inkPhysics

ANSWER BOOK

Density and Hooke's law

Materials · Year 12

AQA 3.4.2.1 · CIE 4.3.1, 6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.2.1, 6.2.2, 6.2.3, 6.2.4
OCR A 3.2.4(a), 3.4.1(a), 3.4.1(b), 3.4.1(c), 3.4.1(d)(i), 3.4.2(a), 3.4.2(b), 3.4.2(f)

18 questions · 57 marks

NAVY EDITION

SECTION A · Warm-up

A1 Density is mass per unit volume, $\rho = m/V$ (1). SI unit: kilogram per cubic metre, kg m^{-3} (1). [2]

A2 $\rho = m/V = 540/200 = 2.7$ g cm^{-3} (1)
$= 2700$ kg m^{-3} (1) [2]

A3 The extension of a spring is directly proportional to the force applied (1), up to the limit of proportionality: $F = k\Delta L$ (1). [2]

A4 The limit of proportionality is the point beyond which force is no longer proportional to extension, where the force–extension graph stops being straight (1). The elastic limit is the point beyond which the wire no longer returns to its original length when the force is removed (1). [2]

A5 The stored energy is the area under the force–extension graph, found by counting squares ($½F\Delta L$ only applies while the graph is straight) (1). [1]

SECTION B · Standard

B1 (a) $k = F/\Delta L = 2.0/0.040$ (1)
$k = 50$ N m^{-1} (1)
(b) $F = k\Delta L = 50 \times 0.060 = 3.0$ N (1) [3]

B2 7800 kg m^{-3} = 7.8 g cm^{-3} (1)
$m = \rho V = 7.8 \times 50$ (1)
$m = 390$ g $= 0.39$ kg (1) [3]

B3 $E = ½k\Delta L^2 = ½ \times 200 \times 0.10^2$ (1)
$E = 1.0$ J (1)
Check: $F = k\Delta L = 20$ N (1)
$½F\Delta L = ½ \times 20 \times 0.10 = 1.0$ J (1) [4]

B4 $V = 62.5$ $cm^3 = 62.5 \times 10^{-6}$ m^3 (1)
$\rho = m/V = 0.50/(62.5 \times 10^{-6})$ (1)
$\rho = 8000$ kg m^{-3} (1) [3]

B5 Mass of copper $= 8900 \times 60 \times 10^{-6} = 0.534$ kg (1). Mass of zinc $= 7100 \times 40 \times 10^{-6}$ $= 0.284$ kg (1). Total mass 0.818 kg in a volume of 100×10^{-6} m^3 (1), so $\rho = 8180$ kg m^{-3} (1). [4]

B6 $V = 3.0^3 = 27\ cm^3$ (1). $\rho = 216/27 = 8.0\ g\ cm^{-3} = 8000\ kg\ m^{-3}$ (1). This matches steel (1). [3]

B7 Each square represents $0.5 \times 0.02 = 0.01$ J (1). Energy = $34 \times 0.01 = 0.34$ J (1). $\frac{1}{2}F\Delta L$ is the area of a triangle and only applies when the graph is a straight line through the origin; for a curved graph the area must be found directly (1). [3]

SECTION C · Stretch

C1 (a) Series: $1/k = 1/50 + 1/100$, so $k = 33.3\ N\ m^{-1}$ (1) [4]
Extension = $3.0/33.3 = 0.090$ m (1)
(b) Parallel: $k = 50 + 100 = 150\ N\ m^{-1}$ (1)
Extension = $3.0/150 = 0.020$ m (1)

C2 Stored energy = $\frac{1}{2}k\Delta L^2 = \frac{1}{2} \times 800 \times 0.050^2$ (1) [4]
= 1.0 J (1)
$\frac{1}{2}mv^2 = 1.0$, so $v = \sqrt{(2 \times 1.0/0.20)}$ (1)
$v = 3.16\ m\ s^{-1}$ (1)

C3 Beyond the limit of proportionality the extension is no longer proportional to the force (1), so the graph stops being a straight line and curves (1). Past the elastic limit the spring no longer returns to its original length when unloaded, which is plastic behaviour (1). [3]

C4 Convert to SI: $\Delta L = 0.030$ m, $m = 0.012$ kg (1). Stored energy = $\frac{1}{2}k\Delta L^2 = \frac{1}{2} \times 450 \times 0.030^2 = 0.20$ J (1). Equate to mgh: $0.20 = 0.012 \times 9.81 \times h$ (1), so $h = 1.7$ m (1). [4]

C5 $k = F/\Delta L = 6.6/0.240 = 27.5\ N\ m^{-1}$ (1). 5% of 25.0 is 1.25, so the claim allows 23.75 to 26.25 $N\ m^{-1}$ (1). 27.5 $N\ m^{-1}$ lies above the upper bound (1), so the spring is stiffer than advertised and does not meet the claim (1). [4]

C6 During loading the graph is a straight line through the origin, obeying Hooke's law, up to the limit of proportionality (1); beyond this the graph curves, and past the elastic limit the deformation becomes plastic (permanent) (1). On unloading, the graph is a straight line parallel to the original loading line (1), meeting the extension axis at a non-zero value, the permanent extension (1). The work done during loading exceeds the energy recovered during unloading, the difference being the area between the loading and unloading lines (1); this energy has gone into rearranging the internal structure of the metal and heating it, and is not recovered (1). [6]