MARK SCHEME

PHYSICS

AS-Level

MATERIALS

TEST 2

Mark schemes

1 A

[1]

2 C

[1]

3

(a) Use of Young Modulus = $\frac{\text{tensile stress}}{\text{tensile strain}}$ ✓

The first mark is for calculating the tensile stress

1

To give tensile stress = $2 \times 10^{11} \times 3.0 \times 10^{-4} = 6.0 \times 10^{7}$ ✓

The second mark is substituting into the tensile force equation

1

Use of tensile stress = $\frac{\text{tensile force}}{\text{cross sectional area}}$

To give tensile force = $6.0 \times 10^{7} \times 7.5 \times 10^{-3} = 4.5 \times 10^{5}$ N ✓

The third mark is for the correct answer

1

(b) Use of strain = extension / original length

To give extension = $3.0 \times 10^{-4} \times 45 = 1.4 \times 10^{-2}$ m

(1.35×10^{-2}) ✓

The first mark is for calculating the extension

1

Use of energy stored = ½ F e

To give

Energy stored = ½ × $4.5 \times 10^{5} \times 1.4 \times 10^{-2}$

= 3.2×10^{3} J ✓

(3.04×10^{3})

The second mark is for the final answer

1

(c) Temperature change = pre-strain / pre-strain per K

$= 3.0 \times 10^{-4} / 2.5 \times 10^{-5} = 12$ K✓

The first mark is for the temperature change

1

Temperature = 8°C + 12 = 20 °C ✓

The second mark is for the final answer

1

(d) So that the rail is not always under stress✓

1

as the rail spends little time at the highest temperature✓

Or

To reduce the average stress the rail is under ✓

as zero stress will occur closer to average temperature / the rail will be under compressive / tensile stress at different times✓

1

[9]

4 (a) 6.5×10^{10} Pa ✓

1

(b) kg m^{-1} s^{-2} ✓

1

(c) Direction of movement of particles in transverse wave perpendicular to energy propagation direction✓

1

Parallel for longitudinal✓

1

(d) $\rho_1 c_1 = \rho_2 c_2$✓

$E = \rho c^2$ or $\rho c = \frac{E}{c}$ seen

1

$\left[\frac{E_1}{c_1} = \frac{E_2}{c_2}\right]$

1

(e) $[\frac{\rho_x}{\rho_y} = \frac{c_y}{c_x}$ and $c_x = 2c_y$]

0.5✓

1

(f) speed of the wave in seawater is less than speed of the wave in glass✓

1

argument to show that ${}_{water}n_{glass} < 1$ ✓ 1

so tir could be observed when wave moves from water to glass ✓ 1

[10]

5 A

[1]

6 C

[1]

7 (a) P at the end of linear section ✓ 1

(b) Measure original length and diameter ✓ 1

Determine gradient of linear section to obtain F / extension ✓ 1

$$E = \frac{F}{e} \times \frac{length}{\pi\left(\frac{d}{2}\right)^2}$$ ✓ 1

Alternative:
Convert to stress–strain graph and determine gradient.

(c) Line from A

Parallel to straight section of original

Ending at horizontal axis ✓ 1

(d) Plastic deformation has produced permanent extension / re-alignment of bonds in material hence intercept non-zero ✓ 1

Gradient is same because after extension identical forces between bonds ✓ 1

(e) 0.2% is a strain of 0.002

Stress = $2.0 \times 10^{11} \times 0.002$ = 1

4×10^{8} ✓

$Force\left(=\frac{\pi(6\times10^{-3})^2}{4}\times 4\times10^{8}\right)$ ✓ 1

= 11.3 kN ✓ 1

(f) Maximum force = 11300 N

Weight of mass = 600 x 9.81 = 5886 N ✓ 1

Accelerating force must be less than

11300 – 5886 = 5423 N ✓ 1

a (= F / m = 5423 / 600)

= 9.0 m s^{-2} ✓ 1

(g) To lift double the load at the same acceleration, would require double the force, ✓

The first mark is for discussing the effect on the force 1

To produce the same strain either use:

- double the diameter of wire – so the stress stays the same and therefore the strain is the same for the same wire, ✓ 1
- a wire with double the Young modulus – so that double the stress produces the same strain for the same diameter. ✓ 1

The other two are for discussing the two alternative methods of keeping the strain the same

[16]

8 (a) tensile stress is the force exerted per/over <u>cross sectional area</u> ✓

can use equation but must define terms 1

tensile strain is the extension per/over <u>original length</u> ✓

NOT compared to 1

(b) material is brittle ✓

2^{nd} mark dependent on first

1

shown on graph by little or no of plastic behaviour OR by linear behaviour/straight line to breaking stress ✓
OR
material has high Young modulus OR material is stiff ✓
shown on graph by large gradient/steep line (compared to other materials) ✓

1

(c) area = $\pi \times (1.5 \times 10^{-4})^2/4 = 1.77 \times 10^{-8}$ ✓

1

tensile force = 1.77×10^{-8} ✓

1

= 23 (N) ✓

1

if use diameter as radius −1

if use incorrect formula (d^2 $2\pi r$ etc. −2)

range 22.5 – 24

power of ten error −1

if calculated area incorrectly get following answers

diameter as radius = 92 (2 marks)

d^2 = 7.3 (1 mark)

$2\pi r$ = 610 000 (1 mark)

if use d for area then zero

(d) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist marking this question.**

Level 3
Correct materials selected for **each** application (B/C for lift and D for bungee). One reason for choices given for **each** application and explanation why at least one other material would be rejected for **each** application.

6

Correct materials selected for **each** application (B/C for lift and D for bungee). One reason for choices given for **each** application and explanation why at least one other material would be rejected for **one** application.

5

The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.

Level 2
Correct material selected for **one** application (B/C for lift and D for bungee). **One** reason for choice given for one application and explanation why at least one other material would be rejected for **one** application.
4

Correct material selected for **one** application (B/C for lift and D for bungee). **One** reason for choices given application.
OR
Correct materials selected for **each** application (B/C for lift and D for bungee). One reason for choices given for **each** application
3

The student presents relevant information and in a way which assists the communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.

Level 1
No correct material selected but at least **two** properties necessary for an application given.
2

No correct material selected but at least **one** property necessary for an application given.
1

The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.

Level 0
No correct material selected and no properties necessary for an application given
The student's presentation, spelling and grammar seriously obstruct understanding.
0

The following statements may be present for cable supporting a lift

material B/C is used for the lift because it has a high breaking stress and a high Young modulus

material A not chosen because lower breaking stress

material A not chosen because fails without warning

material C not chosen because has a lower breaking stress

material D not chosen as larger increase in strain for a given increase in stress

material D not chosen as low breaking stress.

material D a given stress produces a large strain meaning large extension

The following statements may be present for rope or cable used for bungee jump

material D chosen as due large strain for given stress
time taken to come to rest lengthens

material D is chosen because D can store a large amount of energy before failure

not A ,B or C because high Young Modulus so sudden stop resulting in large forces

not A as brittle and therefore limited strain and sudden failure

not C because requires a large strain before plastic behaviour

not C because if behaves plastically will not return to original length

[13]

9 (a) extension of wire Q = 2.7 (mm) ✓

ignore any precision given eg ± 0.1 mm

if > 2 sf condone if this rounds to 2.7

1

(b) mass = 5.8 (kg) ✓

allow ce for incorrect 0.1.1 (only look at 01.1 if answer here is incorrect)

allow ± 0.1 kg

1

(c) 0.51 (mm) ✓

ignore any precision given eg ± 0.005 mm

1

(d) method 1:

use of $E = \frac{\text{(tensile) stress}}{\text{(tensile) strain}}$ $_1$✓

for $_1$✓ expect to see some substitution of numerical data

cross – section area from $\frac{\pi \times d^2}{4}$ $_2$✓

correct use of diameter for $_2$✓; ignore power of ten error; expect CSA = 2.0(4) × 10^{-7}; allow ce from 01.3 (eg for d = 0.37 mm CSA = 1.0(8) × 10^{-7} m^2)

(tensile) stress = $\frac{mg}{\text{CSA}}$ $_3$✓

penalise use of g = 10 N kg^{-1}

(tensile) strain = $\frac{\Delta l}{l}$ $_4$✓

value of Δl must correspond to Figure 2 value of m; answers to 01.1 and 01.2 are acceptable

expect l = 1.82 m but condone 182 etc; accept mixed units for l and Δl

MAX 3

method 2:

evidence of $\frac{\Delta l}{\Delta m}$ from Figure 2 to calculate gradient $_1$✓

expect gradient between 0.45 to 0.48 mm kg^{-1}

$E = \frac{g \times \text{original lenght}}{\text{CSA} \times \text{gradient}}$ $_2$✓ $_3$✓

missing g loses $_3$✓

substitution of l = 1.82 m $_4$✓

condone 182 etc $_4$✓

cross-sectional area from $\frac{\pi \times d^2}{4}$ $_5$✓

correct use of diameter for $_2$✓; ignore power of ten error; expect CSA = 2.0(4) × 10^{-7}; allow ce from 01.3 (eg for d = 0.37 mm CSA = 1.0(8) × 10^{-7} m^2)

MAX 3

result in range 1.84 × 10^{11} to 1.91 × 10^{11} $_5$✓

condone 1.9 × 10^{11}

$_5$✓ mark requires correct working and no power of ten errors: allow ce for error(s) in 01.1, 01.2 and for false/incorrect CSA (eg for d = 0.37 mm allow result in range 3.49 × 10^{11} to 3.63 × 10^{11}, 3.5 × 10^{11} or 3.6 × 10^{11})

1

(e) (smaller diameter) produces larger extensions $_1$✓
reduces (percentage) uncertainty (in extension and in result for Young Modulus) $_2$✓

(smaller diameter) increases (percentage) uncertainty in diameter **or** cross sectional area is smaller **or** increases (percentage) uncertainty in cross sectional area $_3$✓
increases (percentage) uncertainty (in result for Young Modulus) $_4$✓

(smaller diameter) increases likelihood of wire reaching limit of proportionality or of wire snapping or reduces range of readings $_5$✓
increases (percentage) uncertainty (in result for Young Modulus) $_6$✓

outcome and correct consequence for 2 marks, ie $_1$✓ followed by $_2$✓, $_3$✓ followed by $_4$✓ etc

dna 'error' for 'uncertainty'

no mark for consequence if outcome not sensible, eg 'it gets longer and reduces uncertainty' earns no mark for 'diameter smaller so uncertainty greater' award $_1$✓ (need to see further mention of uncertainty to earn $_2$✓)

MAX 4

[11]

10 (a)

breaking stress	✓
stiffness constant, k	
tensile strain	
tensile stress	
Young modulus	✓

1

(b) (i) elastic limit ✓

only one attempt at the answer is allowed

1

(ii) ($E = 300 \times 10^6 / 4 \times 10^{-2} = 7.5 \times 10^9$)

7.5 (Pa) ✓ allow 7.4 to 7.6 (Pa)

$\times 10^9$ ✓

first mark is for most significant digits ignoring the power of 10. E.g. 7500 gains mark

2

(c) <u>straight line</u> beginning on existing line at a strain of 0.10 and hitting the strain axis at a lower non-zero value ✓

line that ends on the x -axis with strain between 0.045 and 0.055 ✓(only allow if first mark is given)

ie accuracy required ± one division

2

(d) 8.99×10^{-3} (m^3) ✓ condone 1 sig fig

allow 9.00×10^{-3}

1

(e) $0.9872 \times 8.99 \times 10^{-3}$ or = 8.8749×10^{-3} (m^3) ✓

allow CE from 4d

($m = \rho V$)= $2700 \times 8.8749 \times 10^{-3}$ = 24 (kg) ✓ (23.962 kg)

allow CE from first part, e.g. if 1.28% was used gives 0.311 kg

$V = 0.9872 \times (d)$

$m = 2.665 \times (d)$

1.28% of vol = 1.15×10^{-4} m^3

2

[9]

Examiner reports

8 Part (a) required students to state the meaning of tensile stress and tensile strain. Marks were frequently lost due to a lack of precision in technical language. For example it was common to see force per unit area rather than cross-sectional area and change in length per length rather than extension per original length. In (b) a significant proportion of students were able to select an appropriate property for material but only about half of those correctly identifying the property were then able to give a suitable explanation. The calculation in part (c) was well done with over half the students being awarded full marks. The main errors were an incorrect calculation of cross-sectional area due to using the diameter as a radius or a power of ten error when using GPa. Question 3.4 was a level of response marked question and some very impressive answers were seen. About 30% of students were placed in the top band. Some answers were spoilt when students did not give complete answers. This was because although they correctly identified the material for the applications they did not explain why other materials would be rejected. Generally students were more successful in the selection of material for the lift cable than they were for the rope for bungee jumping. This was in part due to them thinking that in order for a material to be elastic it had to obey Hooke’s law and thus have linear stress strain characteristics. This led them to think that material D was not behaving elastically and therefore should be rejected for both applications. Overall however, this question seemed to generate better answers than has been the case with extended prose questions in previous specifications.

9 This question was about the determination of the Young modulus of the metal of a wire, one of the six required AS practicals. It gave students the opportunity to demonstrate familiarity with a range of practical equipment and techniques.
The work seen suggested that the majority of students were familiar with the experiment and could process the raw data. Problems arose when students were asked to comment on the effect of changing the dimensions of the wire, for example.

(a) Vernier scales are a common feature of the equipment used to measure extension in a Young Modulus determination. Many students were unable to give the correct answer, however, with 2.8 mm a fairly common error.

(b) Students were allowed to carry an error forward from (a) and many students were able to read the scale correctly. Where the answer to (a) fell outside the graph some students attempted to extrapolate or carry out a $y = mx + c$ calculation; these students may have benefited from checking their answer to (a) first.

(c) Most students were able to correctly compensate for the zero error in the calliper reading, although adding it to obtain 0.37 mm was fairly common. Some students also attempted to use the 20.14 mm value seen at the top of figure 3.

(d) This calculation was reasonably well carried out with the majority of students getting at least 3 marks out of 4. Although students should be encouraged to use the gradient of figure 2 to help calculate a value of E, the use of individual points was acceptable on this occasion. It was common to see the values obtained in the previous three sections used to work out the cross sectional area, and then the strain and stress separately, before combining them to calculate E. The two common errors in this approach were the use of the diameter for the radius, and missing out "g" in the calculation of the force. Several students also made powers of ten errors in the cross-sectional area calculation, or mixed their units in the calculation of strain. This commonly led to the fourth mark being lost. Students should be encouraged to set out their answers logically so that it is easier to check for errors. Some students inevitably lost marks if they made an error attempting to perform the calculation in one go. Over reliance on the data sheet also led to problems with some students using $F = k\Delta l$, and using the Boltzmann constant for k.
Any errors from (a), (b) or (c) were carried forward so that no student was denied the opportunity to earn subsequent marks.

(e) When guiding students with their responses to questions such as this it is important to emphasise the need for clarity in expression, as examiners cannot credit ambiguous or vague answers. To gain credit, answers required an outcome (e.g. the extension increases) and consequence (the percentage uncertainty in E decreases). It was common for students to miss out the word 'percentage' but on this occasion this was not penalised. There were several different correct approaches but each was accompanied by its own common errors. For example, students who simply stated that the wire would get longer, rather than the extension would increase, failed to get the mark. Students who based an answer on the increased percentage uncertainty in the measurement of the diameter often failed to go on to state how this would affect the percentage uncertainty in the value of E. It was also relatively common to see incorrect physics, for example answers claiming that the value of E would be affected.

10 On the whole this question was a good discriminator. In (a) a high proportion of the students did not know which terms referred to the property of a material and hence be independent of the materials' shape. The straightforward question (b)(i) based on simple recall of the term ‘elastic limit’, was scored by less than half the students. ‘Limit of Proportionality’, was the most common wrong answer.

(b)(ii) gave a good spread of marks. Of those that missed one mark out of the two available half chose to calculate the Young modulus using a non-linear part of the graph and the other half made errors in the powers of 10 in the calculation. These students were confused or missed the unit MPa. A majority of students did not know what happens to a stress-strain graph during unloading as was evident from answers to (c). Most that had genuine attempts at the question thought the graph should eventually end up at the origin. The others either got the question correct or they drew very random lines which in many cases did not start from the existing graph or had a shape that had no association with the existing graph.

(d) was performed well and a majority of students had a good attempt at it. The weaker students sometimes found the mass of copper and presented this as an answer or they incorrectly found 1.28% of the mass of aluminium rather than calculate this percentage of its volume.