Mark schemes

1. (a) correctly deduces extension is 2.6 or 2.7 mm ✓

Should see $AC^2 = 1.50^2 + (6.34 \times 10^{-2})^2$;

(new) AC = 1.50134;

Extension of AC = (1.50134 − 1.50 =) 0.00134 m or 1.34 mm; and then doubles this

Final value must be to at least 2 sf

1

(b) evidence of correct working: ✓

$\sin\theta = \dfrac{6.34 \times 10^{-2}}{\text{their new AC}}$ or $\theta = 2.42°$ seen

OR

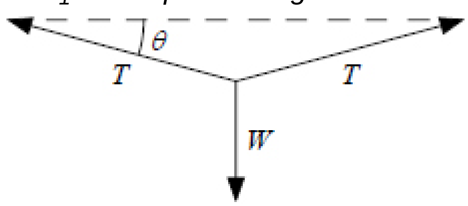
$W = 2T\sin\theta$ seen

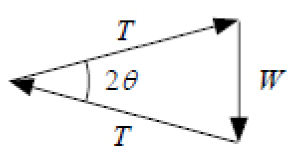
OR

suitable vector diagram with θ labelled

tension correctly calculated from $\dfrac{1.0}{2 \times \text{their } \sin\theta}$ ✓

For $_1$✓ acceptable diagrams are shown below





Correct final answer of 11.8 N or 12 N earns both marks

2

(c) <u>ruled</u> best-fit line between first and sixth points;

line must pass above 2nd point

and

must pass below 4th point $_1$✓

for $_1$✓ withhold mark if line is thick, faint or discontinuous

gradient calculated from $\frac{\Delta(W/y)}{\Delta y^2}$ with $\Delta y^2 \geq 0.004$ $_2$✓

(gradient ~ 3850)

for $_2$✓ condone read off errors of ± 1 division

for $_3$✓ note that $1.50^3 = 3.375$ so allow sub of 3.38

for $_4$✓ reject 2 sf 1.2×10^{11}

evidence of using E = $\frac{\text{their gradient} \times 1.50^3}{1.11 \times 10^{-7}}$ $_3$✓

for $_3$✓ note that $1.50^3 = 3.375$ so allow sub of 3.38

E in range 1.10×10^{11} to 1.24×10^{11} (Pa) $_4$✓

for $_4$✓ reject 2 sf 1.2×10^{11}

4

(d) kg s^{-2} ✓

no credit for N m^{-1}

correct answer only

1

[8]

2. A

$$\frac{mg\Delta L}{2}$$

[1]

3. A

$$\frac{F\rho L^2}{m\Delta L}$$

[1]

4. (a) 37.8 ✓

CAO

1

(b) <u>random</u> (error)

condone 'statistical' ✓

the following are neutral:

'parallax' / 'human (error)' / '(some) results are anomalous'

(c) advantage (of using thinner beam):

(same load produces) larger (values of) s or wtte 1✓

so

the <u>percentage</u> uncertainty / error (in s) is reduced 2✓

for 1✓ accept 'beam bends / deflects more'

'beam extends more' / 'easier to bend' are neutral

for 2✓ the following are neutral:

'easier to make readings' / 'values (of s) are more accurate' / 'more precise' / 'less mass needed' / 'wider range of readings'

disadvantage (of beam bending more):

idea that beam may undergo plastic deformation 3✓

so

the graph will be non-linear / curve or wtte 4✓

or

beam 'may break' / 'slip off knife edges' **and** relevant comment about safety / health / hazard / 'cannot get unload data'

or

reduces range of m or wtte **and** relevant comment about the effect on the graph, eg increase scatter 34✓ = 1 MAX

for 3✓ accept / 'beam may become permanently deformed' or wtte / 'necking may occur' / 'hysteresis may occur' / 'beam can reach (go past) elastic limit'

the following are neutral:

'causes systematic error' / 'beam may go past limit of proportionality' / 'need to increase height of supports' / 'beam may bend under own weight'

MAX 3

(d) $E \approx 10^9$

or

1.14×10^9 seen 1✓

for 1✓ accept 10^9 seen in working

1

correct manipulation seen in **body of answer** of $s = \frac{\eta m}{E}$ 2✓

for 2✓ ***either***

substitution of their E and data from ***Figure 8***
leaving η as only unknown: allow POT in s but not in m

eg $\eta = \frac{\text{their } E \times 25.5\left(\times 10^{-3}\right)}{0.25}$ **or**

substitution of their E and result of a gradient calculation: allow POT in Δs but not in Δm

eg $\eta = 1.14 \times 10^9 \times 1.02\ (\times 10^{-1})$ ***or***

calculation involving orders of magnitude (expect 10^{-1} but allow 10^2 for gradient)

eg $\eta \approx 10^9 \times 10^{-1}$

2

correct raw result (allow POT in E) 3✓

for 3✓ expect 1.16×10^8 but allow 1 sf gradient eg leading to 1.14×10^8

(on answer line) order of magnitude consistent with their raw result 4✓

for 4✓ $\eta = 10^8$ or 8 only; allow use of their E

award 34✓ = 1 MAX for use of gradient ≈ 100
leading to order of magnitude = 10^{11} or 11 only

1

(e) identifies that s and L are linked by a power law ✓

accept any correct expression (unless there is talk-out) with s or log s as the subject;

treat any quantities other than s and L as constant except E and η

possible answers are:

$s \propto L^n$

allow $s \propto L^m$ if m identified as constant

$s \propto L^3$

$s = kL^n$

$\log s = n \log L + (\log) k$

$\log s = 3 \log L + (\log) k$

$\log s = \log L^3 + (\log) k$

reject

$s = L^n$

$\log s = n \log L$

$\log s \propto n \log L$

$10^s \propto 10^L$

's and L are linked logarithmically'

's is directly proportional to L'

1

(f) ($\log L =$) −0.097 seen

for 1✓ accept any log L rounding to −0.097;

1

or

working on **Figure 5** confirming a value of log L between −0.095 and −0.100 1✓

uses **Figure 5** to obtain s in range 2.9 to 3.1 × 10^{-2} (m) 2✓

working can be suitable ruled line or mark on the best-fit line / on graph axes

for 2✓ accept 29, 30 or 31 mm etc

reject 1sf 3 × 10^{-2} (m)

1

use of wrong base

ln L = −0.22(3);

uses **Figure 5** to obtain s in range 1.49 to 1.51 × 10^{-1} or 1.5 × 10^{-1} (m) 12✓

accept 15 cm etc

(g) use of **Figure 4** to determine M ✓

*their (final answer to) (f) × gradient of **Figure 4** (9.8 ± 2.5%)*

minimum 2sf

condone use of 1sf s

1

[13]

5. C

$$\frac{\rho}{4} \quad \frac{E}{4}$$

[1]

6. **D**

[1]

7. (a) Attempt to calculate weight of cage
eg $1.2 \times 10^3 \times 9.81$ or 1.18×10^4 seen ✓

Attempt to find vertical component of tension T_V in one rope
eg 3.7×10^4 cos20 or 3.5×10^4 seen ✓

Uses F = twice their tension – their weight ✓

If weight not calculated, allow MP3 for doubling their tension or their resolved component

5.8×10^4 (N) ✓

4

(b) Use of F = ma with 6×10^4 N or their (a) ✓
50 (m s^{-2}) ✓

Allow 48 (m s^{-2}).

2

(c) Calculation of length of rope
eg 35/cos20 or 37.2 seen ✓

Allow methods using $F = k\Delta L$ and $E = ½\, k\Delta L^2$

Calculation of extension of one rope or calculation of total extension of both ropes
eg their length–24 or 13.2 or 26.4 seen ✓

Use of $E = ½\, F\Delta L$
e.g. $½ \times 3.7 \times 10^4 \times 13.2 = 2.44 \times 10^5$ (J) ✓

4.9×10^5 (J) ✓

4

(d) Use of E lost = ΔE_p
eg $1.2 \times 10^3 \times 9.81 \times h = 5 \times 10^5$ ✓

No credit for use of suvat in either method and MP3 must come from correct Physics.

First method is for calculation of max h and comparison with 50 m.

h = 42 (m) ✓

Allow h from their (c) if it rounds to 5×10^5

42 < 50 (m), so claim not justified ✓

OR

Use of $\Delta E_p = mg\Delta h$ with 50 m
eg $1.2 \times 10^3 \times 9.81 \times 50$ ✓

Second method is for calculation of ΔE_p and comparison with E.

$\Delta E_p = 5.9 \times 10^5$ (J) ✓

$5.9 \times 10^5 > 5 \times 10^5$, so claim not justified ✓

3

(e) 90 km h^{-1} = 25 m s^{-1} ✓

The conversion mark stands alone.

1

Use of $E_k = ½ mv^2$
eg $½ \times 1.2 \times 10^3 \times$ (their v)^2 ✓

3.8×10^5 (J) ✓

ecf for their v

2

(f) If their $E_k > 5 \times 10^5$, claim is unjustified

OR

If their $E_k < 5 \times 10^5$, claim may be justified depending on gain in E_p or losses due to resistive forces ✓

1

[17]

8. (a) resultant/overall/sum of force = 0 OR forces up equal forces down AND forces left equal forces right ✓
(sum of) anticlockwise moments (about any point) = (sum of) clockwise moments/zero resultant moment/torque ✓

1
1

(b) EITHER
the point through which (the line of action of) a force has no turning effect/causes no rotation/ no torque ✓
OR
where the mass of the body can be considered to be concentrated OR where the weight can be considered to act ✓

NOT where mass can be considered to act

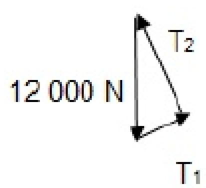
Ignore reference to force of gravity

1

(c) so there is not a resultant moment/turning effect / turning force OR moments do not balance OR (beam) does not rotate / oscillate / swing ✓
about A / because A is pivot ✓

Allow moments balanced for no resultant moment

1
1



(d)
T_1 = 12 000 cos 53 ✓
T_1 = 7200 (7221) (N) ✓
T_2 = 12 000 sin53 ✓
T_2 = 9600 (9583) (N) ✓

OR

T_1 cos 53 + T_2 cos 37 = 12 000 ✓
T_1 sin 53 = T_2 sin 37 ✓
T_2 = T_1 sin53/sin37
hence
T_1 cos53 + T_1 sin53 cos37/sin37= 12 000
T_1 = 7200 (7221) (N) ✓
T_2 = 7221 sin53/sin37 = 9600 (9583) (N) ✓

If T_1 and T_2 are the wrong way round get 3 out of 4

If scale drawing 2 max +/- 300(N)

If values out by a factor of 10 then -1 (i.e. confusion over g)

1
1
1
1

(e) (use of $\Delta l = Fl/AE$)
$A = \pi \times (0.75 \times 10^{-2})^2$ ✓ $(= 1.767 \times 10^{-4})$
$\Delta l = 12\,000 \times 12/(1.767 \times 10^{-4} \times 200 \times 10^{9})$ ✓
$\Delta l = 4.1 \times 10^{-3}$ (m) ✓

No attempt to calculate area scores zero

Wrong area (e.g. d^2 or $2\pi r$ or $2\pi rl$) maximum 1 mark unless diameter used for radius in πr^2 then maximum 2 marks

Accept 4.0×10^{-3}

If 4×10^{-3} then -1 as 1 sig. fig.

1
1
1

[12]

9. **D**

[1]

10. **B**

[1]

11. (a) (use of $\rho = M/V$)
$M = 4.0 \times 10^{-6} \times 920 = 3.68 \times 10^{-3}$ (kg) ✓
weight $= 3.68 \times 10^{-3} \times 9.81 = 3.6 \times 10^{-2}$ (N) ✓

Ecf for second mark

1 sig.fig. -1 mark

1
1

(b) $V = 3.68 \times 10^{-3}/1000 = 3.7\ (3.68) \times 10^{-6}$ m3 ✓

Ecf 5.1 from mass calculation

1

(c) THREE FROM:
any mass divided by 7800 ✓
$V \times 7800 + (4.0 \times 10^{-6} - V) \times 920 = 3.9 \times 10^{-3}$ ✓
$6880\ V = 3.9 \times 10^{-3} - 3.68 \times 10^{-3}$ ✓
$V = 3.2 \times 10^{-8}$ m^3 ✓

Ignore mass value if awarding first mark

1
1
1
(MAX 3)

[6]

12. **D**

[1]

13. **B**

[1]

14. (a) Use of $n_A = \frac{c}{c_A}$ to make c_A the subject of the equation

Condone truncation without appropriate rounding mid-calculation

OR

speed in glass **A** = 2.05(2) × 10^8 ms^{-1} $_1$✓

Speed in glass **B** = 1.985(3) × 10^8

Condone use of c = 3 × 10^8

But must see answer to 4 sf answer

OR

their speed in glass **A** × 0.96748 (or equivalent) $_2$✓

Values obtained using c = 3×10^8:

- *speed in glass A = 2.05(3)× 10^8 ms^{-1}*
- *speed in glass B = 1.98(7) × 10^8*
- *n = 1.510*

OR

Alternative 1st and 2nd marks

Use of $n_A/n_B = c_B/c_A$ by substitution for n_A $_1$✓

Use of $n_A/n_B = c_B/c_A$ by substitution for n_A and $c_B = c_A \times 0.96748$ $_2$✓

OR

n_B = 1.461 / 0.96748 $_1$✓$_2$✓

Watch for maths errors:

Dividing by 1.03252 ≠ multiplying by 0.96748

Multiplying by 1.03252 ≠ dividing by 0.96748

1.510 cao to 4 sf only $_3$✓

Correct answer to 4 sf obtains all 3 marks

Penalise any unit on final answer

3

(b) **Relationship:**

Increase in tension (or stress) in cable produces increase in strain resulting in increase in λ_R

OR

Decrease in tension (or stress) causes decrease in strain resulting in decrease in λ_R $_1$✓

Variation due to motion:

As the lift accelerates downwards, (the tension is less than the weight in the cable, a decrease in tension results) in λ_R decreasing $_2$✓

At constant velocity (the tension again equals the weight and) λ_R returns to the initial, at rest value $_3$✓

Allow a correct comment on the directional relationship between tension, strain and λ_R independent of the motion of the lift for first mark

3

(c) **P** because it will produce a larger increase in λ_R for the (same) <u>increase</u> in strain

OR

P because it has a larger gradient (must be a sense of larger increase in λ_R for the (same) <u>increase</u> in strain) ✓

Hence <u>smaller accelerations</u> (which produce small changes in strain) can produce <u>measurable changes in λ_R</u>

OR

Hence gauge **P** will have a higher resolution ✓

Selecting Q gains zero marks

Linking steeper gradient to being able to withstand a larger force negates this mark

Allow more accurate measurement of <u>acceleration</u>

Allow more readings of <u>acceleration</u> can be taken (over the range)

More sensitive treat as neutral

2

[8]

15. **B**

[1]

16. **C**

[1]

17. (a) EITHER

calculate value for constant using two calculations ✓

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

need to see table to look for any working

OR

calculate ratio between masses and $\sqrt{T}$ for one pair of values ✓

calculate ratio between masses and $\sqrt{T}$ for two pairs of values <u>and</u> make comment about same value ✓

e.g. $0.5/0.8 = \sqrt{110}/\sqrt{140}$

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]

18. (a) energy cannot be created or destroyed ✓
it can only be transferred / changed / converted from one form to another ✓

'Transformed' can be taken to mean transferred from one form to another.

(b) (i) (using $E_k = ½\, mv^2$)

$2.2 = ½ \times 0.40 \times v^2$

$v = 3.3$ (ms^{-1}) ✓

Ignore errors in 3 sig fig.

Answer only can gain mark.

1

(ii) (using work done = $F \times s$) 2.2 = F × 1.2 ✓ (F = 1.83 N) or

(using $a = (v^2 - u^2) / 2\,s$)

$a = (0^2 - 3.32^2) / 2 \times 1.2 = (-)\ 4.59$ ($m\ s^{-1}$)

(F = ma) = 0.4 × 4.59 ✓ = (1.84 N)

A substitution of numbers are necessary for the mark

1

(iii) (work done in moving 0.2 m) = 1.8 × 0.2 (J) ✓ (= 0.36 J)

(allow ecf (bii) × 0.2)

total work done = 2.2 + 0.36 = 2.6 ✓ (same answer is achieved if F = 2N)

J or joule ✓

3

(iv) (use of energy = ½ $F\,x$)

$2.6 = ½\, F_{max}\, 0.2$

F_{max} = 26 N ✓

(allow ecf 10 × (biii))

Allow mark for answer only even for ecf.

1

[8]