Mark schemes

Q1.

(a) Use of appropriate equation(s) of motion ✓

For example:
expect to see use of:
- $v^2 = u^2 + 2as$

use of is:
rearrangement to make s subject.
$s = \frac{u^2}{2a}$ *or* $s = \frac{v^2 - u^2}{2a}$
OR substitution
condone ***one error*** *in substitution.*
- $v = u + at$ ***and*** $s = \frac{u+v}{2} t$

condone one error in substitution.

(*s* =) 112 m ✓

Calculator display = 111.6071428
110 (m) correct to 2 sf

2

(b) Use of $W = mg$ to determine mass

m = 254.8 (kg)

OR

Use of $F = ma$ ✓

with their mass: allow use of m=2500 in F=ma

(P_H =) 380 (N) ✓

allow use of g = 9.8 N kg^{-1} (2 sf)
g = 9.8
calculator display: 382.653061224489
g = 9.81
calculator display: 382.2629969

2

(c) Attempts to use Pythagoras's theorem.

OR

Condone ***one error*** *in attempt to use either Pythagoras's theorem or trigonometric ratios:*
Substitution or rearrangement P_H would be subject.

Attempts to use $\sin\theta = \frac{P_V}{P_{Res}}$ **and** $P_H = P_{Res} \cos\theta$ ✓

P_H = 500 N

OR

Allow $P_H = 90\sqrt{31}$

A correct read-off of their v from **Figure 3** for their P_H ✓

Read-off within $\pm\frac{1}{2}$ *smallest division of their accurate read-off.*

*Must see working to support answer from **MP1** or **MP2** to score **all 3 marks**.*
*Answer in range without **MP1** or **MP2** obtains **MP3** only.*

(v_1 =) 10 (m s^{-1}) ✓

Answer in range 9.75 to 10.25 (ms^{-1})
Condone 10.3 (ms^{-1}) to 3 sf

3

(d) P_H's line of action passes through the centre of the wheel.

OR

the perpendicular distance between P_H's line of action and the centre of the wheel is zero.

OR

$m = Fd$ and d is zero✓

Condone:

Idea that P_H acts through the centre of the trailer's wheel.
Or
The perpendicular distance is zero.

Do not accept:

The distance between the centre of the wheel and P_H is zero.

P_H acts parallel to the centre of the wheel is insufficient.

1

(e) Max 2 from: ✓✓

- Attempts to use principle of moments about the centre of the trailer's wheel.
- D = 2100 (N)
- Read-off from graph of v_2 for their value of D.

*Condone **one error** in attempt to use:*

$$D \times 0.95 = 2500 \times 0.8$$

Read-off within $\pm\frac{1}{2}$ *smallest division of their accurate read-off. Allow a read-off for a force including P_H as D may equal P_H*
v_2 must be greater than zero.

MP3:
(Read-off from graph, v_2 =) 20.5 (m s^{-1}) ✓

Must see working that includes a correct principle of moments equation to score MP3.
Answer in range 20 to 21 m s^{-1}

3

(f) As v increases:

more air particles are given momentum (each second).
OR
each air particle given more momentum.
OR
Idea that more air is displaced (each second)
OR
Idea that the displaced air has a greater velocity.
OR
More air particles change direction (per second)
OR
There are more collisions with the air (particles each second)✓

Compensatory mark, Max 1:
there is a greater force on the air (as v increases)

Idea of a **greater** rate of change of momentum of air requires a **greater** force on air (relates to Newton's 2nd law) ✓

(Greater) force on air by trailer means (greater) force on trailer by air (relates to Newton's 3rd law.) ✓

To achieve 3 marks, must link:
***MP2** to Newton's 2nd law or its formula*
OR
***MP3** to Newton's 3rd law*

3

(g) Max 2 from✓✓

- Use of $P = Fv$

  *Condone **one error** in use of P=Fv*
  Where:
  P and v
  or
  F and v
  have been substituted.
  Expect to see:
  - *$95 \times 10^3 = F \times 25$*
  - *(F =) 3800 (N)*
  - *(P =) 3100 × 25*
  - *(3100 × 25=) 77500*

- Subtracts *D* from their thrust.

  *3800 - D **OR** 3800 - 3100*

- Subtracts their rate of work done by *D* on trailer from 95 kW.

  95×10^3 - 77500
  OR
  17500
  OR
  95×10^3 - their rate of work done by D

(Air resistance on car =) 700 N ✓

3

[17]

Q2.

(a) between *s* = 7.5 m and *s* = 15 m ✓

Tick in 2nd box only

1

(b) Use of $\Delta E_P = mgh$ ✓

Use of: rearrangement where m would be subject or substitution.

*Condone **one error** in substitution.*

(*m* =)65(.0) (kg) ✓

Calculator display =

For g = 9.81 ms^{-2} = 64.96772001

For g = 9.8 ms^{-2} = 65.0340136054421

*Alternative method for an ECF from **part (a)** (tick in 3rd or 4th boxes).*

- *Use of* $E_k = \frac{1}{2}mv^2$

OR

Read-off for v = 15.4 ms^{-1} (Acceptable range 15.2 ms^{-1} to 15.6 ms^{-1})

- *m= 80.6 (kg)*

(Acceptable range 78.57 kg to 82.76 kg)

2

(c) Max 2 from: ✓✓

- Energy difference (*E*) = 9.56 - 7.71 = 1.85 (kJ) ✓

*Accept correct energy conservation statement for **MP1***

For example:

ΔE_P = E_K + energy stored (in rope)

- Use of $E = \frac{1}{2}k\Delta L^2$

Use of:

Rearrangement to make ΔL the subject or by substitution.

*Condone use of their E and **one other error** in substitution. (allow 9.56 (kJ) or 7.71(kJ) for E)*

Condone use of

$E = \frac{1}{2}F\Delta L$ ***and*** *F = kΔL* ***OR***

$E = \frac{1}{2}F\Delta L$ ***and*** *F=mg*

With their F and their E seen in $E = \frac{1}{2}F\Delta L$

- $\Delta L = \sqrt{\frac{2 \times \text{their energy difference}}{k}}$

Must be an energy difference. Condone POT
Do not accept 9.56 (kJ) or 7.71(kJ) for their energy difference.

ΔL = 5.8(0) m ✓

Max 1 mark for:
637.65 = 110 × ΔL giving ΔL = 5.8 m
must be done by considering energy transfers.
OR
answer without working.

(d) (Tension =) 640 (N) ✓

Potential ECF from:

- *m in* ***part (b)*** *where use T=mg*
- *ΔL in* ***part (c)*** *(typical ecf answer = 1300 (N)*

where use T=kΔL

Reason:

Idea that the resultant force / acceleration is upwards (in opposite direction to motion) for tension greater than this value.

OR

Idea that the resultant force / acceleration is downwards (in same direction as motion) for tension less than this value

OR

Resultant force / acceleration is zero (when kinetic energy is at its maximum.)

OR

Tension is directly proportional to the extension / (rope obeys) Hooke's law. ✓

For two marks:
Reason must be consistent with any working seen.
Insufficient to state that tension = weight at maximum kinetic energy.
Apply list rules to the reason.
If use F=Δk without further support in their reason can score max 1 mark.
e.g. Each term to be defined

(e) Use of $k = \frac{EA}{L}$ to show *k* is same for both ropes ✓

Accept

$1.2E = \frac{k \times 1.2L}{A} \Rightarrow 1.2E = \frac{k \times 1.2L}{A} \Rightarrow E = \frac{k \times L}{A}$

Or equivalent

Allow use of k =110 Nm^{-1} in working.

1

(f) Yes:

Must have correct deduction for 3 marks.

MAX 2 from: ✓✓

- (Second) rope's (unstretched) length is greater.
- Has a greater velocity before rope begins to stretch (for second rope).
- Extension of each rope is same (when tension = weight.)
- Work done in stretching rope is same (in travelling to max velocity) / energy stored in rope is same
- Total distance fallen to reach max velocity is greater (for second rope)
- Total distance fallen (to max velocity) = unstretched length + same extension
- Idea of longer time in free-fall

Correct use of principle of conservation of energy **or** correct use of Newton's 2nd law ✓

Conservation of energy:

Gains more kinetic energy before work done by tension becomes greater than work done by gravity.

Newton's 2nd law:

Gains more velocity before acceleration's direction becomes opposite to motion's direction.

3

[12]

Q3.

(a) calculates, using all 4 values, a mean of 0.418 (s) ✓

Expect to see 25.08 (mean average) divided by 60, or 100.32 (sum) divided by 240 in working

1

(b) 2.75 cycles (between **P** and **Q**) $_1$✓

T_{PQ} = 0.42 × their number of cycles $_2$✓

Expect T_{PQ} = 1.15, 1.16 or 1.2 (s)

$_2$✓ *Allow use of >2 sf T_{PQ} that rounds to 0.42 (s)*

$_2$✓ *Their number of cycles must be between 2.5 and 3*

2

(c) 0.170 (m) ✓

Condone 2 sf value on answer line if working shows a 3 sf value or "170 mm" seen or "20 mm" used e.g. '8.5 × 20 mm'.

1

(d) correct use of an appropriate equation of motion $_1$✓

correct evaluation of their *a* $_2$✓

Expect to see a = 0.24, 0.25 or 0.26 (m s^{-2})

$_1$✓ *Expect* $a = \frac{2 \times \text{their } s}{\text{their } (T_{PQ})^2}$ ***OR***

mean $v = \frac{\text{their } s}{\text{their } T_{PQ}}$ ***AND*** $a = \frac{2 \times \text{their mean } v}{\text{their } T_{PQ}}$

Expect mean v = 0.14 or 0.15 (m s^{-1})

$_1$✓ *Allow s in mm*

2

(e) links (absolute) uncertainty of 1 mm for one reading to the resolution of 2 mm of the graph paper $_1$✓

$_1$✓ *Condone 'uncertainty in a single reading is half a grid division'*

idea that *s* is based on two readings so (absolute) uncertainties in each reading are added $_2$✓

$_2$✓ *Allow 's is based on two readings so uncertainty in s is double the uncertainty of each reading'*

2

(f) $\frac{0.002}{their\ s} \times 100$

OR

2 × 0.46 or 0.92 seen $_1$✓

Expect to see % uncertainty in a = 2.1

$_1$✓ *Expect % uncertainty in s = 1.2. Calculator value is 1.17647.*

$_1$✓ *Allow values in mm*

% uncertainty in *a* = (their % uncertainty in *s*) + 0.92 $_2$✓

$_2$✓ *Allow 1 or 2 sf values only*

2

(g) resultant force should be lower $_1$✓

$_1$✓ *Default interpretation of ";a" is the experimental value (from **part (d)**) unless otherwise defined.*

$_1$✓ *Allow idea that experimental value of a would be larger in absence of friction.*

$_1$✓ *Credit algebraic expression that includes friction (F): ma = mgsinθ - F. Condone missing "m".*

(student's value of) *g* is less (than 9.81 m s^{-2}) $_2$✓

$_2$✓ *is contingent on* $_1$✓

2

[12]

Q4.

(a) use of $\rho = \frac{m}{V}$ **AND** $V = Al$ 1✓

260 (m) 2✓

1✓ *Expect to see V = 2.5 m³ or total V = 5.0 m³*

2

(b) calculates total tension of 3.2×10^6 N 1✓

$F = T - W$ seen **OR** subtracts a weight from tension 2✓

uses $F = ma$ 3✓

0.28 or 0.29 (m s^{-2}) 4✓

Expected values seen:
Total mass = 3.17×10^5 kg
Load weight = 2.75×10^6 N
Cable weight = 3.63×10^5 N
Total weight = 3.11×10^6 N
Resultant force = 9.02×10^4 N

4✓ *Calculator values are: 0.28464 (using g = 9.81) and 0.29464 (using g = 9.8)*

4

(c) calculates stress per cable (167 MPa) **OR** breaking force for one cable (8.5×10^6 N) 1✓

Calculations for 1✓ may be seen in response to 2✓

concludes that system operates safely because: 2✓

8.5×10^6 N < $(3 \times 1.6 \times 10^6)$ N

OR

(3 × 167) MPa < 890 MPa, or $167 \text{ MPa} < \frac{890}{3} \text{ MPa}$

N.B. $\frac{890}{3} = 297$

OR

$3 < \frac{890}{167}$ or $3 < \frac{8.5}{1.6}$

N.B. $\frac{890}{167} = 5.3$ and $\frac{8.5}{1.6} = 5.3$

2

(d) Max 3 from: $_1$✓$_2$✓$_3$✓

correctly takes into account energy transfer efficiency $_a$✓

$_a$✓760 MJ × 0.85 gives 646 MJ of useful energy from storage system. Condone POT error.

$_a$✓can be given for stating that at 100% efficiency the storage system would provide 760 MJ.

determines a relevant area of graph between 10:00 and 14:00 $_b$✓

$_b$✓for dashed/demand line: 11.5 'squares' = 1150 kW h; for solid/output line: 9 'large squares' = 900 kW h; between dashed and solid: 2.5 'large squares' = 250 kW h

conversion of energy unit (kW h to J or vice versa) $_c$✓

$_c$✓Expect: 1 'small square' = 14.4 MJ; 1 'large square' = 360 MJ; 1150 kW h = 4.14 GJ; 900 kW h = 3.24 GJ; 250 kW h = 900 MJ

Award $_b$✓and $_c$✓for any area given in J.

quantitative comparison of their energy supply (turbine + storage capacity) to their energy demand or their energy deficit versus their storage capacity $_d$✓

$_d$✓Allow 760 MJ for their storage capacity.

concludes that demand cannot be met, based on comparison of:

4.14 GJ with 3.89 GJ

OR

900 MJ with 646 MJ $_4$✓

demand = 4.14 GJ; supply (turbine+storage) = 3.24 + 0.646 GJ = 3.89 GJ

deficit (demand - turbine supply) = 4.14 GJ - 3.24 GJ = 900 MJ; storage system supply = 646 MJ

4

[12]

Q5.

(a) Either appreciation of mass of He = 4 × mass of neutron OR idea that n and He have equal (and opposite) momenta ✓

Combination of momentum and KE equations (to give idea that KE is inversely proportional to *m* with same *p*) and therefore KE of neutron = 4 × KE of He ✓

Expect to see $\mathrm{KE} = \frac{p^2}{2m}$

2

(b) calculates KE of neutron
OR
uses mass of neutron from data booklet with *their calculated KE* in a KE equation✓

$v = 5.2 \times 10^7$ m s^{-1} ✓

80% × 2.82 × 10^{-12} = 2.26 × 10^{-12} (J)

Do not allow use of 2.82 × 10^{-12} as their calculated KE.

m_n=1.67(5) × 10^{-27} kg

Accept answers of 5.18 × 10^7 or

5.19 × 10^7 m s^{-1}

Calculator values:

5.1823878 × 10^7; (using 1.68)
5.1901169 × 10^7; (using 1.675)
5.1978807 × 10^7 (using 1.67)

2

[4]

Q6.

(a) Formation of a parallelogram OR triangle to draw *W* 1✓

Use of their *W* to obtain the scale at which force diagram is drawn 2✓

Use of their scale to obtain T_1 and T_2 3✓

T_1 = 480 N AND T_2 = 400 N 4✓

Correct by eye.

If a hybrid approach is used, note that MP2 is given for a measurement of their W used to determine a scale OR for the measurement of the two angles within range.

If correct values in range seen for MP4, then it can be assumed that a scale was used to obtain T_1 and T_2, MP3 can be awarded

Expect to see: $\frac{350}{35}\text{mm} = 10\ \text{N mm}^{-1}$

T_1 = 48 mm × 10 T_2 = 40 mm × 10

Range: allow T_1 470 - 490 N and T_2 390 - 410 N

Alternative Approach 1

Formation of a parallelogram OR triangle to draw W 1✓

Allow complementary angles where quoted.

Both angles measured correctly/evaluated to be (34 — 35)° and (11 — 12)° 2✓

$T_1 \sin 34 + T_2 \sin 11 = 350$ AND $T_1 \cos 34 = T_2 \cos 11$ 3✓

In MP3 allow their angle values OR angle symbols consistent with labels on their diagram.

T_1 = 480 N AND T_2 = 400 N 4✓

Allow correct application of sine or cosine rules.

Range: allow T_1 470 - 490 N and T_2 390 - 410 N

4

(b) Max 4 from:

- $m = \frac{350}{g}$ ✓
- their *m* to give KE with *v* = 6.5 m s^{-1} at B ✓
- 350 N and 4.5 m in GPE equation✓
- evidence of *their* ΔGPE - *their* ΔKE to give work done against friction ✓

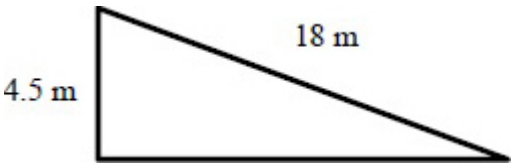
- evidence of friction force $= \frac{\text{their work done}}{18}$ ✓

Expect to see 36 kg

Expect to see 754 J
Expect to see 1575 J

Expect to see 821 J

*Alternative for first **four** marks. Must see a labelled diagram indicating use of this approach:*



If the diagram is not seen, mark according to the main scheme. Max 4 from:

- $m = \frac{350}{g}$ ✓
- *Use of suvat to obtain a = 1.17 m s^{-2}*✓
- *Uses F =ma to obtain their effective resultant force*✓
- *Uses 350 × (4.5÷18) or equivalent to obtain their effective component of weight*✓
- *Subtracts their resultant force from their component of weight*✓

Accept answers that round to 46 N.

Calculates average force = 46 N ✓

5

(c) Idea that contact time or distance travelled during contact is increased ✓

Generic mark scheme for MP2 and MP3

- reference to physical principle ✓
- application of principle to explain why force is reduced ✓

Momentum approach (time increased)

- *reference to Force is rate of change of momentum*
- *change in momentum/impulse/ F×∆t constant therefore force decreased*

Energy approach (distance increased)

- *reference to force × distance = change in KE/work done*
- *change in KE/work done/F×s constant so force reduced*

Newton 2 approach (time/distance increased)

- *reference to Force = mass × acceleration*
- *change in velocity constant, so acceleration reduced so force reduced*

3

[12]

Q7.

(a) Max 2 from one route ✓✓

Alternative 1

- $\Phi = BA \cos\theta = 4.9 \times 10^{-5} \times (2 \times 8.0) \times \cos 68° = 2.9(4) \times 10^{-4}$ (Wb)

  OR

  $\Phi = BA = 4.9 \times 10^{-5} \times (2 \times 8.0) = 7.84 \times 10^{-4}$ (Wb)
- Time to fall to the ground = 1.3 (1.28) (s)
- $\varepsilon = \frac{\Delta\Phi}{\Delta t}$ with their $\Delta\Phi$ and t

Marks can only be awarded from one route.

mp1 and 2 the mark can be awarded from seeing a substitution.

For mp1 condone sin 68° in both routes

$$t = \left(\frac{2s}{a}\right)^{\frac{1}{2}} = \left(\frac{2\times 8.0}{9.81}\right)^{\frac{1}{2}} = 1.28$$

*In 3rd bullet do **not** allow* $\varepsilon = \frac{\Delta B}{\Delta t}$ *or* $\varepsilon = \frac{\Delta B \cos\theta}{\Delta t}$ *but condone any value for A.*

Alternative 2

- $\varepsilon = Blv$ or $\varepsilon = Blv \cos\theta$ seen
- $v = \sqrt{2g\Delta h}$ OR $\sqrt{2as} = 12.5$ (m s^{-1})

  OR

  Time to fall to the ground = 1.3 (1.28) (s)
- $v_{avg} = \frac{v}{2}$ with their v

  OR

  $v_{avg} = \frac{s}{t}$ for their t

$\varepsilon = 2.3 \times 10^{-4}$ ✓ (V)

3

(b) Max 4✓✓✓✓

Fall to the left

Statement	Explanation
the direction of the emf changes	the rod cuts across the magnetic field in both directions / passes parallel point
the emf goes through a zero (when 68° to the vertical)	momentarily the rod travels parallel to the field or does not cut lines of flux / 0 change in flux
emf reduces (and then increases)	as (direction of) velocity or motion gets closer to being parallel to field / same direction as field / cuts less flux per unit time

Fall to the right

Statement	Explanation
the direction of the emf stays the same	the rod cuts across the magnetic field always in the same direction
Idea that the emf goes through a maximum (when 22° to the vertical)	the rod cuts across the magnetic field at right angles or the cutting of field line is a maximum
emf increases (and then decreases)	as (direction of) velocity or motion gets closer to perpendicular to field / cuts more flux per unit time

All marking points are to be OWTTE.

Ignore comments about different direction falling left and right.

Statement and explanation are separate marking points.

Explanation must not contradict statement to be awarded.

Condone emf increases as speed of fall increases (Blv) or smaller time $\left(N\frac{\Delta\Phi}{\Delta t}\right)$ ✓ ✓ *for either direction but not both.*

*Allow the following statement and explanation as an alternative to **either** a fall to the left or to the right but not both:*

*Statement - when falling left the **average** emf is less than falling to the right.*

Explanation - as the total change in flux / number of flux lines cut is less than when falling to the right.

4

[7]

Q8.

(a) Attempts to set forces equal with double a component of tension.

OR

Attempts to set forces equal with single horizontal component of tension (T cos θ) ✓

(T =) 310 (N) ✓

*Expect to see F = 2T cos 75 **OR** 80 = T cos 75*
*Condone F = 2 T sin 75 **OR** 160 = 2 T sin 75*
OR F = 2T sin (their acute angle)
OR F = 2T cos (their acute angle)
OR $\frac{80}{\sin 75}$ *seen **and** 83 N on answer line.*
*Condone F = T cos 75 **OR** 160 = T cos 75*
OR *(T=)* $\frac{160}{\cos 75}$ *with 620 N on answer line*
An answer of 83 N due to F and T being interchanged obtains zero marks.
Alternative
closed triangle (75-75-30) of forces
*An attempted use of Sine or Cosine Rule seen with correct closed triangle **MP1***

Accept answer correctly rounded to at least 2 sf.
Answer = 309 (N) to 3 sf
Calculator display= 309.0962644

2

(b) Read off for F = 208 N

OR

use of $F = ma$ ✓

Range for read-off is 208 N to 210 N

In use of F = ma:
• must see substitution for F and m
• condone either POT error in m or F outside range but not both.

(a =) 9900 (m s^{-2}) ✓

Accepted range = 9900 to 10000
Penalise 1 x 10^4 N as a 1 sf answer.

2

(c) Area under graph calculated in J for either s = 0.10 m or s= 0.385 m ✓

s = 0.385 m is approximately 64 blocks, 1 J per block (64 J)

s = 0.10 m gives 8 blocks at 1 J per block (8 J)

Or $\frac{1}{2}$ *× 0.1 × 160 = 8 J (less than 64 J)*

s_r = 0.385 m✓

Range for s_r *between 0.38 m and 0.385 m*

Do not accept W=Fs for ***MP1***

Do not accept s_r *= 0.4 m for* ***MP2***

2

(d) (Energy transferred to arrow =) 0.82 × 64

OR

converts 190 km h^{-1} to 52.8 m s^{-1} or working seen ✓

Energy transferred to arrow = 52.48

$52.8 = 52.\dot{7} = \frac{475}{9}$ *accept any answer that rounds to 53*

Use of $E_k = \frac{1}{2} mv^2$✓

Use of is:

• A rearranged expression where m would be subject.

• Substitution: condone one error in the substitution either v ***or*** E_k *where m would be subject (condone rounding error in v)*

Do not accept their power (F v) equal to $\frac{1}{2} mv^2$

m = 0.038 (kg) ✓

Accept answer correctly rounded to at least 2 sf.

m = 2.2 x 10^{-16} *kg where incorrect v of 6.84 x* 10^8 *is used. (Worth 2 marks) (one error in v)*

m = 0.056 kg where incorrect Ek is used ($\frac{64}{0.82}$ *= 78) (Worth 2 marks) (one error in Ek)*

Calculator display = 0.03768093075

3

[9]

Q9.

(a) (Use of volume (per sec) =) $\frac{\pi d^2}{4}$ × 17.2 ✓

(Volume per second =) 19.45 (m^3 s^{-1}) = $\frac{774\pi}{125}$

$\frac{\pi d^2}{4}$ × *17.2* = $\frac{9\pi}{25}$ × *17.2*

Use of $\rho = \frac{m}{V}$ ✓

Substitutes their volume (per second) and density where $\frac{m}{t}$ *would be subject. Do not award MP2 if 2 errors are made in substitution.*

(mass per second =) 0.389 (kg s^{-1}) ✓

Answer seen to at least 2 sf.

Calculator display = 0.3890548342

3

(b) Use of $F = \frac{m}{t} \times v$ or (*F* =) 6.69 N or 6.708 (N) or 6.88 (N)

OR

Use of *W=mg*

OR statement:

Upward force = weight ✓

Possible ECF from ***(a)*** *where their m rounds to 0.4 kg.*

W = 3.72m seen or 3.72m as the subject of a force equation.

Do not allow 3.72 x 0.4 as use of W=mg

.

Applies condition for equilibrium by setting *F = mg*

OR

6.69 = 3.72 *m or* 6.708 = 3.72 *m* or 6.88 = 3.72 *m*✓

(*m* =) 1.80 (kg) ✓

Accept answer correctly rounded to at least 2 sf.

F= 6.88 N where $\frac{m}{t}$ *= 0.4*

m=1.85 kg or 1.8 kg

3

(c) Use of $E = Pt$

OR

converts kWh to J ✓

(E =) 340 × 39 ***or*** *13260 (J)*

(0.035 kWh =) 35 × 3600 ***or*** *126000 (J)*

Alternative MP1 *converts to any of the following units of energy.*

- *0.34 (kW) x 0.0108 (h)* ***or*** *0.00368 (kWh)*
- *0.035 kWh = 35 (Wh)*
- *340(W) ×* $\frac{13}{1200}$ *(h)* ***or*** $\frac{221}{60}$ *(Wh) or 3.683 (Wh)*

Or equivalent e.g W mins

Do not accept incorrect unit.

Do not accept incorrect subject.

MP2

Do not allow answers obtained using incorrect power $\left(\frac{126000}{39}\right)$

$\frac{340}{\text{incorrect power}}$ *such as* $\frac{340}{\frac{126000}{39}}$

(=) 11% ✓

Accept answer correctly rounded to at least 2 sf.

Calculator display = 10.5238

2

(d) Incorrect:

- this will increase weight **OR** helicopter must provide a greater lift **OR** (more mass therefore) greater GPE (for same height) **OR** (more mass therefore) greater KE (for same speed) **OR** idea that more energy is required. ✓
- the helicopter must displace more (atmospheric) gas (every second to produce greater lift force) **OR** blades must spin faster✓
- the helicopter must do more work every second (so will transfer stored energy at a greater rate) **OR** the helicopter needs more power to fly✓

OR

Incorrect:

- this will increase weight ✓
- atmosphere is too thin and can't displace sufficient mass of gas per second **OR** blades can't spin **fast enough**✓
- can't get off ground due to insufficient lift force ✓

Do not accept increase in resistive forces or increase in drag for increase in weight.

***Must state that it is incorrect for all 3 marks**.*

Maximum of 2 marks for suggestions that more than doubles flight time.

Accept lift or thrust or upward force.

*A maximum of 1 mark for **MP3** and **MP1** where only mark seen is : idea that more energy is required.*

***MP2** can be scored independent of this.*

3

(e) Use of an appropriate equation of motion:

$v = u + at$ ✓

*By correct substitution including signs **or** correct rearrangement to make t subject.*

(t =) 0.15 (s) ✓

Accept answer correctly rounded to at least 2 sf.

Calculator display = 0.14784946236559

2

(f) Use of $v^2 = u^2 + 2as$

OR

Use of $v = u + at$ **and** $s = ut + \frac{1}{2}at^2$ **ECF**

OR

$mg\Delta h = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ ✓

(h =) 0.61 (m) ✓ **ECF**

***MP1** (Downward journey)*

Allow s = 0.65m

$2.2^2 = 0^2 + 2 \times 3.72 \times s$

OR

$2.2 = 0 + 3.72\,t$ ***and*** $s = 0 + \frac{1}{2}\,3.72\,t^2$ ***ECF***

OR

$m \times 3.72 \Delta h = \frac{1}{2} m2.2^2$

MP1 (Upward journey)

Allow s=0.041 m obtained from

$s = 0.55 \times 0.15 - \frac{1}{2} 3.72 \times 0.15^2$ ***ECF***

OR

$0^2 = 0.55^2 - 2 \times 3.72 \times s$

*Check possible **ECF** for t from (e) used in calculation.*

*Condone sign suppression in **MP1** where answer of 0.65 m or 0.041 m or 0.6(1) m is seen.*

Accept answer correctly rounded to at least 2 sf.

Calculator display = 0.60987903225806

2

(g) Student is correct:
Weight is the only force acting on the helicopter.
OR
Acceleration = (-)3.72 ms^{-2}✓
Due to **Newton's 2nd law**, the acceleration acts in the **same direction** as the weight (which is always downwards).

OR

Due to **Newton's 2nd law**, the acceleration is **constant** because the (mass and) weight are **constant** ✓

MP1 statement that the object is in freefall. Where (resultant) force is mentioned must be identified as weight.

Where acceleration is quoted must have correct unit.

Accept F=ma as a statement of Newton's 2nd law.

MP2 Accept no mention of force being weight where mass is included their answer, for e.g.:

*Due to **Newton's 2nd law** the acceleration is constant because the force **and** mass are constant.*

Neutral for statements that refer to deceleration / acceleration.

Do not accept arguments based on drag or air resistance affecting the motion of the helicopter.

***Zero marks** for statement that indicates the **acceleration varies**.*

*Must state that student is correct **or** that the acceleration is constant to gain 2 marks.*

2

[17]

Q10.

(a) idea that moments are balanced or that there is no resultant moment ✓

*Answer must relate to the context e.g. reference to **Q** or weight of food/spoon*

Allow 'force × distance' or 'F × d' for 'moment'.

(because)

(overall) centre of mass is now beneath/at **Q**

OR

line of action of (overall) weight is through **Q** ✓

*'Anticlockwise moment of weight of spoon about **Q** = clockwise moment of weight of M about **Q**' gains both marks.*

2

(b) statement of balanced moments seen e.g. $mgx = Mg(16 - 4 - x)$, leading to required formula ✓ ✓

For 1 mark: condone absent g if credible evidence for '12 - x' presented e.g. mx = M(16 - 4 - x) or mx = M(28 - 16 - x)

OR

condone lack of evidence for '12 - x' if g is shown e.g. mgx = Mg(12 - x).

Need to see g and evidence for '12 - x' for both marks. Evidence for '12 - x' need not be in an expression of a moment.

Allow 9.81 or 9.8 instead of g.

2

(c) max two from: ✓ ✓

- reads off a pair of values (e.g. 115 g, 5.0 cm)
- substitutes into formula
- multiplies their *m* by *g*

answer that rounds to 1.5 or 1.6 (N) ✓

Allow correct conversion of M to kg and/or x to m for read offs or in the substitution.

Expect to see 160 g for mass of spoon.

Allow credit for an algebraic solution to get m:

$$\frac{m}{M} = \frac{(12 - x)}{x} = 1$$

e.g. when m = M,

So, 12 = 2x, x = 6.0 cm. Reads off M at 6.0 cm to get 160 g.

3

(d) (absolute) uncertainty in *M* increases as *M* increases ✓

(because) as *M* increases:

marks on the scale get closer **OR** range of values of *M* for a fixed range of *x* increases (or vice versa) ✓

the gradient (in Figure 3) increases so the scale markings are unequal owtte ✓

MP1 only awarded supported by some relevant explanation. Treat 'percentage' uncertainty as neutral.

*Allow MP2 and MP3 for quantitative evidence given using Figure 3 e.g. from 0 g to 25 g, Δx ~ 1.5 cm; from 175 g to 200 g, Δx ~ 0.4 cm **OR** calculates gradients at low and high M.*

3

[10]

Q11.

(a) Conversion of 1230 km h^{-1} to m s^{-1}

Expect to see 342 m s^{-1} (341.7)

OR

Calculates time for 343 m s^{-1} run

Expect to see 4.69 s

OR

Calculates total time (using total distance, 3.22 km, and speed record)

Expect to see 9.42 s

OR

Calculates unknown speed ✓

Expect to see 340.3 m s^{-1}

Answer that rounds to 4.73 (s) ✓

Do not accept 2sf for final answer.

2

(b) speed from graph: 450 m s^{-1} ✓

Accept 445 - 455 m s^{-1}

Use of their speed and KE equation to give consistent answer ✓

Expect to see 6.6×10^8 (J)

2

(c) **MAX three** from: ✓✓✓

- Use of graph to determine gradient
- Uses (their) speed and (their) gradient to give acceleration
- Use of $F = m \times$ (their a) to give resultant force
- Use of $P =$ (their F)× (their speed)

Final answer between 16% and 17%✓

Expect to see 450 m s^{-1} for their speed

Evidence for gradient may be on figure

Allow ECF from (b)

- $\frac{450}{5600}$ *= 0.080(4)*
- *Expect to see 450 × 0.08 = 36(.2) m s^{-2}*
- *Expect to see 2.35 × 10^{5} N*
- *Expect to see 450 × 2.35 × 10^{5} = 106 MW*

Reject power that is calculated assuming a constant speed.

4

(d) Identifies distance decelerating

AND

max velocity = (470 ±5) m s^{-1} ✓

Uses *suvat* equation(s)

to get a = (-) 15 m s^{-2} which is less than 3g (so yes). ✓

allow 7000 m to 7600 m

allow answer consistent with their distance that rounds to 15 or 16

give full credit to calculations that show that an acceleration of 3g would stop the car in a (much) shorter distance, with a statement that this means that the actual acceleration must be (much) less than 3g.

For MP2 allow calculation of

gradient × average speed to give

a = (-) 15 m s^{-2} which is less than 3g (so yes)

2

[10]

Q12.

(a) Evidence of appropriate use of Figure 1 e.g.

$105 \times 10^{6} \div 7.5 \times 10^{-4}$

Some evidence that Figure 1 is used:

calculation based on a point on line between 75 MPa and 125 MPa

OR calculation from point on straight line extended

OR

Use of triangle from more than half of the linear section.

leading to an answer in the range 1.38 to 1.42 × 10^{11} Pa ✓

Allow 2 sf answer 1.4 × 10^{11} (Pa).

1

(b) Idea that wire undergoes only (very) small (increase in) strain beyond the linear section before fracture ✓

*Reject idea that there is **no** increase in strain.*

Condone 'extension' or '(plastic) deformation' for 'strain'.

Condone 'shortly after' for 'beyond'

Accept: does not show 'necking' before fracture

Accept: fracture occurs very near the limit of proportionality (condone 'elastic limit').

Accept references to a particular value of strain e.g. 9 x 10^{-4} to 12.7 x 10^{-4}

1

(c) Evidence of determination of total load or load on one wire ✓

(halves load)

Use of $E = \frac{(\text{their } F) \times L}{A \times \Delta L}$ ✓

ΔL = 1.1(4) × 10^{-3} (m) ✓

Total load = (4.4 + 16.0) × 9.8(1) = 200(.1) N

Allow 'g' for 9.8(1)

Expect to see F = 100 N and

A = 5.03 × 10^{-7} m^2. Condone use of d in calculation of cross-sectional area A in MP2.

Or separate calculations using σ = F÷A, E = σ÷strain, strain = ΔL÷L

Condone POT error in MP2.

3

(d) Evidence of extension/strain in each wire is the same $_1$✓

Substitutes data leading to $F_a = 1.33\ F_s$ $_2$✓

Calculates F_s or F_a $_3$✓

Evidence of an attempt at a moment equation $_4$✓

Distance = 1.18 m ✓$_5$

ΔL = {FL÷AE} steel = {FL÷AE} aluminium {F÷d²E} steel = {F÷d²E} aluminium $_1$✓

$$\frac{F_s}{0.8^2 \times 210} = \frac{F_a}{1.6^2 \times 70}$$

$F_a = 1.33\ F_s$ OR $F_s = 0.752\ F_a$ $_2$✓

$1.33\ F_s + F_s = 200$ N

$F_s = 86$ N, $F_a = 114$ N $_3$✓

Attempt to take moments about A or B or other suitable point, expect to see $16.0gx = 228 - 4.4g$ ✓$_4$

Note that an answer of 1.14 m comes from not taking into account the weight of the beam

*Award **max 4** for this approach.*

ECF for MP2 and MP3 in MP4

5

[10]

Q13.

(a) total kinetic energy of the particles ✓

Condone "molecules" or "atoms" for "particles"

Kinetic energy will be taken to mean total kinetic energy but do not accept use of mean kinetic energy or reference to kinetic energy of a single particle.

Do not allow any reference that implies there is potential energy or any other energy added to the kinetic energy.

1

(b) (the speed before and after a collision is the same in the elastic collision)

Δp (= p_f - p_i) = - mc - mc = -2mc ✓

Use of subscripts i and f or before and after do not need explanation.

Δ will be assumed to mean (final - initial).

Either the initial momentum or the final momentum must be described clearly enough to justify the negative final answer

1

(c) Time between colliding with **W** $\left(=\frac{s}{c}\right)=\frac{2l}{c}$

$f = \frac{1}{T}\left(=\frac{c}{2l}\right)$ ✓

Must show evidence of a time calculation using distance and speed

Do not allow any attempted use of $v = f\lambda$

1

(d) Reference to a Newton law **AND** $P = \frac{F}{A}$ ✓1

$P\left(=\frac{F}{A}=\frac{mc^2}{l}\times\frac{1}{l^2}\right)=\frac{mc^2}{V}$ ✓2

The reference to Newton law could be a simple link between Newton's name and an equation.

2

[5]

Q14.

(a) attempted use of principle of moments:

seen by one correct side of an attempted principle of moments equation.

examples of acceptable responses for MP1 1150 × 3.6 ***or*** *1400 × 3.6* ***or*** *1800 × 1.8 + 750(3.6 – d)* ***or*** *1800 × 1.8 + 750 × or 750 × d + 1800 × 1.8* ✓

full use of principle of moments ✓

Condone ***one*** *error in distance or signs or force in an attempted use of principle of moments (must have 3 forces multiplied by 3 distances)*

(d =) 2.4 (m) ✓

For moments about ***B*** *(or* ***Q****):*

1150 × 3.6 = 1800 × 1.8 + 750(3.6 − d) /

1150 × 3.6 = 1800 × 1.8 + 750 x

Alternative

Finds component of tension in **P** due to worker's weight = 250 N /
Finds tension in **P** (due to weight of worker) by dividing weight of platform by 2 and subtracts from 1150 N

OR

Finds component of tension in **Q** due to worker's weight = 500 N /
Finds tension in **Q** (due to weight of worker) by dividing weight of platform by 2 and subtracts from 1400 N ✓

Recognises the ratio of weight distribution to worker position relative to cables **P** and **Q**

250 N : 500 N = 3.6 − d : d ✓ (principle of moments)

x seen (with appropriate working) as 1.2 m or 2.4 m (even when not answer line) gains MP1 and MP2

Moments about ***A*** *(or* ***P****):*

750 × d + 1800 × 1.8 = 1400 × 3.6

Alternative for MP1 and MP2:

Moments about worker's centre of gravity:

1150 × d + 1800(1.8 − d) = 1400 (3.6 − d)

MP1 for one correct side of equation seen.

MP2 all correct terms seen (condone one error).

(d =) 2.4 (m) ✓

d = 1.2 m ***with supporting working gains*** *MP1 and MP2 (need principle of moments)*

(b) Extension = 0.18 m **or** use of $\varepsilon = \frac{\Delta L}{L}$ **or** reads off d correctly for their extension (+/- half a square) (where working for extension seen) ✓

*Use of $\varepsilon = \frac{\Delta L}{L}$ is by rearrangement to make ΔL the subject **and** 6 × 10^{-5} × 3 seen (condone use of L = 3.6 m here).*

Condone POT error on extension

(d =) 1.8 m ✓

Some supporting use of graph for read-off seen

Allow range of 1.75 m to 1.85 m

2

(c) (σ =) 1.1(4) × 10^{7} (N m^{-2}) ✓ c.a.o

1

(d) Straight line with negative gradient that intercepts extension axis and has a d range of 3.5 m to 3.7 m ✓

Penalise double and thick lines (limit on thickness of line: must be less than half square thick)

Straight line passes through (0, 0.46) ✓

Within 1/2 square

Straight line passes through (3.6, 0.26) ✓

Within 1/2 square

*Condone accuracy within a square **max 1** for MP2 and MP3*

3

[9]

Q15.

(a) (component of total weight parallel to slope =) 640 sin θ ✓

Allow mg sin θ or 65g sin θ or 638 sin θ

or 637.7 sin θ or 637.65 sin θ

Condone labelling this component as W in statements such as

W = 640 sin θ

Do not accept

W sin θ unless W is defined as mg

1

(b) use of $P = Fv$ ✓

Ecf from part (a) for MP1 and MP2

Use of $P = Fv$ by substitution and rearrangement to make F the subject.

Expect to see (F =) 190(.184) (N)

Accept a correctly rounded answer to 2 or more significant figure.

(θ =) 17(.4) (°) ✓

(Calculator displays: 17.35298907 for mg sin θ and 65g sin θ and 637.65 sin θ)

As an alternative to 17.35298907 may see Calculator display or answer of:

- *17.34316751 for 638 sin θ = 17(.3)*
- *17.3515853 for 637.7 sin θ = 17(.4)*
- *17.28726034 for 640 sin θ = 17(.3)*

Common ecf:

(65gcosθ = 190) = 72.6 (°) or 73(°) scores MP1 and MP2

(65 tanθ = 190) = 71.1 (°) or 71(°) scores MP1 and MP2

Use of $W = Fs$ cosθ is only acceptable as an ecf where F = 65g and component of weight is given as 65gcosθ (or equivalent) in part (a)

Alternative MP1:

height gain per second = 0.486 m ***and*** *distance along the slope per second = 1.63 m*

OR

Use of $\sin\theta = \dfrac{\text{height gained per second}}{\text{distance travelled per second}}$

2

(c) Less (useful) power output ✓

Same gain in (gravitational) potential energy (in climbing hill) / same amount of work done (in climbing hill) / gains same height (in climbing hill) ✓
Gains less (gravitational) potential energy every second ✓

OR (component of weight doing work against)
Less (useful) power output ✓

Effective θ has decreased / mg sin θ has decreased / component of the weight parallel to the slope has decreased ✓

General marking principle:
MP1 less (useful) power output
MP2 basic point
MP3 explains consequences of basic point in terms of power (MP3 is an extension of MP2, quoting $P = \frac{\Delta W}{\Delta t}$ *without linking to an appropriate explanation is insufficient).*

Smaller force does less work per second ✓

OR (component of vertical velocity)
Less (useful) power output ✓

The vertical component of the velocity has decreased / height gained per second decreases ✓

Loses MP1: where conflicting statements made about (useful) power output / states more power output / total power output is same.
Loses MP3 for conflicting statements made in support of explanation.
Accept θ as the effective angle to the slope.

(P =) mgv sin θ has decreased / $P = \frac{\Delta W}{\Delta t}$ has decreased / less work done (against the weight) per second / Less gain in (gravitational) potential energy per second ✓

OR (distance travelled)

Less (useful) power output ✓
Less force is exerted over greater distance (for same change in height) ✓
Smaller force does less work per second ✓

Treat 'inputs more energy' or 'does more work' as neutral.
Condone P = E/t has decreased as MP3

(d) Draws tangent which touches curve between 9 and 11 s ✓

Must see an attempt to draw a tangent to curve to score any marks.

Determine gradient of a tangent drawn at 5s /
Determines gradient of tangent drawn at 10s ✓

Read-offs must be within square of accuracy $\frac{1}{2}$

Condone one read-off error.

For tangent at t = 5s, expect to see an answer of 0.61 to 0.71 (m s^{-2}). MAX 2 marks for this.

(acceleration =) 0.21 (m s^{-2}) ✓

Accept answers in range 0.15 to 0.27 (m s^{-2})

Accept 2 or 3 significant figures only.

MAX 1 mark

*Condone a correctly determined gradient for a tangent to the curve at **any other** point **between** 5 and 11 seconds.*

3

(e) Air resistance increases (with speed) / resistive forces increase (with speed) / Energy is transferred from the cyclist (due to work done) by resistive forces ✓

Condone 'frictional forces increase with speed'
Treat kinetic energy is transferred from the cyclist as neutral.

MAX 3 from:

Initially, any of the gravitational potential energy that is transferred is transferred to kinetic energy of cyclist ✓

As speed increases, less of the gravitational potential energy transferred per second is transferred to kinetic energy of cyclist ✓

As speed increases, energy transferred per second to the air increases / as the speed increases, the energy transferred per second from the cyclist increases ✓

At top speed, the gravitational potential energy that is transferred (per second) is transferred to the air / the gravitational potential energy (transferred per second) is being transferred (from the cyclist) due to work done by resistive forces ✓

The answer must be written in terms of energy transfers

4

[13]

Q16.

(a) (a =) 9.81 sin30 = 4.9 ($m\ s^{-2}$) seen ✓

Allow g sin30

Accept cos60

1

(b) Substitutes into $v^2 = u^2 + 2as$ eg $v^2 = 2 \times 5 \times 0.3$

OR

Uses $\frac{v^2}{2} = g\ 0.3 \cos 60$ ✓

1.7 ($m\ s^{-1}$) ✓

Do not allow 9.81 for a in suvat equation.

2

(c) attempt to find area between 0.35 s (**B**) and 0.80 s (**C**) $_1$ ✓

*Max 1 for counting (small) squares **AND** a conversion factor of 2 N s stated*

Do not allow use of approximated shapes.

For $_1$ ✓ need to see working for at least one part of the area under the graph.

May see:

Triangle: 0.5 × 0.05 × 1100 = 27.5

Trapezium: 0.5 × (1100 + 1300) × 0.10 = 120

Trapezium: 0.5 × (1000 + 1300) × 0.15 = 172.5

Triangle: 0.5 × 0.15 × 1000 = 75

answer in range 390 to 400 (N s) $_2$ ✓

Treat "400" as a 2 sf answer.

2

(d) uses a relevant time in suvat equation(s) to get s $_1$ ✓

For $_1$ ✓ condone 9.81 for a.

Do not allow $_1$ ✓ or $_3$ ✓ for solutions that use u = 1.7 $m\ s^{-1}$

*For $_1$ ✓ allow 0.60 to 0.63 s for duration **C** to **D**.*

1. *Direct method: $s = \frac{1}{2} at^2$*
2. *a) Obtains u first using $v = u + at$ **OR***

$s = ut + \frac{1}{2} at^2$

*2. b) Then s using $s = \frac{1}{2}(u + v)t$ **OR***

$v^2 = u^2 + 2as$

doubles their s **OR** halves their **C** to **D** duration $_3$ ✓

Expect to see $u = 1.5$ (m s^{-1})

answer that rounds to 0.5 (m) $_3$ ✓

For $_3$ ✓ accept 0.44 (m).

3

(e) reads resting force from graph = 360 N **OR**
divides an incorrect reading by 5 (4.91 N/kg) $_1$ ✓

72 (kg) or 73 (kg) $_2$ ✓

*for $_1$ ✓ allow use of their **part (c)** with $\Delta v = 3.2$ m s^{-1}*

2

[10]

Q17.

(a) Volume of A = area × length = 4.16×10^{-4} m^3
OR
Mass of A = W/g = 3.6 kg ✓

Condone POT error in MP1

Use density equation ✓

Do not allow use of weight in density equation

Compares

a calculated property of brass (e.g. weight, length or diameter) with A

OR

the calculated density of A with density of brass

Do not accept 8.3×10^3 for density of A .

OR

the calculated mass of A with the calculated mass of brass

Award zero marks for an unsupported answer "Brass"

and therefore brass ✓

Only award MP3 if answer "brass" given.

Example:

Volume of A = area × length = 4.16×10^{-4} m^3 ✓
Mass if brass = density × volume = 3.58 kg ✓
Weight = 3.58 × 9.81 = 35 N (which is weight of A) and therefore brass is correct.

3

(b) Use of T = (35) cos 55 ✓
2 × their T (= 40 N) ✓

2

(c) Angle (to horizontal) decreases ✓

(Weight/tension in rope remains constant at 35 N)

So horizontal components (from tension in rope) increase ✓

Do not award MP2 if answer suggests that tension in rope increases.

(Therefore tension in cable must increase)

Do not allow "tension increases" for credit.

2

(d) Component of the force at right angle to door

= 41 cos (90−12) / 41 sin (12)

= 8.5 N ✓

Moment = 8.5 × 0.95 = 8.1 $(\mathrm{N\ m})$ ✓

Alternative:
Perpendicular distance = 0.95 sin (12)
= 0.198 m ✓
Moment = 41 × 0.198 = 8.1 ✓

Allow ecf from their value of weight component .

Allow ecf from their value of perpendicular distance.
(Calculator value is 8.098 160 3)

Award zero marks for simply multiplying 41 N × 0.95 m.

2

(e) ALTERNATIVE 1

Increase weight / density / mass / volume of **A** ✓

Increases tension (and therefore moment) ✓

ALTERNATIVE 2

Position pulley **R** further (out) from gate hinges / increase diameter of pulley **R**. ✓

Increases angle and therefore bigger perpendicular component (and therefore moment). ✓

Any 2 alternatives

ALTERNATIVE 3

Decrease angle of rope eg by putting P and fixed point closer together / further to right. ✓

Increases tension (and therefore moment). ✓

If more than two answers given, mark first two.
Ignore the 1 and 2 in answer lines.

ALTERNATIVE 4

Move **D** further from hinge/**R** OR make **C** longer. ✓

Increases perpendicular distance (and therefore moment). ✓

4

[13]