elastic is reversible, plastic is permanent.

**8.** A wire obeys Hooke's Law up to 1.5 mm extension. Its original length is 1 m. Calculate the strain at the elastic limit. **(PP)**

*Working and Answer:*

$$\text{strain} = \frac{1.5 \times 10^{-3}}{1} = 1.5 \times 10^{-3}$$

*Answer:* $1.5 \times 10^{-3}$

**9.** Calculate the work done to stretch a spring from equilibrium by 4 cm if its force constant is 200 N/m. **(PP)**

*Working and Answer:*

$$E = \frac{1}{2}kx^2 = \frac{1}{2} \times 200 \times (0.04)^2 = 0.16 \text{ J}$$

*Answer:* 0.16 J

**10.** A wire of length 1 m and cross-sectional area 1 mm$^2$ is stretched by 1 mm under a force of 5 N. Calculate the Young's modulus. **(PP)**

*Working and Answer:*

Area $A = 1 \times 10^{-6}$ m$^2$.
Stress $= 5/1 \times 10^{-6} = 5 \times 10^6$ Pa.
Strain $= 1 \times 10^{-3}/1 = 10^{-3}$.

$$E = \frac{5 \times 10^6}{10^{-3}} = 5 \times 10^9 \text{ Pa}$$

*Answer:* $5 \times 10^9$ Pa

**11.** Describe the shape of a typical stress-strain graph for a metal wire and explain what happens at the elastic limit. **(PPP)**

*Working and Answer:*

Initially a straight line (Hooke's law), then yield point (plastic deformation starts), then strain hardening, necking, and fracture.
Elastic limit is the max stress for reversible deformation. *Answer:* Linear elastic region, elastic limit is max reversible stress.

**12.** Calculate the extension of a 2 m steel wire (Young's modulus $2.0 \times 10^{11}$ Pa, area $1.0 \times 10^{-6}$ m$^2$) when a 100 N force is applied. **(PPP)**

*Working and Answer:*

$$\text{Stress} = \frac{100}{1.0 \times 10^{-6}} = 1.0 \times 10^{8} \text{ Pa}$$

$$\text{Strain} = \frac{\text{stress}}{E} = \frac{1.0 \times 10^{8}}{2.0 \times 10^{11}} = 5.0 \times 10^{-4}$$

$$\Delta L = \text{strain} \times L_0 = 5.0 \times 10^{-4} \times 2 = 1.0 \times 10^{-3} \text{ m} = 1.0 \text{ mm}$$

*Answer:* 1 mm

**13.** Explain the difference between brittle and ductile materials with examples. **(PPP)**

*Working and Answer:*

Brittle materials fracture without significant plastic deformation (e.g., glass). Ductile materials deform plastically before breaking (e.g., copper). *Answer:* Brittle = break suddenly; ductile = deform first.

**14.** Calculate the energy stored in a wire stretched by 2 mm if the force applied is 20 N and the extension is within elastic limit. **(PPP)**

*Working and Answer:*

$$E = \frac{1}{2}Fx = \frac{1}{2} \times 20 \times 0.002 = 0.02 \text{ J}$$

*Answer:* 0.02 J

**15.** A wire with length 2 m and diameter 0.8 mm is stretched by 1 mm by a force of 30 N. Calculate the Young's modulus. **(PPPP)**

*Working and Answer:*

Radius $r = 0.4$ mm $= 4.0 \times 10^{-4}$ m.
Cross-sectional area $A = \pi r^2 = 3.14 \times (4.0 \times 10^{-4})^2 = 5.0 \times 10^{-7}$ m$^2$.
Stress $= \frac{30}{5.0 \times 10^{-7}} = 6.0 \times 10^7$ Pa.
Strain $= \frac{1 \times 10^{-3}}{2} = 5.0 \times 10^{-4}$.

$$E = \frac{6.0 \times 10^7}{5.0 \times 10^{-4}} = 1.2 \times 10^{11} \text{ Pa}$$

*Answer:* $1.2 \times 10^{11}$ Pa

**16.** Explain what is meant by the 'limit of proportionality' on a stress-strain graph. **(PPPP)**

*Working and Answer:*

The maximum stress at which stress is directly proportional to strain (Hooke's law). Beyond this point, the graph is no longer a straight line. *Answer:* End of linear region, Hooke's law stops.

**17.** Calculate the breaking stress of a wire that breaks under a force of 600 N with cross-sectional area $4 \times 10^{-7}$ m$^2$. **(PPPP)**

*Working and Answer:*

$$\text{Breaking stress} = \frac{F}{A} = \frac{600}{4 \times 10^{-7}} = 1.5 \times 10^9 \text{ Pa}$$

*Answer:* $1.5 \times 10^9$ Pa

**18.** A copper wire of length 1.5 m and diameter 0.7 mm carries a 50 N tensile force. Calculate the extension given Young's modulus for copper is $1.1 \times 10^{11}$ Pa. **(PPPP)**

*Working and Answer:*

Radius $r = 0.35$ mm $= 3.5 \times 10^{-4}$ m.
Area $A = \pi r^2 = 3.14 \times (3.5 \times 10^{-4})^2 = 3.85 \times 10^{-7}$ m$^2$.
Stress $= \frac{50}{3.85 \times 10^{-7}} = 1.3 \times 10^8$ Pa.
Strain $= \frac{\text{stress}}{E} = \frac{1.3 \times 10^8}{1.1 \times 10^{11}} = 1.18 \times 10^{-3}$.
Extension $=$ strain $\times L_0 = 1.18 \times 10^{-3} \times 1.5 = 1.77 \times 10^{-3}$ m $= 1.77$ mm.
*Answer:* 1.77 mm

**19.** A wire of length 2 m and diameter 0.6 mm is stretched by 1.5 mm by a force of 45 N. Calculate the energy stored in the wire. **(PPPPP)**

*Working and Answer:*

Radius $r = 0.3$ mm $= 3.0 \times 10^{-4}$ m.
Cross-sectional area $A = \pi r^2 = 3.14 \times (3.0 \times 10^{-4})^2 = 2.83 \times 10^{-7}$ m$^2$.
Stress $= \frac{45}{2.83 \times 10^{-7}} = 1.59 \times 10^8$ Pa.
Strain $= \frac{1.5 \times 10^{-3}}{2} = 7.5 \times 10^{-4}$.
Young's modulus:

$$E = \frac{\text{stress}}{\text{strain}} = \frac{1.59 \times 10^8}{7.5 \times 10^{-4}} = 2.12 \times 10^{11} \text{ Pa}$$

Energy stored:

$$E_{\text{stored}} = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{volume}$$

Volume $= A \times L = 2.83 \times 10^{-7} \times 2 = 5.66 \times 10^{-7}$ m$^3$.

$$E_{\text{stored}} = 0.5 \times 1.59 \times 10^8 \times 7.5 \times 10^{-4} \times 5.66 \times 10^{-7} = 0.034 \text{ J}$$

*Answer:* 0.034 J

**20.** Explain why the loading and unloading curves of a ductile material differ, and define hysteresis. **(PPPPP)**

*Working and Answer:*

On loading, the material stretches elastically and plastically. On unloading, only elastic recovery occurs. The curve shows hysteresis — the energy lost as heat.
*Answer:* Hysteresis is energy loss between loading/unloading; curves differ due to plastic deformation.

**21.** Calculate the extension of a steel wire of length 3 m and diameter 0.4 mm when subjected to a 120 N tensile force. Young's modulus for steel is $2.0 \times 10^{11}$ Pa. **(PPPPP)**

*Working and Answer:*

Radius $r = 0.2$ mm $= 2 \times 10^{-4}$ m.
Area $A = \pi r^2 = 3.14 \times (2 \times 10^{-4})^2 = 1.26 \times 10^{-7}$ m$^2$.
Stress $= \frac{120}{1.26 \times 10^{-7}} = 9.52 \times 10^8$ Pa.
Strain $= \frac{\text{stress}}{E} = \frac{9.52 \times 10^8}{2.0 \times 10^{11}} = 4.76 \times 10^{-3}$.
Extension $=$ strain $\times L_0 = 4.76 \times 10^{-3} \times 3 = 0.0143$ m $= 14.3$ mm. *Answer:* 14.3 mm

**22.** A copper wire is stretched elastically by a force of 60 N causing an extension of 0.002 m. The wire has diameter 0.5 mm and length 1.8 m. Calculate the energy stored in the wire. **(PPPPP)**

*Working and Answer:*

Radius $r = 0.25$ mm $= 2.5 \times 10^{-4}$ m.
Area $A = \pi r^2 = 3.14 \times (2.5 \times 10^{-4})^2 = 1.96 \times 10^{-7}$ m$^2$.
Volume $= A \times L = 1.96 \times 10^{-7} \times 1.8 = 3.53 \times 10^{-7}$ m$^3$.
Work done (energy stored)

$$E = \frac{1}{2}Fx = 0.5 \times 60 \times 0.002 = 0.06 \text{ J}$$

*Answer:* 0.06 J