Mark schemes

Q1.

(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:

  $\Delta E_P = E_K$ + 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 $E = \frac{1}{2}F\Delta L$

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

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

2

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

Accept
$1.2\,E = \frac{k \times 1.2\,L}{A} \Rightarrow \cancel{1.2}\,E = \frac{k \times \cancel{1.2}\,L}{A} \Rightarrow E = \frac{k \times L}{A}$
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]

Q2.

(a) value in range 2.9×10^4 to 3.0×10^4 (N) ✓

Use of data from any point (plotted or using their line or using their B for brass) is acceptable

1

(b) smooth curve through at least 4 saltires $_{1a}$✓

$_{1a}$✓ *Reject thick or discontinuous lines*

$_{1a}$✓ *can be awarded if no credit gained in* $_{1b}$✓ *or* $_{2b}$✓

correct read off at 1.60 mm, leading to answer in range 58 to 64 (kg mm^{-2}) $_{2a}$✓

$_{2a}$✓ *2 or 3 sf values only*

OR

use of $B = \frac{\text{their } F}{\pi \times g \times 10 \times 1.6}$ $_{1b}$✓

$_{1b}$✓ *Condone use of D and h in metres if also seen (and penalised) in* ***part (a)***

consistent calculation of *B* $_{2b}$✓

$_{2b}$✓ *2 or 3 sf values only*

$_{2b}$✓ *Their B should be* $\frac{\text{their } F}{493}$

2

(c) uses $B = \frac{F}{\pi g D h}$ to:

evaluate *h*, and compare to radius/diameter of steel sphere

OR

evaluate (minimum value of) *B* based on radius/diameter of steel sphere, and compare to 5 (kg mm^{-2}) $_1$✓

$_1$✓ *Expect h = 19 mm*

$_1$✓ *Condone 'steel ball will be completely pushed into the lead' for comparison*

$_1$✓ *Reject references to graph scale e.g. 'h scale only goes up to 3.5 mm on graph'*

reduce *F*

OR

increase *D* $_2$✓

$_2$✓ *Condone 'use a steel sphere with D > 19 mm' or 'use a bigger sphere'.*

2

(d) travelling microscope

OR

micrometer / screw gauge

OR

digital vernier calliper ✓

1

(e) *d* is (always) larger (than *h*) 1a✓

so percentage / % uncertainty is smaller 1b✓

1 mark for an advantage AND 1 mark for a relevant explanation. No credit for an explanation without the relevant advantage.

Allow reverse arguments throughout e.g. 'h is (always) smaller than d '

OR

d can be measured in different directions 2a✓

so can obtain an average 2b✓

2a✓Allow 'can take multiple readings of d' or 'h can only be measured once'

2b✓Allow 'can identify anomalous readings' or 'can reduce the effect of random error'

OR

idea that readings for *d* are clearer to judge (than for *h*) 3a✓

so measurement is closer to true value / more accurate 3b✓

3a✓Allow 'difficult to see where the centre of indentation is for h' or wtte.

3a✓ Allow 'easier to define d'. Reject 'easier to measure d '.

3b✓ Allow idea that parallax error can be reduced.

2

[8]

Q3.

(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]

Q4.

(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. 9×10^{-4} *to* 12.7×10^{-4}

1

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

(halves load)

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

$\Delta L = 1.1(4) \times 10^{-3}$ (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

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

Or separate calculations using $\sigma = F \div A$, $E = \sigma \div \text{strain}$, $\text{strain} = \Delta L \div L$

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]

Q5.

(a) place mirror behind ruler $_1$✓

for $_1$✓ do not insist on contact between mirror and ruler

1

adjust position (of eye / head) until pin hides / lines up with its own reflection / image $_2$✓

condone use of (non-hypotenuse) edge of set-square to define horizontal plane $_1$✓

adjust position until horizontal edge of set square meets/is touching pin or wtte $_2$✓

if no other mark given award $_{12}$✓ = 1 max for 'read value at eye level' OR move (clamped) ruler closer to pin

give credit for any relevant annotation to Figure 1 or in additional sketch

1

(b) valid strategy using apparatus in **Figure 2**:

y (as the dependent variable) measured (or wtte) for different values of one independent variable (only L or m are acceptable) $_1$✓

for $_1$✓ must refer to variables only using the symbols and/or terms given in ***(a)****;*

accept 'weight' / mg as independent variable

condone mock table as intent / y = 'extension'

1

identifies the correct control variable (besides w and t) $_2$✓

for $_2$✓ L = control variable if m = independent variable OR m = control variable if L = independent variable;

if L is being varied and m = 250 g is stated, this can be taken as m = control variable and therefore known;

take a similar approach if m is being varied but in this case L must have a ***quoted value*** *that is ≤ 30 cm;*

for more than one independent variable, eg variation of both m and L $_{12}$✗✗ but allow ECF for $_4$✓ as long as plot is valid, eg y against mL_3

1

suitable measuring instruments for L OR w OR t $_3t$ $_3$✓

ANY ONE of the following (for more than one response mark as LIST)

for L: use ruler;

for w: use (any type of vernier) callipers; accept micrometer (screw gauge);

for t: use micrometer (screw gauge); accept digital / electronic (vernier) callipers

1

analysis:

suggests valid plot $_4$✓

identifies correctly how E can be found from a valid plot $_5$✓

for $_4$✓ expect y [by itself or combined with another factor] on one axis and their independent variable [by itself or combined with another factor] on the other axis; do not insist on y as ordinate

1

for $_5$✓ E must be the subject; some examples include:

ordinate	abscissa	$E =$
y	m	$\frac{4 \times L^3 \times g}{w \times t^3 \times \text{gradient}}$
mg	y	$\frac{4 \times L^3 \times \text{gradient}}{w \times t^3}$
y	L^3	$\frac{4 \times m \times g}{w \times t^3 \times \text{gradient}}$
y	$\frac{4 \times L^3}{w \times t^3}$	$\frac{m \times g}{\text{gradient}}$
$\log y$	$\log m$	$\frac{4 \times g \times L^3}{w \times t^3 \times 10^{\text{intercept}}}$
$\log y$	$\log L$	$\frac{4 \times m \times g}{w \times t^3 \times 10^{\text{intercept}}}$

1

[7]