Topic 2 Materials
2B Solid material properties

2B.1 Hooke's law

1 7.0 N m^{-1}

2 The line would be steeper.

3 Formula given in text is that $\Delta E_{el} = \frac{1}{2}F\Delta x$. Hooke's law has $\Delta F = k\Delta x$ so substituting expression for ΔF into first equation gives the formula $\Delta E_{el} = \frac{1}{2}k(\Delta x)^2$

4 (a) From the graph, each square represents 1.25×10^{-3} J. There are approximately 100 squares under the line, so accept estimates of around 0.125 J.

(b) Underneath unloading curve are about 80 squares, so accept estimates of approximately 0.10 J

(c) Students calculate the difference between (a) and (b): approx. 0.025 J

2B.2 Stress, strain and the Young modulus

1 0.072

2 7.81×10^7 Pa

3 5.09×10^9 Pa

4 (a) 3.50×10^5 Pa

(b) 3.50×10^{-5} m, assuming that the elephant's weight is split evenly over two leg bones that are still vertical cylinders

2B.3 Stress–strain graphs

1 Straight line starts to curve beyond stress of 400 MPa.

2 Any temperature variation that should alter the length of the test wire will also occur in the control wire. As the extension is measured relative to the control wire, such temperature extensions will not be measured.

2B Exam practice

1 D

2 C

3 B

4 D

5 C

6 (a) QWC (quality of written communication) – work must be clear and organised in a logical manner using technical wording where appropriate, and include some of the following points:

Apparatus

- arrangement which secures wire
- arrangement allowing force to be varied

What to measure

- force
- original length
- extension
- diameter

Measurement

- diameter with micrometer
- length with metre rule
- force by adding known weights or use of tensometer
- extension with rule or vernier scale

How to calculate

- substitution in $E = Fx / A\Delta x$ OR plot F v Δx graph OR plot stress−strain graph
- determination gradient of F v Δx graph and process correctly
  OR determine a gradient of stress−strain graph

(b) Any one from:

Eye protection / watch out for feet / foam on floor, etc.

(c) Any suitable precaution and explanation, such as:

Measure diameter in different places

Use a reference marker

Avoid parallax when measuring extension

Do not extend wire past limit of proportionality

7 (a) Straight line / constant gradient shown on graph

So extension or change in length proportional to force

Therefore k is constant

(b) $k = \frac{F}{\Delta x}$

$k = \frac{1.6\text{ N}}{(0.51\text{ m} - 0.41\text{ m})}$

$k = \frac{1.6\text{ N}}{0.1\text{ m}}$

$k = 16\text{ N m}^{-1}$

(c) (i) $F = k\Delta x$

$F = 16\text{ N m}^{-1} \times (0.41\text{ m} - 0.09\text{ m})$

$F = 5.1\text{ N}$

(ii) $E = ½F\Delta x$

$E = 0.5 \times 5.1\text{ N} \times (0.41 - 0.09\text{ m})$

$E = 0.82\text{ J}$

(d) QWC (quality of written communication) – spelling of technical terms must be correct and the answer must be organised in a logical sequence. Include at least three of the following points:

Change in length greater so the compression greater

More force

More elastic energy / more strain energy

Greater acceleration

Therefore more kinetic energy and greater speed

8

(a) Upthrust = (−)weight

Thrust = (−)viscous drag

(b) Calculate weight of water as $U = W$

m = density × volume

$m = 1030\text{ kg m}^{-3} \times 7100\text{ m}^3$

$m = 7.3 \times 10^6\text{ kg}$

$W = mg$

$W = 7.3 \times 10^6\text{ kg} \times 9.81\text{ N kg}^{-1}$

$W = 7.2 \times 10^7\text{ N}$

(c) (i) Decrease in length

(ii) Pump out water / replace water in tanks with air to decrease weight (accept mass) / to compensate for decreased upthrust / to make density the same as water

(iii) QWC (quality of written communication) – work must be clear and organised in a logical manner using technical wording where appropriate, and include two of the following points:

A much greater (compressive) strain will be produced

Compresses more easily

Producing a larger decrease in volume

Compressive strain may exceed yield point.

9 (a) $k = \frac{7.7\ \text{N}}{0.008\ \text{m}}$

$k = 960\ \text{N m}^{-1}$

(b) $F = 960\ \text{N m}^{-1} \times 0.047\ \text{m} = 45.1\ \text{N}$

$E_{el} = 0.5 \times 45.1\ \text{N} \times 0.047 = 1.06\ \text{J}$

(c) (i) $\frac{1}{2}mv^2 = 1.1.\ \text{J}$

$v = \sqrt{\frac{(2 \times 1.1\ \text{J})}{0.0094\ \text{kg}}} = 15.3\ \text{m s}^{-1}$

(ii) All elastic energy to kinetic energy / no friction between parts of device for swatting flies

(d) (i) $t = \frac{3.0\ \text{m}}{15.3\ \text{m s}^{-1}} = 0.196\ \text{s}$

$v = 9.81\ \text{m s}^{-2} \times 0.196\ \text{s} = 1.92\ \text{m s}^{-1}$

$v = \sqrt{((15.3\ \text{m s}^{-1})^2 + (1.92\ \text{m s}^{-1})^2)} = 15.4\ \text{m s}^{-1}$

Angle $= \tan^{-1} \frac{1.92\ \text{m s}^{-1}}{15.3\ \text{m s}^{-1}} = 7.15°$

(ii) Use of $s = \frac{1}{2} \times 9.81\ \text{m s}^{-2} \times (0.196\ \text{s})^2$

$s = 18.8\ \text{cm}$

(e) Any sensible suggestion:

e.g. Less air resistance

Less warning given to fly from pressure changes

Less mass so greater speed for same kinetic energy

Less mass so greater acceleration for same force