A-Level Physics

Bulk Properties of Solids

Mark Scheme

Time available: 84 minutes
Marks available: 60 marks

1.

(a) Centripetal force acts inwards / towards the centre of rotation ✓

Links reaction force to centripetal force ✓

2

(b) Equates forces AND states **either** centripetal force with correct symbols✓

$F = m_A r\omega^2$

$F = m_B (L - r)\omega^2$

In MP1 condone: equations containing v; use of ω_A and ω_B for the angular velocities.

cancelling ω✓

$m_A r\cancel{\omega^2} = m_B(L - r)\cancel{\omega^2}$

$r = \frac{m_B L}{m_A + m_B}$

E.g.

In MP2 it must be clear that the angular velocity and not the velocity.

2

(c) The angular speed is the same for A & B or

Rotational radius for B less than that for A ✓

Both of these points AND $v = r\omega$ so velocity of A is greater.✓

Alternative for MP2:

Both of points in MP1 AND

A travels greater distance in the same time.

2

(d) Use of safety factor e.g. maximum stress << 0.300 GPa ✓

$F = ma$ = 1.32 × 10^6 × 3.7✓ (= 4.9 × 10^6 N)

$A = \frac{F}{\sigma}$ valid substitution ✓

$\sqrt{\frac{4A}{\pi}}$ ✓ (expect > 0.144 m)

Valid justification for selection of maximum stress used e.g. using a stress that is from the linear / elastic section of the graph or reference to either safety factor or trying to limit weight of cable. ✓

Alternative for MP1: they can work through for a stress of 0.3 GPa and then increase the diameter, if justified as a safety factor. Do not allow use of stress ≈0.3 GPa for full marks.

Allow ecf for stress and force

5

[11]

2. (a) Substitution of data in $Y = \frac{FL}{A\varepsilon}$

3.1 × 10^{-3} (m) ✓

2 marks can be awarded if 4mm used to show T>500 N provided an explanation is provided, otherwise award zero.

2

(b) (500 = Tcos 65)

T = 1200 N ✓

1

(c) Wind produces a wave / disturbance that travels along the wire ✓

Wave is reflected at each end / waves travel in opposite directions✓

(Incident and reflected) waves interfere / superpose ✓

Only certain frequencies since fixed ends have to be nodes. ✓

4

(d) Mass per m of the wire = 0.14(2) kg ✓

1

(e) Use of $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}} (= 2.47)$ to find fundamental

$(\text{or } f = \frac{3}{2l}\sqrt{\frac{T}{\mu}})$

Third harmonic = 7.4 (Hz) ✓

The second mark is for multiplying the fundamental frequency by 3 – allow ecf

2

(f) Diagram showing three approximately equally spaced loops

Condone single line

1

(g) Copper may be stretched beyond elastic limit / may deform plastically ✓

Permenant deformation / Does not return to original length ✓

Allow 'will remain longer than original' or 'will be permenantly deformed'

2

[13]

3. (a) EITHER

calculate value for constant using two calculations ✓

calculate value for constant using three calculations and make a comment that they have same value ✓

need to see table to look for any working

OR

calculate ratio between masses and √T for one pair of values ✓

calculate ratio between masses and √T for two pairs of values and make comment about same value ✓

e.g. 0.5/0.8 = √110/√140

OR

work out constant and use to predict one other frequency or mass ✓

work out constant and use to predict two other frequencies or mass ✓

no comment needed with this alternative

2

(b) $\mu = \rho A = 1150 \times \pi(5.0 \times 10^{-4}/2)^2$

$\mu = 2.258 \times 10^{-4}$ (kg m^{-1}) ✓

use of consistent *m* and *f* Substituted in $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ including g but

condone powers of 10 error ✓

Award second mark if T and f substituted correctly (ignore μ)

0.67 m ✓

If used diameter for radius incorrectly then lose first mark but can get third mark (answer 0.335 m)

3

(c) appreciation of reducing diameter when string is stretched. ✓

lower mass per unit length so (constant of proportionality and hence) frequency is higher (than would be predicted) ✓

2

[7]

4. (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 x 10^{11} x 0.002 =

1

4 x 10^{8} ✓

$$Force \left(= \frac{\pi (6 \times 10^{-3})^2}{4} \times 4 \times 10^{8} \right) \checkmark$$

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]

5. (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 ✓

2nd mark dependent on first

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

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]