AQA A-LEVEL PHYSICS · 7408

PHYSICS



MARK SCHEME

3.4.1 FORCE, ENERGY AND MOMENTUM · PACK 4

SCORE	PERCENTAGE
/428	%

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Mark schemes

1. (a) ANY 2 from

- Slow moving neutrons or low (kinetic) energy neutrons

B1

- (They are in) thermal equilibrium with the moderator / Are in thermal equilibrium with other material (at a temperature of about 300 K)

B1

- Have energies of order of 0.025 eV
- Have (range of) KE similar to that of a gas at 300 K or room temperature

2

(b) (i) Use of $mgh = ½ mv^2$ by substitution or rearranges to make h the subject

PE for use of equation of motion (constant acceleration)

C1

0.086(1) (m) or 0.086(2) (m)

A1

2

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(ii) Correct equation for conservation of momentum

$m_1u_1 (+ m_2u_2) = m_1v_1 + m_2v_2$

or states momentum before = momentum after **or** $p_{before} = p_{after}$

B1

(Correct clear Manipulation =) 0.065 (+ 0) = − 0.0325 + 0.0975

or −0.065 (+ 0) = 0.0325 − 0.0975 must see signs

Condone non−SI here:
65 (+0) = − 32.5 + 97.5

B1

States initial kinetic energy = final kinetic energy **or**
States kinetic energy is conserved

Allow equivalent on RHS where masses are summed in one KE term

B1

(Correct clear Manipulation=) 0.04225 = 0.0105625 + 0.0316875

Or equivalent workings with numbers seen

and 0.04225 = 0.04225 / KE before = KE after

B1

4

(iii) (Percentage / fraction remaining after 1 collision =) ¼ = 25% **seen**

C1

OR

% remaining = 100 × ½ $m(1.3^2 - 0.65^2)$/ ½ $m1.3^2$
or hockey ball = 0.0317 **and** initial ke = 0.04225
or their KE_{hb} / 0.04225 or their KE_{hb} / their KE_T

75(%) range 75 to 76

A1

2

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(iv) **Demonstrates:**
Slowing down / loss of KE of golf ball is like neutrons slowed down / Neutrons can lose KE by elastic collisions also

B1

Differs:
Collisions in a reactor are not always / rarely head-on
or
KE loss is variable
or
Collisions are not <u>always</u> elastic
or
Ratio of mass of neutron to mass of nucleus is usually much smaller in a reactor

B1

2

(v) Water

B1

1

[13]

2. (a) (i) $(s = \frac{1}{2}gt^2\ )$

Allow g=10 (0.5477)

$1.5 = \frac{1}{2}9.81t^2$ OR $t = \sqrt{\frac{2s}{g}}$ OR $t = \sqrt{\frac{2\times1.5}{9.81}}$ ✓

(= 0.553) = 0.55 (s) ✓

0.6 gets 2 marks only if working shown. 0.6 on its own gets 1 mark.

2

(ii) ($s = v\,t$ = 430 × 0.553 = 237.8 =) 240 (m) ✓
ecf a(i)

1

(b) their vertical motion is independent of their horizontal motion
OR <u>downward</u> / <u>vertical</u> acceleration is the same for both
OR acceleration <u>due to gravity</u> is the same for both
OR <u>vertical</u> speed / velocity is the same for both ✓

Allow 'time is constant'
Don't allow 'similar'

(bullets A and B will be in the air) for the same time ✓

(Horizontal acceleration is zero and thus horizontal) distance is proportional to <u>horizontal</u> speed **OR** $s = ut$ where u is the <u>horizontal</u> velocity ✓

'velocity smaller so distance smaller' is not sufficient

3

[6]

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3.

(a) (i) $W = 2mg\cos\varphi \quad \therefore m = W/(2g\cos\varphi)$✓

The question says <u>show that</u>, so the candidates must write down both steps.

1

(ii) Well drawn straight line of best fit.✓

The line should follow the trend of the points with an even scatter of points on either side of the line.

1

(b) (i) Triangle drawn with smallest side at least 8 cm in length. ✓
Correct readings taken from the line for the triangle ✓
Gradient in the range 0.45 to 0.49 (0.445 to 0.494) quoted to 2 or 3 significant figures ✓

The size of the triangle can be identified from readings taken from the line.
The third mark is independent of the other two: error carried forward for incorrect readings (or for a poor line of best fit) which give a gradient out of range is not allowed.

3

(ii) Candidate's answer for gradient in (b)(i) correctly multiplied by g (expected answer 4.6)✓
N ✓

No s.f. penalty.
The second mark is for the unit and can be awarded if the numerical answer is incorrect.

2

(c) $\delta x\% = 0.2$ and $\delta y\% = 0.5$✓
$\delta(x/y)\% = \delta x\% + \delta y\% = 0.2 + 0.5 = 0.7$ ✓
Use of $\delta(x/y.)^2\% = 2 \times \delta(x/y)(\%)$ ✓

Final answer is (±) 1.4 (%) which automatically gains all three marks
Otherwise
Accept only 1 s.f. for 1st and/or 2nd marks.
The third mark is for the method, not the final answer

3

(d) (i) Systematic errors in measurements are errors which show a pattern or a bias or a trend ✓

Some acceptable alternatives
- ***A systematic error** is one which deviates by a fixed amount from the true value of a measurement*
- *An error which has the same value in all readings*
- *A difference between the true value of a quantity and the indicated value caused by a fault in the measuring device*
- *Accept a good example of systematic error.*

1

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(ii) y would be larger✓
because angle θ would be smaller
or
because friction would be opposing the increasing weight of m✓

2

[13]

4. (a) (i) 1000(N) AND 6000(N) seen
Independent marks

OR

$F = \sqrt{(1000)^2 + (6000)^2}$ ✓ allow incorrect values seen
= **6083** (N) (= 6100) ✓ More than 2 sf seen
Allow full credit for appropriate scale drawing
Ignore rounding errors in 3rd sig fig.

2

(ii) tanΘ = 1000 / 6000 or correct use of sin or cos ✓
Θ = 9.5 (9.46°) ✓
Allow range 9.4 − 10.4
Use of cos yields 10.4
Allow use of 6100
Some working required for 2 marks.
Max 1 mark for correct calculation of vertical angle (range 79.6 − 80.6) some working must be seen

2

(iii) (*m = W/g* =) 6500 / 9.81 (= 662.6 kg) ✓
(*a = F / m* = 6083 / 662.6)
= 9.2 (ms^{-2}) ✓ (9.180)
Use of weight rather than mass gets zero
Correct answer on its own gets 2 marks
Penalise use of g=10 in this question part only (max 1)

2

(b) (i) = 6500 × 600 ✓ (662.6 × 9.81 × 600)
= 3 900 000 ✓ (J)
Look out for W x g x h which gives 39000000 (gets zero)
Correct answer on its own gets 2 marks
Do not allow use of 1/2 mv² (= 39 000)

2

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(ii) (E= Pt =) 320 000 ×; 55 (= 17 600 k J)
OR P= 1(b)(i) / 55 (7.09×10^4) ✓
3.9 / 17.6 OR 70.9 / 320 OR = 0.22(16) ✓ ecf from first line
Some valid working required for 3 marks

conversion to a percentage (= 22 %) ✓
Look out for physics error: Power / time (320/55) then use of inverted efficiency equation yielding correct answer
Do not allow percentages >= 100% for third mark

3

[11]

5. (a) Force proportional to extension ✓

up to the limit of proportionality (accept elastic limit) ✓ dependent upon award of first mark
Symbols must be defined
Accept word equation
*allow 'F=kΔL (or F ∝ ΔL) up to the limit of proportionality ' **for the second mark only***
*allow stress ∝ strain up to the limit of proportionality' **for the second mark only***

2

(b) Gradient clearly attempted / use of *k=F / ΔL*✓
k = 30 / 0.026 = 1154
or 31 / 0.027 = 1148

correct values used to calculate gradient with appropriate 2sf answer given (1100 or 1200)
1100 or 1200 with no other working gets 1 out of 2

OR 1154 ± 6 seen
Do not allow 32/0.0280 or 33/0.0290 (point A) for second mark.

AND load used >= 15 ✓ (= 1100 or 1200 (2sf))
32 / 0.028 is outside tolerance. 32/0.0277 is just inside.

Nm^{-1} / N / m (newtons per metre) ✓ (not n / m, n / M, N / M)

3

(c) any area calculated or link energy with area / use of 1 / 2FΔL ✓
(or 0.001 Nm for little squares)

35 whole squares, 16 part gives 43 ± 1.0
OR equivalent correct method to find whole area ✓

0.025 Nm per (1cm) square × candidates number of squares and correctly evaluated
OR (= 1.075) = 1.1 (J) (1.05 to 1.10 if not rounded) ✓

3

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(d) permanent deformation / permanent extension ✓

Allow: 'doesn't return to original length'; correct reference to 'yield'
*e.g. allow '**extension beyond the yield point**'*
do not accept: 'does not obey Hooke's law' or 'ceases to obey Hooke's law',

1

(e) any line from B to a point on the x axis from 0.005 to 0.020 ✓

straight line from B to x axis (and no further) that reaches x axis for 0.010<=ΔL<= 0.014 ✓

2

(f) work done by spring < work done by the load

Accept 'less work' or 'it is less' (we assume they are referring to the work done by spring)

1

[12]

6. (a) 8300 × 9.81 OR = 81423 ✓
(8300 × 9.81 sin 25)
= 3.4×10^4 (N) ✓ (34 411 N) ecf from first line unless g not used

msin25 gets zero

Penalize use of g = 10 here only
(35 077 N)
Allow 9.8 in any question
Correct answer only, gets both marks for all two mark questions

2

(b) (i) ($E_k = ½mv^2$)
= ½ × 8300 × 56^2 ✓
= 1.3×10^7 (J) ✓ (13 014 400) allow use of 8300 only

In general: Penalise transcription errors and rounding errors in answers

2

(ii) *mgh* = KE (13 014 400) for *mgh* allow GPE or E_p
OR 13 014 400 / 81 423 ✓
h = 160 (m) ✓ (159.8) ecf 1bi

Allow use of suvat approach

2

(c) (i) (work done) by friction \ drag \ air resistance \ resistive forces ✓
(energy converted) to internal \ thermal energy ✓

Allow 'heat'

2

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(ii) 0.87 x (8300 x 9.81 x 140 = 9 917 000) OR $v = \sqrt{\left[\frac{2 \times (9\,917\,000)}{8300}\right]}$ ✓

= 49 (= 48.88 ms^{-1}) ✓

87% of energy for 140m or 160m only for first mark.
Use of 160 (52.26) and / or incorrect or no % (52.4) gets max 1 provided working is shown
Do not credit suvat approaches here

2

[10]

7. (a) (i) vector has direction **and** a scalar does not **(1)**

(ii) scalar examples; any two e.g. speed, mass, energy, time, power

vector examples; any two e.g. displacement, velocity, acceleration, force or weight

(1)(1)(1) for 4 correct, **(1)(1)** for 3 correct, **(1)** for 2 correct

4

(b) (i) horizontal component (= 2.8 cos 35) = 2.3 (kN) (2293.6) **(1)**

vertical component (= 2.8 sin 35) = 1.6(kN) (1606.0) **(1)**

(ii) power = force × velocity **or** 2.3 kN × 8.3 m s^{-1} **(1)** (ecf from (b) (i))

= 1.9 × 10^4 (19037 or 19100) **(1)** ecf

W (or J s^{-1}) **(1)** (or 19 W (or kJ s^{-1}))

5

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(c) (area of cross–section of cable =) $\pi \times (\frac{1}{2}\ 0.014)^2$ **(1)**

$= 1.5(4) \times 10^{-4}\ (m^2)$ (1)

stress (=F/A) = $\frac{2800\ N}{1.54 \times 10^{-4}\ m^2}$

(allow ecf here if attempt to calculate area) **(1)**

$= 1.8(2) \times 10^7$ **(1)** ecf

Pa (or N m^{-2}) **(1)**

QWC	descriptor	mark range
good-excellent	The candidate provides a comprehensive and coherent description which includes all the necessary measurements in a logical order. The description should show awareness of the need to use a range of standard masses. In addition, the use of the measurements is explained clearly, including an outline of a graphical method to find the mass of the rock sample, or calculation using two or more standard masses and averaging. For 6 marks there must be a description of how to make accurate measurements.	**5-6**
modest-adequate	The candidate's description includes the necessary measurements using one standard mass as well as the rock sample. The description may not be presented in a logical order and they show little consideration in relation to making the measurements accurately. A clear explanation is provided of how to find the mass of the rock sample from their measurements, including correct use of Hooke's law through calculations or inadequate graphical method.	**3-4**
poor-limited	The candidate knows the necessary measurements to be made using a standard mass and the rock sample. The explanation of how to find the mass of the rock sample may be sketchy.	**1-2**

5

[14]

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8. correct boxes ticked

gravitational potential energy **(1)**

B1

potential energy **and** kinetic energy **(1)**

B1

elastic potential energy (in 'rope') **(1)**
(condone gravitational PE in addition)

B1

[3]

9. (a) 2800/cos 20 = 3000 (2980)N **(1)**

B1

1

(b) 42000J **(1)**

B1

1

[2]

10. (a) velocity vector tangential to path and drawn from the ball, arrow in correct direction **(1)**

acceleration vector vertically downwards, arrow drawn and in line with ball **(1)**

2

(b) (i) $s = \frac{1}{2} gt^2$ gives $t = \sqrt{\frac{2y}{g}} = \sqrt{\frac{2 \times 24}{9.8(1)}}$ **(1)** = 2.2(1) s **(1)**

(ii) v (= s/t) = 27/2.2(1) **(1)** = 12(.2 m s^{-1}) or 12(.3) **(1)** (ecf from (b)(i))

(answer only gets both marks)

4

[6]

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11. vertical component of rope = 610 × cos (20) or 573(N)

C1

610 cos 20 seen in an equation

(vertical component of resultant) = 590 – 573 or their F_v

C1

16.8 or 17(N) cao

A1

[3]

12. work done = 1500 × 0.35(525J)

or power = work done/time taken **(1)**

C1

615-620W **(1)** 2 or 3 sf only

A1

[2]

13. (a) (i) 65 × 9.8 × 35 seen and evaluated to 22295 or 2231 or 22300J

B1

(ii) correct substitution of 65 kg and either 11000J or 18 m s^{-1} in ke formula seen

B1

18.4 (18.397) (m s^{-1}) to at least 3 sf

B1

(iii) distance = energy loss/force or work done/force or numerical equivalent

C1

64-64.3 using E_p = 20kJ or 79 – 81(m) using 22.3 kJ

A1

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(iv) friction

B1

air resistance

B1

further detail eg friction at ski-ice surface

or caused by need to move air when passing through it

B1

8

(b) (i) time = $\Delta v/a$ or numerical equivalent

C1

6.4(3) – 6.6(6.57) (s)

A1

(ii) use of appropriate kinematic equation

C1

(57.8 – 60.4) 58 m or 60 (m) to 2 sf

A1

4

[12]

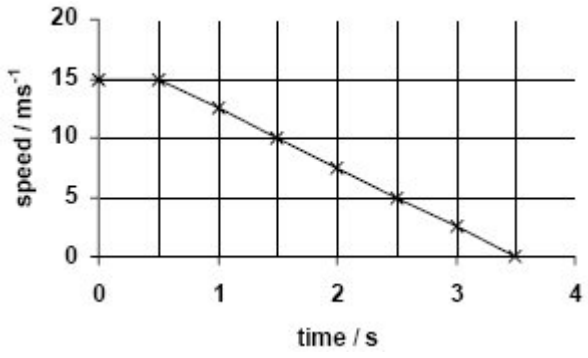
14. (a) axes labelled correctly with correct units shown **(1)**

suitable scales **(1)**

6 points plotted correctly **(1)**

all points plotted correctly **(1)**

both sections of line drawn correctly **(1)**



5

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(b) (i) the gradient (of the slope section) represents the deceleration/ calculates 5 m s^{-2} **(1)**

(deceleration is uniform because) the gradient is constant/ line is straight **(1)**

(ii) distance travelled = area under line (0 to 3.5 s or 0.5 to 3.5 s) **(1)**

(= 15.0 × 0.5) = 7.5 m in first 0.5 s **(1)**

(= 0.5 × 15.0 × 3.0) or s = ½(u + v)t, etc) = 22.5 m (from 0.5s to 3.5s) **(1)**

(= ½(0.5 + 3.5) × 15 gets all three method marks) (total distance travelled = 7.5 + 22.5) = 30m **(1)**

6

[11]

15. (a) (i) clear working:

attempts to evaluate area under line (12 – 13 squares × 0.1 N s) or ½ × 106(105) × 24 × 10^{-3} seen

B1

1.260 – 1.272 (N s) 1.2 – 1.3 for square counting

B1

(ii) area under graph/impulse = Δ*mv*

B1

22.3 (22.8) (m s^{-1})

B1

4

(b) use of Pythagoras $\sqrt{22.3^2 + 6.1^2}$ or $\tan^{-1}$ (6.1/22.3)

B1

or $\sqrt{20^2 + 6.1^2}$ or $\tan^{-1}$ (6.1/20)

22.8 – 23.8(m s^{-1}) 20.9 or 21(m s^{-1})

B1

14.9 – 15.5 (°) (15 – 16 (°)) 17/18(°)

B1

3

[7]

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16. (a) a force/1300 (condone power of ten error)

C1

6200 ÷ 1300

C1

4.77 (m s^{-2})

A1

3

(b) use of suitable kinematic equation

C1

eg distance = $27^2/(2 \times 4.8)$ correct sub

C1

76/76.4 m/72.9 from a = 5/75.9 from a = 4.8

A1

3

[6]

17. B

[1]

18. (a) (i) ($E_K = ½ mv^2$ =) 0.5 × 68 × 16^2 **(1)** = **8700** or 8704(J) **(1)**

(ii) ($\Delta E_P = mg\Delta h$ =) 68 × 9.8(1) × 12 **(1)** = **8000** or 8005 (J) **(1)**

(iii) any **three** from

gain of kinetic energy **>** loss of potential energy **(1)**

(because) cyclist does work **(1)**

energy is wasted (on the cyclist and cycle) due to air resistance or friction or transferred to thermal/heat **(1)**

KE = GPE + W – energy 'loss' **(1)** (owtte)

energy wasted (= 8000 + 2400 - 8700) = 1700(J) **(1)**

7

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(b) (i) (u = 16 m s^{-1}, s = 160 m, v = 0, rearranging s = ½ (u + v) t gives)

160 = ½ × 16 × t or $t = \frac{2s}{(u+v)}$ or correct alternative

$\frac{2 \times 160}{16}$ (gets 2 marks) **(1)** = 20s **(1)**

(ii) acceleration $a = (\frac{v-u}{t} =) \frac{0-16}{20}$ ecf (b) (i) **(1)** = (–) **0.80** (m s^{-2})
resultant force $F = ma$ = 68 × (–) 0.80 **(1)** = (–) 54 (N) **(1)** or 54.4
or (work done by horizontal force = loss of kinetic energy
work done = force × distance gives)

force = $\frac{\text{(loss of kinetic) energy}}{\text{distance}}$ **(1)** = $\frac{8700\ \text{J}}{160\ \text{m}}$

ecf (a) (i) **(1)** = 54 (N) **(1)**

6

[13]

19. (a) (i) area under graph = energy stored

B1

area = ½ base × height

B1

or quotes ½ $F\Delta l$ **and** identifies F as F_{max} and Δl as d_{max}

B1

2

(ii) equates ½ $F\Delta l$ and ½ mv^2 clearly

M1

$v^2 = F_{max}d_{max}/m$ shown

A1

2

(b) (i) √650*0.60/0.060

M1

81(80.6) (m s^{-1})

A1

2

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(ii) **max 1 from**

friction between arrow and bow during release

B1

bow moves during release so absorbs some energy in kinetic form flight feathers provide drag

B1

uneven stretch/distortion in bow during draw

B1

1

(c) (i) $65\cos(35°) = 53.2$ (m s^{-1})

B1

1

(ii) $0 = 53.2 - 9.8 \times t$ seen condone sign errors

B1

t = 5.4 s to top of motion

B1

in air for 10.8/10.9 s

B1

or $0 = 53t - ½ \times 9.8 \times t^2$ seen

condone sign errors

B1

$53t = ½ \times 9.8 \times t^2$

sign working must be correct

B1

in air for 10.8 s

must be from correct working

B1

3

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(iii) $s = 65 \times \cos(55°) \times 10.8$

C1

400 (m) 2 sf/405 (m) sf/410 m from 11 s

A1

2

[13]

20. D

[1]

21. (a) conversion to seconds seen (60×40)
or velocity = 300/40 seen
or energy gain in 40 mins = $750 \times 300 = 2.25 \times 10^5$ (J)

C1

use of $p = Fv$
power = $750 \times (300)/(2400)$
or 750 × their velocity (eg seen 750 × 300/40)

C1

94 (93.8) (W) cnao

A1

3

(b) $k = \frac{750}{15 \times 10^{-3}}$ (allow use of m or mm) use of $k = F/\Delta L$

C1

5.0×10^4

A1

N m^{-1} (allow if calculation not attempted or incomplete)

A1

3

[6]

22. (a) $\sqrt{(1.3^2 + 1.0^2)}$

C1

1.6/1.64 (m s^{-1})

A1

2

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(b) angle = $\tan^{-1}$ (1.0/1.3)

C1

N38°E/N37.6°E

A1

2

[4]

23. (a) (i) *(s = ½(u + v) t) t = 2s/v* ✓ (correct rearrangement, either symbols or values)

(= 100/6.7) = 15 ✓ (s) (14.925)

or alternative correct approach

2

(ii) (*KE* = 1/2mv^2 = ½ × 83 × 6.7^2) = 1900 ✓ (1862.9 J)

2 sf ✓

2

(iii) GPE = 83 × 9.81 × 3.0 ✓ penalise use of 10, allow 9.8

= 2400 (2443 J) ✓ do not allow 2500 (2490) for use of g = 10

2

(b) (i) 5300 + 3700 (or 9000 seen)

or – 2443 – 1863 (or (–) 4306 seen) ✓

= 4700 (J) ✓ (4694) ecf from parts aii & aiii

2

(ii) mention of friction and appropriate location given ✓

mention of **air** resistance (or drag) ✓

do not allow energy losses or friction within the motor

do not allow energy losses from the cyclist

must give a **cause** not just eg 'heat loss in tyres'

2

[10]

24. (a) (i) (*m* = *ρV*) = 1.2 × 3.5 × 10^5 must be seen **(1)**

4.2 × 10^5 (kg) seen **(1)**

2

(ii) ($E_k = \frac{1}{2} mv^2$) = $\frac{1}{2}$ × 4.2 × 10^5 × 11^2 **(1)**

2.5 or 2.4 × 10^7 (J) **(1)** (25.4 or 24.2 MJ)

2

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(iii) $\frac{10 \times 10^6}{2.54 \times 10^7}$ **(1)** allow ecf from (a) (ii)

39 to 41.6 (%) **(1)** allow ecf from (a) (ii) unless percentage is greater than 100

2

(b) **advantages**, any one:

wind has: no fuel cost/causes no air pollution/no CO_2/is renewable **(1)**

disadvantages, any one from:

wind: varies/is intermittent/unreliable/causes visual pollution/noise/ danger to birds/has a high capital cost/high 'start up' cost/requires changes to National Grid need **(1)** allow 'unpredictable'

2

[8]

25.

(a) (i) $v = \frac{s}{t}$ **(1)**

t = 0.015 (s) or 15 (ms) **(1)**

0.68/0.015 **(1)** (= 45)

3

(ii) $\left(a = \frac{\Delta v}{\Delta t} = \frac{45.3}{0.015}\right)$ = 3000 (m s^{-2}) (3022) **(1)**

1

(b) (i) $s = (ut) = \frac{1}{2} gt^2$ or $t = \sqrt{\frac{2s}{g}}$ **(1)**

correct substitution seen = $\sqrt{\frac{2 \times 2.3}{9.81}}$ **(1)**

0.68 to 0.69 correct answer to more than one dp seen **(1)**

3

(ii) ($s = vt$) = 45(.3) × 0.685 or 0.7 **(1)**

= 30.6 to 32 **(1)** (m)

2

(iii) mention of air resistance or drag **(1)**

causing **horizontal** deceleration or 'slowing down' **(1)**

2

[11]

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26. (a) (i) force × perpendicular distance **(1)**

between line of action of force and the point **(1)**

2

(ii) rear **(1)**

at rear + idea that centre of mass is closer to the rear wheel (than to the front wheel) **(1)**

2

(iii) 14000 × 1.4 = F × 2.5 **(1)**

F = 7840 (N) **(1)**

divides their final answer by 2 **(1)**

= 3900 (N) **(1)** (3922)

4

(b) ($F = k\Delta l$) $\frac{F}{k}$ or ($\Delta l =$) $\frac{\text{(a)(iii)}}{100000}$ **(1)**

= 0.039 (m) **(1)** ecf

2

(c) F = (100000 × 0.065 =) 6500 (N) **(1)**

F = (2 × 6500) = 13000 (N) **(1)**

2

[12]

27. (a) (i) 180000 × 2.8 ✓

= 500000 ✓ (504000 Nm) ecf from first line for incorrect power of 10

2

(ii) 7.4 × lift fan thrust ✓

= 180000 × 2.8 (504000 Nm) ✓ ecf from part ai

F = 68000 or 68 k (N) ✓ (68108 N) ecf

3

(iii) 180k − 68.1k = (111.9 =) 112 k (N) ✓ ecf from part aii

or by taking moments

1

(b) (i) ($m = W/g$) = 180 000/9.81 ✓ (= 18349 kg)

$a = F/m$ = 155 000/18349 = 8.4 ✓ (8.4475 ms^{-2})
ecf for use of 180 in 1st mark

use of weight rather than mass gets zero

2

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(ii) **cross-sectional or surface** area / shape / streamlining / aerodynamics / nature of surface / drag coefficient ✓

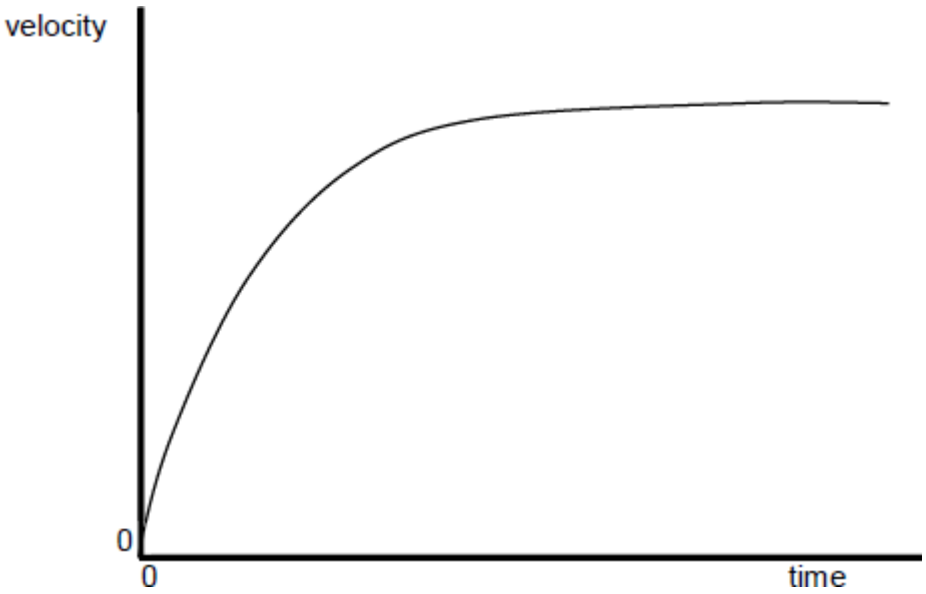
correctly linked to its effect on air resistance/drag ✓

or maximum thrust/force power of engine ✓

counterforce increases with speed

or when drag equals thrust (forces are balanced) ✓

2



line starting at zero and **curving with decreasing gradient** ✓

reaching a constant velocity ✓

2

(c) steepest/maximum gradient ✓

1

[13]

28. (a) *GPE* to *KE* to *GPE* ✓

no energy lost (from system) / no work done against resistive forces ✓

initial *GPE* = final (*GPE*) / initial (*GPE*) = final *GPE*

OR $h = GPE/mg$ and these are all constant so h is the same ✓

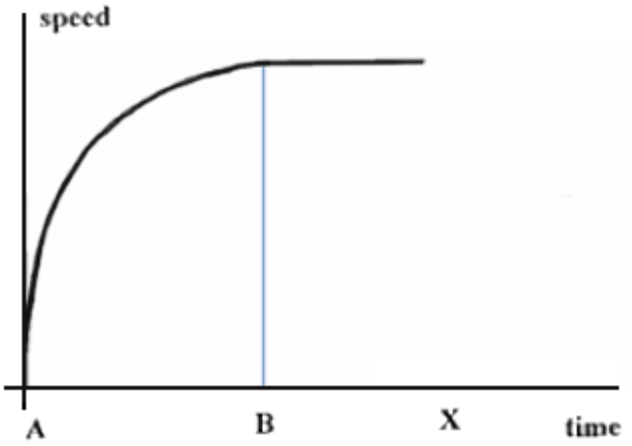
3

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(b) Initial curve with decreasing gradient and reaching constant maximum speed before X and maintaining constant speed up to X ✓

B labelled in correct place ✓

B labelled in correct place **AND** constant speed maintained for remainder of candidates graph and line is straight ✓



3

(c) (first law) ball travels in a straight line at a constant speed / constant velocity / (maintains) uniform / no change in motion / zero acceleration ✓

there is no (external) **unbalanced / resultant** force acting on it ✓

2

[8]

29. (a) extension divided by its **original** length ✓

do not allow symbols unless defined ✓

1

(b) 1.9×10^8 (Pa) ✓

1

(c) point on line **marked 'A'** between a strain of 1.0×10^{-3} and 3.5×10^{-3} ✓

1

(d) clear evidence of gradient calculation for **straight section**
eg 1.18 (1.2) $\times 10^8 / 1.0 \times 10^{-3}$ ✓

= 120 GPa **and stress used ≥ 0.6×10^8 Pa** ✓ allow range 116 − 120 GPa

Pa or Nm^{-2} or N/m^2 ✓

3

(e) (i) clear attempt to calculate correct area (evidence on graph is sufficient) ✓

(32 whole squares + 12 part/2 = 38 squares)

(38 × 10000 =) 380000 (J m^{-3}) ✓ allow range 375000 to 400000

2

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(ii) $V = m/\rho$ **or** 0.015/8960 **or** 1.674×10^{-6} (m^3) ✓

$380\,000 \times 1.674 \times 10^{-6} = 0.64$ (0.6362 J) ✓ ecf from ei

2

(f) straight line passing through origin (small curvature to the right only above 160 MPa is acceptable) end at 176 MPa ✓ (allow 174 to 178)

straight section to the left of the line for copper (steeper gradient) ✓

2

[12]

30. (a) $170 \times 10^3 \times \cos 40$ (**or** 1.3×10^5) ✓

$\times 1000$ ✓ ($= 1.302 \times 10^8$J)

2

(b) (i) ($P = Fv$) $= 1.3 \times 10^5 \times 7.0$ ✓

$= 9.1 \times 10^5$ ✓ (911.6 kW) ecf wrong force from part a

or correct alternative approach using $t = s/v$ and $P = E/t$

2

(ii) (total power =) 9.1 ($\times 10^5$) + 21 ($\times 10^5$) ✓ ecf from bi

powers of 10 must be consistent for this mark (eg not 9.1 + 2.1)

(percentage = (9.1/9.1 + 21) × 100)

= 30 (%) ✓

ecf for power of 10 error in first mark

ecf from bi, but must have attempted to calculate **total power**

eg 9.1/21 gains zero

2

(c) **any two from**

(surface) **area** (of the sail) ✓

wind speed/strength/power/KE/force (not air resistance) ✓

acceleration or speed of the ship ✓

2

[8]

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31. (a) (i) uses trigonometry *(mg sin*5 *or mg cos*85 seen)

B1

829.3 / 828.5 (N) at least 3 sf

B1

2

(ii) tension = 830 (N)

C1

$E = \frac{1}{2} F\Delta L$ **and** $F = k\,\Delta L$ identified / or combined to $E = \frac{1}{2}(F^2/k)$

C1

correct sub condone power 10 error

C1

13.8 (J) range 13.9 to 13.7

A1

4

(b) lower speed

B1

less extension

B1

less energy stored (in rope)

B1

3

[9]

32. (a) $\Delta h = 2.51 - 1.00 = 1.51$ (m) / (s =) 1.51 m seen

M1

use of appropriate kinematics formula correctly makes t subject

M1

time = 0.555 (s) / 0.56 (s) (allow 0.55 (s))

A1

3

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(b) (i) use of appropriate kinematics equation to find vertical v

C1

$v = 5.4$ (ms^{-1}) (accept 5.4 to 5.9)

A1

2

(ii) any use of Pythagoras where $v_h = 18$ or use of appropriate trig ratio where $v_h = 18$ and angle is to horizontal

C1

velocity = 18.8 / 18.9 / 19 (ms^{-1})

A1

angle = 16.8 to 18.1 (°)

A1

3

[8]

33. A

[1]

34. A

[1]

35. (a) (i) (moment = 520 x 0.26) = 140 (135.2) ✓

Nm ✓

2

(ii) **180 x 0.41** and **0.63 X** seen ✓

135.2 = 180 x 0.41 + 0.63 X ✓ ecf from (a)(i)

(X = (135.2 – 73.8) / 0.63)

= 97 ✓ (N) (97.46) allow 105 from use of 140Nm ecf from (a)(i)

3

(iii) (520 – (180 + 97.46))

= 240 ✓ (242.5 N) ecf (or from correct moments calculation)

1

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(b) (i) ($v^2 = u^2 + 2as$)

$9.3^2 = 2 \times a \times 35$ OR $9.3^2 = 70a$ OR $a = v^2/2s$
OR $9.3^2/70$ ✓

OR correct alternative approach

1.2 (1.2356) ✓ ($m\ s^{-2}$)

2

(ii) ($m = W/g$) = 520/9.81 (= 53.0) ✓ (kg)

$F = ma$ = 53 × 3bi (1.2356) = 65 (N) (65.49) ✓

accept use of 1.2 giving 64(63.6) , allow 53 x 124 = 65.7

2

[10]

36. A

[1]

37. C

[1]

38. B

[1]

39. (a) direction of induced emf (or current) ✓
opposes change (of magnetic flux) that produces it ✓

2

(b) (i) (volumes are equal and mass of Q is greater than that of P) density of steel > density of aluminium ✓

Allow density of Q greater (than density of P).

1

(ii) use of $s = \frac{1}{2} g t^2$ gives $t^2 = \frac{2 \times 1.0}{9.81}$ (from which $t = 0.45$ s) ✓

Backwards working is acceptable for 1st mark

(vertical) acceleration [**or** acceleration due to gravity] is independent of mass of falling object
[**or** correct reference to $F = mg = ma$ with m cancelling] ✓

2nd mark must refer to mass.
Do not allow "both in free fall" for 2nd mark.

2

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(c) (i) moving magnet [**or** magnetic field] passes through tube ✓ there is a change of flux (linkage)(in the tube)

[**or** flux lines are cut **or** appropriate reference to $\varepsilon = N(\Delta\phi / \Delta t)$] ✓

In this part marks can be awarded for answers which mix and match these schemes.

[**Alternative:**
(conduction) electrons in copper (or tube) acted on by (moving) magnetic field of Q ✓
induced emf (or current) is produced by redistributed electrons ✓]

2

(ii) emf produces current (in copper) ✓
this current [*allow* emf] produces a magnetic field ✓
this field opposes magnetic field (or motion) of Q
[**or** acts to reduce relative motion **or** produces upward force] ✓
no emf is induced by P because it is not magnetised (or not magnet)
[**or** movement of P is not opposed by an induced emf or current] ✓

***Alternative** to 3rd mark:*
current gives heating effect in copper and energy for this comes from ke of Q ✓

max 3

(d) time for P is unaffected because there is still no (induced) emf
[**or** because P is not magnetised
or because there is no repulsive force on P] ✓
time for Q is shorter (than in (c)) ✓
current induced by Q would be smaller ✓
because resistance of brass ∝ resistivity and is therefore higher
[**or** resistance of brass is higher because resistivity is greater] ✓
giving weaker (opposing) magnetic field
[**or** less opposition to Q's movement] ✓

Condone "will pass through faster" for 2nd mark.
If emf is stated to be smaller for Q, mark (d) to max 2.

max 3

[13]

40. (a) *(Ep = mgΔh)*
$= 65 \times 9.81 \times 54$ ✓
$= 3.44 \times 10^4 = 3.4 \times 10^4$ (J) ✓ (34433)

max 1 if g =10 used (35100 J)

Correct answer gains both marks

2

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(b) $v = \sqrt{\frac{2Ep}{m}}$ OR $v = \sqrt{\frac{2\times 34433}{65}}$ ✓ = 33 (32.55 ms^{-1}) ✓ ecf 1(a)

allow 32 (32.3) for the use of 34000
allow 32.6

OR correct use of $v^2 = 2\,g\,s$

don't penalise g = 10 (32.863)

2

(c) (s =1 / 2 gt^2 or other kinematics equation)

$t = \sqrt{\frac{2s}{g}}$ OR $t = \sqrt{\frac{2\times 54}{9.81}}$ ✓ = 3.318 = 3.3 (s) ✓

With use of g= 9.8 or 9.81 or 10 and / or various suvat equations, expect range 3.2 to 3.4 s.
No penalty for using g= 10 here.

ecf from 1(b) if speed used

2

(d) (all G)PE (lost) is transferred to KE
no (GP)E transferred to 'heat' / 'thermal' / internal energy
OR ✓

Must imply that <u>all</u> GPE is transferred to KE. E.g. accept 'loss of GPE is gain in KE' but not: 'loses GPE and gains KE'.

(therefore) $mg\Delta h\ \frac{1}{2}mv^2$ ✓
mass cancels. ✓

Accept 'm's crossed out

3

[9]

41. scale <1cm to 1 m s^{-1} stated or obvious from calculation (allow × 3, 7 etc. here)

B1

allow 2 max for correct calculation

correct resultant direction by eye (needs arrow if not clear from parallelogram or triangle)

B1

allow 1 max for

2.6±0.2 (m s^{-1})

B1

correct method of calculation but with error(s)

3

[3]

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42. D

[1]

43. D

[1]

44. A

[1]

45. (a) (*W* = *mg*)

= 4.8 × 35 × 9.81✓

=1600 (1648 N) ✓

Allow g=10 : 1680 (1700 N)

g = 9.8 → 1646 N

max 1 for doubling or halving.

Max 1 for use of grammes

2

(b) (stress = tension / area)

For first mark, forgive absence of or incorrect doubling / halving.

= (0.5 ×) $1.5 \times 10^{6} / 6.2 \times 10^{-4}$ OR = $1.5 \times 10^{6} / (2 \times) 6.2 \times 10^{-4}$ ✓

= 1.2×10^{9} (1.21 GPa) ✓

Forgive incorrect prefix if correct answer seen.

2

(c) (i) (weight = stress × area)

max 1 mark for incorrect power of ten in first marking point

= 400 ×(10^{6}) × 6.2×10^{-4} (= 248 000 N)✓

max 1 mark for doubling or halving both stress and area

(× 2 =) 5.0×10^{5} (496 000 N)✓

Forgive incorrect prefix if correct answer seen.Look out for YM ÷ 400k Pa which gives correct answer but scores zero.

2

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(ii) $\Delta L = \frac{F\ L}{A\ E}$ **OR** correct substitution into a correct equation (forgive incorrect doubling or halving for this mark only ✓

OR alternative method:
strain = stress / E
then ΔL = L × strain

$= \frac{(\text{Ans 4ci}/2) \times 35}{6.2\times10^{-4} \times 2.1\times 10^{11}}$ **OR** $\frac{\text{Ans 4ci} \times 35}{2 \times 6.2\times10^{-4} \times 2.1\times 10^{11}}$ ✓ ecf from 4ci

If answer to 4ci is used, it must be halved, unless area is doubled, for this mark

$(= \frac{(4.96\times10^{5}/2) \times 35}{6.2\times10^{-4} \times 2.1\times 10^{11}} =)$ 6.7×10^{-2} $(6.667\times10^{-2}$ m) ✓ ecf from 4ci

Any incorrect doubling or halving is max 1 mark.
Allow 0.07

3

(iii)

$(k = \frac{F}{\Delta L})$

$= \frac{2 \times 248\ 000}{6.667\times10^{-2}}$ OR correct substitution into $F=k\Delta L$ ✓ ecf ci and cii (answer 4c(i) ÷ answer 4c(ii))

Allow halving extension for force on one cable

$= 7.4(4)\times 10^{6}$ ✓(Nm^{-1})

Correct answer gains both marks

2

(iv) $(E = \frac{1}{2}F\Delta L$ or $E = \frac{1}{2}k\Delta L^2)$

Correct answer gains both marks

$= ½ \times 496\ 000 \times 6.667 \times 10^{-2}$ OR $½ \times 7.4(4) \times 10^{6} \times (6.667 \times 10^{-2})^2$ ✓ ecf ci, cii, ciii

$= 1.6(5) \times 10^{4}$ (J)✓

Forgive incorrect prefix if correct answer seen.

Doubling the force gets zero.

2

[13]

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46.

(a) $(s = \frac{1}{2}(u + v)t)$

Correct answer with no working gets 2 out of three.

$u = \frac{2s}{t}$ - v **OR** substitution in above equation **OR** $u = \frac{2\times1.5}{0.43}$ - 5.0 ✓
= 6.9767 – 5.0 ✓ = 2.0 ✓ (1.98 m s^{-1})

Full credit for use of gsin25 = acceleration down slope. This yields answer 3.22 m s^{-1}
Allow 1sf answer (2).

3

(b) (i) (F = 75 × 9.81 ×) sin25 (°) ✓
= 310 (311, 310.94) (N) ✓

use of g = 10 not penalised here
'sin25' on its own
Use of g = 10 yields 317
Allow cos65

2

(ii) $W = Fs$
= 311 × 2.0 = 620 (622 J) ✓ ecf (2bi) × 2.0

1

(c) Idea that GPE is ultimately transferred to: internal (energy) / 'heat'/ 'thermal' (energy in the surroundings) ✓

Allow transfer of GPE to KE and then to 'thermal' etc
Do not allow reference to 'sound' on its own

Correct reference to a named resistive force: friction / drag / air resistance ✓

Don't accept implication that a resistive force is a form of energy

All GPE becomes 'heat', etc **OR** no (overall) increase in KE **OR** reference to work done against or by a resistive force ✓

Do not allow references to loss of body heat.
Allow: '(GPE) not converted to KE'

3

[9]

47.

(a) (sum of) clockwise moment(s) = (sum of) anticlockwise moment(s) ✓
sum of clockwise moment **s** = **sum of** anticlockwise moment **s** (about any given point) ✓
(for a system in) equilibrium ✓ allow 'balanced'

third mark depends upon the first
Don't allow references to 'forces' being balanced.
Don't allow 'stationary'.
Allow 'total', etc instead of sum
Ignore definitions of moment

3

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(b) (i) $35 \times 110\ (\times 10^{-3})$ ✓
(= 3.85) = 3.9 (or 3.8) ✓
allow 4 or 3.90 but not 4.0

(3.9) **Nm** / allow (3850, 3900) **Nmm** ✓ don't allow nm, NM
unit must match answer

3

(ii) $3.85 = T \times 25\ (\times 10^{-3})$ ✓ ecf from (bi)
Correct answer with no working gets 2 out of three.

$T = 3.85 / 25\ (\times 10^{-3}) = 0.150\ (\times 10^{3})$ ✓ ecf
Allow 156 (160) N from rounding error

= 150 (154 N) ✓

3

(c) *(P = Fv , F = P / v)*
$= 2.8(\times 10^{3}) / 15$ ✓
= 190 (186.7 N) ✓

2

[11]

48. (a) (i) force per unit mass ✓
a vector quantity ✓
Accept force on 1 kg (or a unit mass).

2

(ii) force on body of mass *m* is given by $F = \frac{GMm}{(R+h)^2}$ ✓

gravitational field strength $g\left(=\frac{F}{m}\right) = \frac{GM}{(R+h)^2}$ ✓

For both marks to be awarded, correct symbols must be used for M and m.

2

(b) (i) $F\left(=\frac{GMm}{(R+h)^2}\right) = \frac{6.67\times10^{-11}\times5.98\times10^{24}\times2520}{\left((6.37\times10^{6})+(1.39\times10^{7})\right)^2}$ ✓

$= 2.45 \times 10^{3}$ (N) ✓ to **3SF** ✓

1st mark: all substituted numbers must be to at least 3SF.
If 1.39×10^{7} is used as the complete denominator, treat as AE with ECF available.
3rd mark: ***SF mark is independent.***

3

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(ii) $F = m\omega^2 (R + h)$ gives $\omega^2 = \frac{2450}{2520 \times 2.03 \times 10^7}$ ✓

from which $\omega = 2.19 \times 10^{-4}$ (rad s^{-1}) ✓

time period $T\left(=\frac{2\pi}{\omega}\right) = \frac{2\pi}{2.19 \times 10^{-4}}$ **or** = 2.87 ✓ 10^4 s ✓

[**or** $F = \frac{mv^2}{R+h}$ gives $v^2 = \frac{2.45 \times 10^3 \times \left(\left(6.37 \times 10^6\right) + \left(13.9 \times 10^6\right)\right)}{2520}$ ✓

from which v = 4.40 ✓ 10^3 (m s–1) ✓

time period $T\left(=\frac{2\pi(R+h))}{v}\right) = \frac{2\pi \times 2.03 \times 10^7}{4.40 \times 10^3}$ **or** = 2.87 × 10^4 s ✓]

[**or** $T^2 = \frac{4\pi^2 (R+h)^3}{GM}$ ✓

$= \frac{4\pi^2 ((6.37 \times 10^6) + (13.9 \times 10^6))^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}$ ✓

gives time period T = 2.87 × 10^4s ✓]

$= \frac{2.87 \times 10^4}{3600}$ = 7.97 (hours) ✓

number of transits in 1 day = $\frac{24}{7.97}$ = 3.01 (≈ 3) ✓

Allow ECF from wrong F value in (i) but mark to max 4 (because final answer won't agree with value to be shown).

First 3 marks are for determining time period (or frequency). Last 2 marks are for relating this to the number of transits.

Determination of f = 3.46 × 10^{-5} (s^{-1}) is equivalent to finding T by any of the methods.

5

(c) acceptable use ✓

satisfactory explanation ✓

e.g. monitoring weather **or** surveillance:

whole Earth may be scanned **or** Earth rotates under orbit

or information can be updated regularly

or communications: limited by intermittent contact

or gps: several satellites needed to fix position on Earth

Any reference to equatorial satellite should be awarded 0 marks.

2

[14]

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49. (a) thermionic emission / by heating

B1

cathode heated / heating done by electric current / overcoming work function

B1

Must mention anode for third mark

anode which is positive wrt cathode / accelerated by electric field between anode and cathode

B1

3

(b) (i) one relevant equation seen: $E = V/d$ / $F = Ee$ / $a = F/m$

B1

Equation should be in symbols

$$a = \frac{1.6 \times 10^{-19} \times 270}{9.1 \times 10^{-31} \times 0.015} \quad / \; F = 2.88 \times 10^{-15}$$

B1

Substitution may be done in several stages

3.16×10^{15} (m s^{-2})

B1

Must be more than 2 sf

3

(ii) $s = (ut) + \frac{1}{2} at^2$ or $v = u + at$ and $s = v_{av}t$ OR $s = vt$ used

B1

Appropriate symbol equation seen and used for 1st mark

3.56×10^{-3}m

B1

Expect at least 3 sf but condone 3.6 for candidates who use $a = 3.2 \times 10^{15}$

2

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(iii) $v = u + at$ / v = at $v^2 = u^2 + 2as$ used

B1

May also use $eV = \frac{1}{2}mv^2$

4.74×10^6 m s^{-1} to at least 3 sf

B1

Allow 4.8 (2 or more sf) – consistent with use of $a = 3.2 \times 10^{15}$

2

(iv) $t = 7.5 \times 10^{-9}$ s seen or used

C1

May use ratios for 1st 2 marks: $s_v/s_h = v_v/v_h$ *C1*

3.53×10^{-2} (m) A1

3.53×10^{-2} (m) **ecf** for wrong t

A1

adds 3.56×10^{-3} (m) to their 3.53×10^{-2}

B1

clipped with b(i) and b(ii)

Allow reasonable rounding

3

[13]

50.

(a) $K = \frac{45}{30^2} \left(= \frac{45}{900} = 0.05\right)$ or $\frac{d}{45} = \frac{15^2}{30^2} \left(= \frac{1}{4}\right)$

$d = 11.25$ (m)

C1

A1

2

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(b) rearrangement or substitution into $v^2 = u^2 + 2as$ or $s = \frac{v+u}{2}t$

C1

$a = (-)10$ or $t = 3.0$

A1

allow use of more than one equation of motion provided it gives a deceleration or time

use of $F = ma$ or $Ft = mv - mu$ (−)7000 (N)

C1

A1

4

(c) mention of $E_K = \frac{1}{2}mv^2$

B1

allow a mark for kinetic

all used to heat brakes / surroundings

B1

energy to 'heat'

since both ke and d are proportional to V^2

B1

d must be proportional to heat generated or to the kinetic energy

B1

E = md / 2 k gains two marks

3 max

[9]

51. A

[1]

52. (a) (i) use of $\left(s = \frac{1}{2}gt^2\right)$ OR $t^2 = 2s / g$ ✓

$t = \sqrt{\frac{2 \times 1.2}{9.81}}$ ✓

= 0.49 (0.4946 s) ✓ allow 0.5 do not allow 0.50

Some working required for full marks. Correct answer only gets 2

3

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(ii) ($s = vt$)
= 8.5 × 0.4946 ✓ ecf ai
= 4.2 m ✓ (4.20) ecf from ai

2

(b) (i) $\left(s = \frac{1}{2}(u + v)\,t\right)$

$t = \frac{2s}{u(+v)}$ or correct sub into equation above ✓

$= \frac{2 \times 0.35}{8.5} = 8.2 \times 10^{-2}$ (s) ✓ (0.0824) allow 0.08 but not 0.080 or 0.1

Allow alternative correct approaches

2

(ii) $a = (v - u) / t$ OR correct substitution OR a = 103 ✓
(= −8.5) / 8.24×10^{-2} = 103.2)

($F = ma$ =) 75 × (103.2) ✓ ecf from bi for incorrect acceleration due to arithmetic error only, not a physics error (e.g. do not allow a = 8.5. Use of g gets zero for the question.

= 7700 N ✓ (7741) ecf (see above)

Or from loss of KE

Some working required for full marks. Correct answer only gets 2

3

[10]

53. C

[1]

54. A

[1]

55. (a) (i) Use of $KE = \frac{1}{2} m v^2$

C1

21.7 (J)

A1

2

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(ii) Use of $W = Fs$

Allow 1 mark for use of suvat or F=ma

C1

0.70 (m)

A1

2

(b) Use of $\Delta E_p = mg\Delta h$

C1

Correct sub for h (1.7 sin 18°)

C1

77.3 (W)
OR
Use of $P=Fv$
Correct sub for F (mg sin 18°) or v (1.7 sin 18°)
77.3 (W)

A1

3

[7]

56. (a) (i) 11 (m)

B1

1

(ii) Use of $F = k\Delta L$ or $W = mg$

Allow use of ΔL =12 m

C1

3400 (N)

A1

2

(b) Sets $mg = k\Delta L$

C1

1.9 (m)

A1

2

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(c) Correct use of $W = ½k\Delta L^2$ or $½F\Delta L$

$\Delta L = 5$ m

C1

Correct use of $\Delta GPE = mg\Delta h$

$\Delta h = 25$ m

C1

States or uses $(mg\Delta h) – (½ k\Delta L^2) = ½mv^2$

C1

19 (m s^{-1}) cnao

A1

4

(d) Same kinetic energy when rope begins to stretch

B1

More work done per unit extension / stops in shorter distance

"Shorter time" gets no credit

B1

Increases force on jumper (increasing the risk of injury)

B1

3

[12]

57. (a) $m = W / g)$

$(3.4 \times 10^4 / 9.81 =)$ 3500 (3466 kg) ✓

Allow use of g = 10

1

(b) (moment = 34 000 × 5.0) = 1.7×10^5 ✓ (Nm)

Nm ✓ do not allow NM \ nM etc

allow in words

2

(c) 170 000 = T x 12 OR T = 170 000 / 12 ✓ ecf aii

$= 1.4(167) \times 10^4$ ✓ (N)

2

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(d) (component of T perpendicular to lever) = T cos 24
OR 14 167 × 0.9135 **OR** 12942 (N) ✓ ecf aiii allow 2.5cos24 × T

(12942) × 2.5 = **F** × 8.0
OR F = ((12942) × 2.5) / 8.0 ✓ ecf for incorrect component of T or T on its own
F = 4000 (N) ✓ (4044) ecf for incorrect component of T or T on its own

allow 4100 for use of 14 200 (4054)

Some working required for full marks. Correct answer only gets 2
Failure to find component of T is max 2 (4400 N)

3

[8]

58. A

[1]

59. D

[1]

60. (a) use of E = mgh **(1)**

2680 J **(1)**

2

(b) use of $v^2 = 2$ as **(1)**

9.1 m s^{-1} **(1)**

2

(c) increases the time taken for the athlete to come to rest/reduced deceleration

force = mass × acceleration/mass × change in velocity/time **(1)**

or momentum argument

or energy argument **(1)**

2

[6]

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Examiner reports

1.

(a) The majority of candidates were able to score at least 1 mark in this explanation. Only the best candidates were producing quality answers that gained full credit. Many candidates were unfamiliar with the term and offered answers suggesting that these were neutrons that were produced due to heat.

(b) (i) Surprisingly, only 50% of candidates gained full marks here. A significant proportion of candidates attempted to use the equations of motion and consequently were awarded no marks. Candidates must be aware that these equations only apply to situations were acceleration is constant. Some candidates lost marks by rounding the final answer to 1 significant figure. Many lower achieving candidates failed to correctly rearrange $\frac{1}{2} m v^2 = m g h$, dropping the factor of $\frac{1}{2}$ was a common mistake.

(ii) This was another “Show that...” style question and again it posed problems for many candidates with just over 20% of candidates gaining 3 or 4 marks. A very large proportion of candidates did not attempt the elastic collision part of the question and limited themselves to 2 marks. Many of these candidates had difficulty with the vector nature of momentum and their signs were often inconsistent or incorrect. Grade A candidates typically presented well laid out workings that were easy-to-follow, convincing.

(iii) Most candidates achieved both marks here. However, some had casual use of powers of 10 errors on their KE calculations due to keeping the mass in grams. This of course cancelled due to the ratio aspect of the question. A number of candidates thought that 25% was the answer; this was due to not reading the question carefully enough.

(iv) Most candidates gained 1 mark for stating how the demonstration related to the moderation process. Only a small number of candidates were able to develop their answer by providing information that was more than the converse of the information provided, thus demonstrating a sound knowledge of the moderation process.

(v) Just under 80% of candidates knew that water was the moderator in a PWR. A few candidates incorrectly thought that the moderator was heavy water.

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2.

(a) (i) A very large number of candidates took 430ms^{-1} as the final vertical velocity and obtained a time of 44 seconds for the bullet to fall 1.5m. Many used $t = s / v$ with v = 430m^{-1}. This gave a time of 3.5 ms to fall 1.5m. Students need to be encouraged to look at their answers and consider whether they are sensible.

(ii) Here we saw the usual erroneous use of 'suvat': e.g. s = 1 / 2 $(u + v)t$ with either u or v being set to zero. Given that this type of question is not uncommon, it is surprising how many students do not understand that the horizontal velocity is constant and that the suvat equations are not necessary.

(b) Some candidates thought that the slower bullet reaches the ground first and some did not distinguishing between *velocity and horizontal velocity*. It is important to be very specific when describing motion.

This is a very good question for addressing misconceptions. One could perhaps use the following examples in class and ask students to mark them and analyse the physics:

'Because the horizontal velocity of B is less than A, the bullet is slowed down more by drag. Also the pull of gravity will allow it to travel less horizontal distance than A because the bullet has less resistance to the gravitational force causing it to be pulled down to earth quicker.'

'It has less forward force to use. This means that gravity will have an affect on this bullet sooner. The lower the horizontal force, the quicker the vertical force overpowers it, thus making it hit the ground sooner and a shorter distance travelled.'

3.

(a) (i) Answered well by most candidates. The explanation had to demonstrate that candidates understood the resolving process.

(ii) Correctly answered by most candidates, with only a small proportion of inappropriate lines of best fit.

(b) (i) This question features on all ISA's but many candidates still fail to achieve the full 3 marks. The most common error was again misreading of one of the data points, and this then usually gives a gradient value out of tolerance, hence losing another mark. Triangles were generally large enough to meet the 8 cm criteria, with fewer lost marks on this point than in previous years.

(ii) Answered reasonably well by most candidates – by multiplying their gradient by 'g'.

A significant proportion of candidates lost the mark awarded for the unit. (Some candidates using 'n' instead of 'N' !).

(c) This question discriminated well, with only the most able candidates scoring all three marks. Significant figure errors and failing to double the combined uncertainty in x and y were the most common mistakes.

(d) (i) A surprising number of candidates failed to give an adequate description of a systematic error.

(ii) A large proportion of candidates scored the first mark, explaining that y would be larger. Only the most able candidates were able to give an adequate explanation, usually relating to friction opposing the increasing weight of m.

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4.

(a) (i) Nearly all showed a 3 or 4 significant figure answer before rounding to 6100 and very few dropped marks here.

(ii) Some selected the wrong angle (angle to vertical rather than horizontal) but apart from that the question was very well done.

(iii) Generally well answered but the wrong force was sometimes used, e.g. 6000N rather than 6083N and sometimes weight was used rather than mass.

(b) (i) Most were successful here, but some thought 6500N was the mass and multiplied this by 9.81.

(ii) Some confusion over the calculation of useful power, with many candidates wrongly trying to calculate kinetic energy or calculating power from $P = Fv$. Some divided an *energy* by a *power*. The evidence suggests that many centres need to practice more of these questions.

5.

(a) This question was well answered. Some left out 'up to limit of *proportionality*' and some put *'elastic limit'* - though this was forgiven. Some gave the equation only in symbols, and this was not sufficient.

Again, with recall questions, not enough students are learning definitions and laws, producing instead vague descriptions rather than precisely memorised statements. E.g. *'Hooke's law is the extension of a spring when a force is applied.'*

(b) There were quite a few mistakes with units here; 'Nm', 'Nm $^{-2}$ 'and 'Pa' were all common incorrect units. In calculating the gradient, the point labelled '**A**' was often used. However, at this point, the line had clearly ceased to be straight and thus the answer fell outside the range of tolerance.

(c) For calculating the work done up to point **B**, there was much use of ½ FL = ½ × 38 × 0.045, and sometimes simply 38 × 0.045, rather than an attempt to sum up the area under the line. Many estimates of the area were wildly inaccurate due to the approach being too approximate, counting some areas twice or missing bits out.

Summing the area under a curve is a technique that students must practise.

(d) Most candidates got this correct. A few said words to the effect of *'no longer obeys Hooke's law'*, which was not sufficient.

(e) There were many careless graphs drawn here, with the line not drawn exactly parallel, and this lost a mark. This means that some very straightforward marks are needlessly dropped by many candidates. In order to ensure that a line is parallel, students should be encouraged to make a quick measurement of the distance between the lines at a couple of points.

It would also appear that many students elect to sketch with a pen and are then reluctant to scribble out their line and replace it with a more accurate one. For diagrams only, please encourage students to use an HB pencil; this will show up perfectly well on the scans that are seen by the examiners.

(f) The majority of candidates understood that the area underneath the unloading line was less than for the loading. However, a significant number of candidates thought that the work done would be the same since *'energy is conserved'* .

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6. (a) The number of mistakes on this question was surprising. Most candidates knew it was something to do with 'cos' or 'sin' but they resolved incorrectly. Common errors included resolving the mass rather than the weight (8300sin25), finding the wrong component (mg cos25), incorrect trigonometry (mg / sin25) or simply calculating the weight without resolving (8300 × 9.81). Plenty of practice and assessment on resolution of forces on inclined planes is needed for many students.

(b) (i) These presented few problems apart from an occasional power of ten error or use of weight instead of mass.

(ii) As above.

(c) (i) There were lots of really good answers on this question with correct descriptions of energy transformations and mention of friction and 'thermal energy'.

However, some mentioned the appropriate force (friction, drag, etc.) but not the form of energy (internal, 'thermal', 'heat') and vice versa. Some candidates do not know the difference between a form of energy and the process that causes the transformation: 'kinetic energy is converted to friction' being a typical comment.

(ii) This was generally well done, but some used 160 m instead of 140 m.

Some candidates used a 'suvat' equation but this is incorrect physics due to the fact that the acceleration is not constant. Students must first identify if a situation involves constant velocity, uniform acceleration or changing acceleration. If the acceleration is changing, the kinematics equations used at AS will not be applicable.

7. Part (a) was answered very successfully. A common error was to state .length. or 'height' rather than distance, although 'length' was tolerated.

On part (b) (ii), candidates knew what to do but most did not gain full marks due to confusion over powers of ten or units for power.

Half of candidates achieved four or five marks out of five on part (c). Again there was confusion with prefixes/powers of ten and units. It is important that candidates stated 'Pa' not 'pa'.

8. Those who gained one mark usually had the first line correct. Those who gained two marks usually forgot the gravitational PE in the second line.

9. The common error in part (a) was to multiply the frictional force by cos 20 instead of dividing. Had candidates written the equation in the form $F \cos 20 = 2800$ first, many more could have been successful.

In part (b), the majority multiplied the value from (a) by the distance moved forgetting that the distance moved is the force × distance moved **in the direction of the force.**

10. In part (a), a large number of candidates thought that the horizontal component of velocity was to be shown rather than the instantaneous velocity at a tangent to the path. Many candidates who had the right idea still did not gain marks due to a badly drawn tangential arrow. The mark for the acceleration was gained by many candidates. Of those candidates who gained no marks in part (b) (i), many simply could not rearrange s = 1/2gt^2. Those who successfully did this picked up both marks. A majority of candidates gained two marks but some believed they had to use a 'suvat. equation and gained no marks.

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11. Solution to this question required candidates to find the vertical component of the tension from 610 cos 20 and realisation that the sum of the upward forces produced by the rope and reaction force is equal to the weight. There was a good proportion of completely correct answers but some who could do the resolution correctly did not realise what the next step should be. Some candidates overcomplicated the problem by trying to calculate the reaction force shown on the diagram.

12. The majority of candidates correctly used the data to obtain a correct value but many quoted the answer to too many significant figures. Some candidates appeared to think they needed to find a new force (perhaps confusing force and power). These candidates made no use of the distance moved and used 1500 N as ΔW in the formula $t F = \frac{\Delta W}{\Delta t}$.

13. Most candidates successfully completed part (a) (i).

Part (ii) was also successfully completed by a majority of the candidates.

The use of the equation for uniform decelerated motion was inappropriate in part (iii). Only a minority of the candidates appreciated that the work done had to be equated to the gravitational potential energy that had been transferred to forms other than to kinetic energy.

Only a small minority did not gain some credit in part (iv) and most stated friction and air resistance. A significant proportion of these did not identify where the friction was occurring. Vague answers such as between the skier and the ground were not accepted.

Most candidates completed part (b) (i) successfully.

Part (ii) was also done well by the majority of the candidates.

14. Part (a) proved to be a very easy question, with the majority of candidates correctly plotting all the points and gaining all five marks.

A large number of candidates only got one mark out of two for part (b) (i), because they did not point out that the gradient is the deceleration - though it is possible that the majority knew this. Most recognised the significance of the straight line.

For half the candidates, part (b) (ii) was a straightforward calculation of the area. However, many candidates did not recognise its simplicity. A common incorrect approach was to select a kinematics equation and substitute in 15 m/s and 3.5 s. Candidates would gain higher marks on this type of question if they routinely state the principle they are using, e.g. in this case .distance travelled = area under line..

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15. Only a minority of the candidates made progress with part (a) (i). The working in many responses did not convey a correct physics approach to the problem. Multiplying the peak force by half the time did not show that the aim was to determine the area, but rather that the aim was to find a number that fitted that given in the question. It would help demonstration of a correct approach to a problem, and in particular to 'show that' questions, if candidates were to include a subject for the formula and/or numerical substitution.

Candidates were generally more successful in part (a) (ii), almost half the candidates gaining both marks.

In part (b), candidates either coped very well or not at all with the straightforward task of finding the resultant magnitude and direction of the vector addition of horizontal and vertical velocities, both of which were given in the question. Many were unsuccessful because they could not successfully use Pythagoras' rule or identify the appropriate relationship to find the angle.

16. The very straight forward part (a) was well answered with generally clear solutions being provided.

Part (b) was answered more unevenly. About 60% of candidates arrived at a complete answer with the remainder making more or less progress with what was a straightforward question. Inconsistencies of sign in the treatment of deceleration and the velocities were very common and were penalised. It is not acceptable simply to ignore the fact that an equation yields a squared quantity with a negative sign.

17. This question required candidates to determine the momentum of the water flowing out of a garden hose in one second. This called for mathematical application as well as knowledge and it was therefore much more demanding. 41% of the candidates selected the correct answer, and the question was not a strong discriminator. The most popular incorrect distractor, chosen by 28%, was C (0.20). This numerical value could be found by multiplying the density of water by the flow rate, ignoring the cross-sectional area value given in the question.

18. Part (a) (i) was straightforward and was answered very well.

Again, part (a) (ii) proved to be a particularly accessible question and candidates performed well.

In part (a) (iii), most grasped the concept that energy was wasted but less able candidates did not realise that the cyclist did work, believing it to be a simple transfer of potential energy to kinetic energy. Many candidates perhaps did not realise that marks could be gained by performing the relevant calculation.

In part (b) (i), a surprising number of candidates used time = distance/speed = 160/16 = 10 s. They did not appreciate that the situation involved uniform deceleration and therefore a kinematics equation should be used.

Part (b) (ii) was generally done well, with most calculating the acceleration and then using $F = ma$. It was possible to gain full marks even with the use of an incorrect answer from the previous question.

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19. In part (a) (i), only partial credit was available to those who failed to relate the area under the graph to the stored energy.

Many were able to successfully begin part (a) (ii) by equating the stored energy with kinetic energy. But, from this point on, explanations became poor with the full detail of the algebraic manipulations either not being shown or being fudged.

The straightforward substitution and evaluation from the equation in (a) (ii) was done well in part (b) (i).

Full credit was rare to part (b) (ii). Candidates are too fond of stating .air resistance. as their full answer without suggesting the seat of the energy loss. There are a number of air resistance possibilities in this situation and many candidates left it to the examiners to decide which one was operating here. There were frequent answers that suggested air resistance when the arrow had left the bow despite the question's focus on the initial acceleration of the arrow whilst in the bow. Examiners are looking for more awareness of the context in this type of question.

Those who attempted the three parts to part (c), all of which examined the use of kinematic equations and vector components, did well, often achieving full credit. However, many (about one-fifth) did not attempt (c) (iii).

20. This was a straightforward test of candidates' knowledge. It required candidates to decide whether or not mass, momentum, kinetic energy and total energy would be conserved in an inelastic collision. 85% of the candidates appreciated that everything except kinetic energy would be conserved. Incorrect responses were fairly evenly spread around the other three distractors.

21. More than half of the candidates answered part (a) correctly and most gained some credit for making some progress with the question. Incorrectly converting 40 minutes to seconds was common. A significant proportion did not appreciate the difference between mass and weight. The weight was given in N but many multiplied this by *g* in there working.

The unit prefix again presented problems for many when attempting to convert 15 mm to mm in part (b) and 106 was not uncommon. The vast majority divided 750 by 15 or 15 × 10.3 but then gave an inconsistent unit.

22. Part (a) was done well by the overwhelming majority.

About half the candidates completed part (b) successfully. Errors here usually centred around non-clarity in the direction of the velocity. It was often unclear whether the angle was to the east or west of north.

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23. A common error in part (a) (i) was to use $t = s/v = 50/6.7$. Students are not always aware that, for uniform acceleration, the 'suvat' equations must be used. Another common error was to use $t = \sqrt{(2s/a)}$ with the speed used as the acceleration.

Nearly all students were successful with the calculation in part (a) (ii). However, a large number stated an answer to more than two significant figures and lost a mark.

Part (a) (iii) was very straightforward and most students got this right.

A pleasingly large number of students were successful in part (b) (i). It was necessary to fully understand the situation to get both marks. There were errors such as subtracting the KE from the GPE rather than adding them, or only taking one of them from the input energy of 9 kJ.

Energy losses within the motor are not a cause of the energy loss calculated in part (b) (i). This is because the work done by the motor is the energy output from the motor. The energy losses from the rider also are not relevant here. The energy losses are therefore due to drag and friction. However, the candidate must make it clear that the frictional losses are between tyre and road or between other moving parts of the bike other than within the motor. Many students did not state where the friction was acting and many mentioned the losses within the motor. Many gained a mark for mentioning air resistance or drag.

24. Part (a) (i) was a fairly easy two marks for the majority of candidates. Most gave 420000 but about 10% omitted this and lost one mark.

Part (a) (ii) was straight forward for most but a common error was the use of the volume instead of the velocity.

For part (a) (iii), perhaps 10-20% didn't know 'M' was 10^{6}. Quite a few divided by 10×10^{-6}. About 14% left this question out, either indicating that they had run out of time or they had forgotten how to calculate efficiency. About 43% gained full marks.

Perhaps candidates pressed for time had spotted part (b) and sensibly decided to skip part (a) (iii) and pick up this little gift instead; still a little surprising that only 56% managed to get both marks even though 95% attempted the question.

25. In part (a) (i), most candidates quoted the equation and correctly calculated the time. The most frequent misconception was the belief that a 'suvat' equation should be used even though the velocity is constant.

The correct answer of 3000, or 3022, was accepted in part (a) (ii) and the majority successfully produced this value.

In part (b) (i) most select and quoted the correct equation and showed the correct substitution. Some lost the mark as they did not show the answer to more than one significant figure.

Part (b) (ii) was a very easy question for over 40% of candidates who understood that the horizontal acceleration was zero. For these students, $45.3 \times 0.685 = 31$ gained two marks. However, 13% did not attempt the question and another 40% misapplied a kinematics equation to the situation often using 9.81 as the acceleration.

The vast majority of candidates identified air resistance as the key factor to part (b) (iii). However, only 7% mention that **horizontal** deceleration is caused by air resistance.

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26. In part (a) (i), the majority of candidates stated 'force × perpendicular' distance but only 16% stated the full definition. Many did not recall the definition accurately or did not say the distance was between the line of action of the force and the point. Many said 'force × perpendicular distance from the line of action' or 'force × perpendicular distance to the point'. These candidates were only awarded one mark. A significant number of candidates stated the Law of moments rather than the definition of a moment and some produced a vague description of a turning effect rather than a definition. Students should be encouraged to learn the full definition off by heart.

In part (a) (ii) 57% scored two marks very easily. However, a surprising number selected the front springs rather than the rear due to 'a larger distance from the pivot causing a greater moment on the front'; confusing the *centre of mass* with the 'pivot'. Some candidates assumed the *centre of mass* is always closer to the front of a truck. However, the question shows a rear-engined pick-up. Some candidates thought that the rear springs were 2.0 m from the *centre of mass* having incorrectly interpreting the dimensions on the diagram. Some felt that since the truck was in equilibrium, both sets of springs would be equally compressed.

For such a simple moments question, part (a) (iii) was done poorly by the majority. Perhaps the context made it seem more difficult than it really was, but many chose the wrong distances and equated a moment with a force rather than another moment. Common incorrect answers were $14000 \times 1.4 = 19600$ and $14000 \times 1.4 = 14000 \times 1.1$. Many common answers given were greater than the weight of the truck. Most of those who couldn't pick up any marks for the moments calculation did realise that it would be necessary to divide by two at the end and so most scored at least one mark.

In part (b) most gained two marks with the error carried forward from their previous answer.

The poor response to part (c) was very surprising. Only 5% gained two marks with 47% getting zero and 18% not attempting the question. Perhaps those who had struggled on previous parts of this question made the assumption that this would be difficult as it was the final part of the question. However, it was perhaps the easiest part of the question and was independent of the previous parts.

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27. Part (a) (i) was very straightforward and most students scored two marks. Some scored zero by attempting a moments calculation. There were a few mixn-ups with powers of ten; some thought that kN was 10^6 N and some did not spot k.

Many students used 4.6m rather than 4.6 + 2.8 = 7.4m to calculate the moment of the lift-fan force in part (a) (ii). There is still a lot of confusion with moments questions for students in the January paper, and the evidence may suggest that many schools have not practised enough of these.

The maths of this question could not be made much simpler apart from perhaps giving the 7.4m dimension on the diagram. It was again apparent that a large number of students believed a complicated solution must be required; perhaps the context persuaded them that this must be so. However, once the candidate has simplified the diagram, the question is straightforward and simply dividing their previous answer by 7.4 yields all three marks. Given the frequency of this style of question on PHYA2 papers, it is really worth going over as many of these as possible with students.

The weight of the aircraft minus the engine thrust previously calculated yielded the mark for most students in part (a) (iii). However, a significant number did not know this or used the law of moments again.

In part (b) (i) a very large number of students used a=*F/m* with the weight of the aircraft used for mass. This approach did not gain any marks. Many rounded their mass before using it to calculate the acceleration, this was forgiven in this question, as was the use of $g = 10\ ms^{-2}$. These errors are condoned here because we do not penalise the same mistake several times in a paper.

In response to part (b) (ii), many students did not realise they had to state a characteristic of the aircraft. This meant referring to the shape or aerodynamics in some way or the maximum thrust. Marks could not be scored unless one of these was mentioned. There seemed to be a common misconception that 'its air resistance' was a characteristic of the plane. The question was interpreted by many as 'explain why the plane reaches a terminal velocity'. Many believed that the mass of the aircraft would be a factor. However, the mass would limit the acceleration rather than the top speed.

In part (b) (iii), examiners were looking for an understanding that the acceleration would be falling towards zero as the terminal velocity was approached. Many students recognised that the velocity would increase and then remain constant. However, a very large proportion of students drew a straight diagonal line with an abrupt change to constant velocity. There were also many 's' shaped curves and curves that showed the acceleration continually increasing. Many also drew straight diagonal lines that did not 'level off'.

Part (c) was an easy question but students did not read it well and many lost the mark because they simply stated that the maximum acceleration is the gradient rather than the **maximum** gradient. A large number also believed that the area represents the acceleration or that the gradient at maximum velocity would be the maximum acceleration. Note that the response; 'the part of the graph where the gradient is steepest' does not make it clear that the gradient = the acceleration.

Many students lost the mark because they said the maximum acceleration was the initial gradient. This would apply to the graph in part (b) (iii) but it was not enough for the mark. Some students responded that 'the gradient of the flat part of the graph' should be found.

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28. The answers to part (a) were generally very detailed with many students continuing to write to the bottom of the page. Answers could have been more succinct perhaps. eg *No energy lost, so all* GPE at A *is converted to KE at B which is converted to back to an equal amount of GPE* at C. Some students explained that GPE transfers to KE but then failed to mention the conversion back to GPE. eg 'all the GPE is converted to KE at B, so it gets to the same height at C'. Often the law of energy conservation was quoted but they did not explicitly state that there were no energy 'losses' due to no friction or drag.

In part (b) there was some carelessness in the positioning of the label for B. Many students had a significant straight section at the start and showed the ball decelerating after point X.

In part (c) students often stated that the speed was constant but did not point out that the ball would move in a straight line. They often explained the motion in terms of there being 'no forces' acting on the ball rather than 'balanced forces'.

29. In part (a), many students confused strain with stress and there were many vague descriptions rather than definitions, for example 'amount of extension due to a force applied'. The definition has to describe how a correct strain would be calculated. Therefore, it is essential that the 'original' length is specified and the phrase 'divided by' rather than 'compared to' needs to be used. Some students used the word 'from' to convey 'divided by' for example, 'the extension from the original length'. This was not accepted. 'The ratio of the extension from the original length' was acceptable.

Only 1.9×10^8 was accepted as an answer to part (b). Few students strayed from 1.9. However, many lost the mark by missing out the power of ten.

Most students did very well on part (c). Nearly all put the point in a sensible place just beyond the linear section but a few did not include a suitable label and therefore they did not get the mark.

Most students were very successful in part (d). Most chose the straight section for the gradient calculation and most chose a large enough section of it. Some went to a stress of 1.3 or more where the line was clearly curving. The unit was usually correct but a few had capital M or m^{-1}. Surprisingly, a significant number missed the unit out altogether.

Part (e)(i) should have been a straightforward question. Most students identified the correct area to evaluate but either did not use an accurate method or did not recognise the value of each square they counted. A very common answer was 38 rather than 38×10^5. Many divided the area into two triangles and a rectangle, leaving out a significant area from their calculation. With a number of similar examples of area approximation on past papers, it was surprising that very few were able to score both marks here. Many students do not know how to find the area under a curve to a sufficient accuracy.

Many students obtained the volume in answer to part (e) (i) but did not realise that they then needed the value they calculated from part (e) (i).

In part (f), many students did not recognise that a higher Young Modulus would give a steeper line and many who did realise this did not stop their line at 176 MPa. Many showed excessive curvature not characteristic of a brittle material.

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30. Most students were successful on part (a) (i). A few used 170 N rather than 170 kN or did not multiply by the distance of 1000 m.

Many used 170 kN rather than the resolved horizontal component in answer to part (b) (i). Some students used the value of the power from part (a) and lost both marks.

In part (b) (ii) many students did not calculate the total power or inverted the calculation.

Many students mentioned the drag force in part (c) but by itself, this was too obvious. Examiners needed to see what factors changed the drag on the sail such as the area and the wind speed. Many students referred to the drag force on the ship, the 'tension in the sail' and the weight of the ship.

31. Most students performed well in part (a) with many examples of well laid out calculations in part (a) (ii).

Part (b) again provided a good discriminator which challenged students' understanding of the situation and looked for detailed analysis of the situation.
Many students correctly identified that the hook would have a lower speed but often the supporting explanation was superficial and lacked the rigour expected at this level.
Best examples used a knowledge of physics to support explanations through thorough use of equations and coherent multi–staged arguments.

32. This question posed the greatest problems for students with less than half presenting work in a convincing manner. Many students failed to deal with the perpendicular nature of the horizontal and vertical velocities.
In part (a) a significant number of students were unsure how to tackle this problem. Many assumed that the initial vertical velocity was 18 ms^{-1}. These students also failed to realise that the ball had undergone a vertical displacement of 1.51 m on reaching the net.
Part (b) proved to be an excellent discriminator with under half of the students showing an understanding of the situation and demonstrating the knowledge and mathematical skills required. Again in part (b) (i) students failed to realise that the initial vertical velocity was zero. In part (b) (ii) many students attempted to use equations of motion showing little awareness of how to solve this type of problem.
Correct calculations were well organised with equations and processing being arranged in a logical manner.

33. This question tested basic facts concerning the quantities that are conserved when two bodies – two skaters in this question – separate from each other with a release of kinetic energy. Almost 70% of the students gave the correct response. The most common incorrect response was distractor B, the students involved not realising that kinetic energy must increase when two stationary bodies start to move.

34. Students often find that questions in which the result of a calculation is shown algebraically are harder than ones in which the calculation is purely numerical. In this question, where the recoil speed after an explosion was to be found in terms of kinetic energy. Just under half of the students arrived at the correct expression, and the question did not discriminate very well. 27% of the students selected distractor B, because they regarded the mass of the daughter nucleus still to be M (instead of $M - m$) after it had emitted the $\propto$ particle.

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35. For part (a)(i) most students successfully gained the unit mark here, but a few put Nm^{-1}, N/m, NM or Nm^{-2}. In part (a)(ii) students fared better on this moments problem than we have seen on previous papers. However, there were still plenty of problems. In particular, some students are unable to identify clockwise and anticlockwise moments. It is perhaps surprising how many AS physics students do not understand the concept of a moment and are unable to identify the direction of rotation that it would cause about a given point if no other forces acted. One possible strategy is get students to identify the clockwise and anticlockwise moments in many situations before teaching them how to use the law of moments. There were also a lot of mathematical errors by those who had equated the moments correctly and then could not rearrange correctly. Many rounded 97.46 to 97.5 and then rounded again to 98. For part (a)(iii) most were successful. Very few resorted to an unnecessary moments calculation for this one and many picked up the mark for an error carried forward if their previous answer had been wrong.

In part (b)(i) nearly all students were successful here though some used s rather than 2s. In part (b)(ii) a significant number of students used 520 N as the mass, not realising it was necessary to divide the weight by 9.81 to get the mass. Some multiplied by 9.81 instead of dividing. However, this was an easy two marks for most.

36. This question had appeared in an examination previously; it tested the fairly familiar knowledge of the trajectory of charged particles in electric and magnetic fields and this time had a facility of 71%.

37. This question was an easy starter that required the application of “change of momentum = area under force/time graph”. This question discriminated well, and just over two-thirds of the students gave the correct answer. The most popular incorrect response was distractor D, no doubt because the students who chose it overlooked the factor of ½ when calculating a triangular area.

38. This question required an understanding of whether the accelerations in two perpendicular directions are constant or zero when a beam of electrons travels through a uniform electric field. This was well known, giving over 70% of correct responses.

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39. Acceptable statements really needed to refer to both the direction of the induced emf (or current) and to the change (in magnetic flux) that produces the effect. In part (b)(i) an explanation of the greater mass of Q was required, so a simple statement that density was involved was inadequate; candidates had to state that steel (or Q) has a greater density than aluminium (or P). In part (b)(ii) the time of 0.45s was usually justified through the application of $s = ut + ½ at^2$, although some candidates made no attempt to justify this value. Backwards working, such as showing that the distance fallen is approximately 1.0m when the time of fall is 0.45s, was accepted. Explanations of why the two times are equal were expected to refer to acceleration due to gravity being independent of the mass of a falling body.

There was widespread misunderstanding in candidates' attempts to answer part (c). In part (i), clearly Q is a moving magnet passing through a conducting tube and so the magnet's flux lines are cut by the tube – hence an emf is induced. A significant number of responses stated that Q would be cutting through the flux lines of the tube. The tube was regularly referred to as a magnet. A very common misapprehension was that when a current is induced in the tube, it is the current that causes the emf. In part (c)(ii) many answers were too trivial, such as ones which referred to the repulsion of poles, or were simply wrong, such as attributing the effect to induced *charges*. Some responses even suggested that the induced electromotive force acts as a mechanical force to oppose the falling magnet. Examiners were pleased to encounter logical answers stating that the induced emf caused a current to flow in the copper, which then produced a magnetic field to oppose the movement of the falling magnet Q by opposing the magnet's own field. Relatively few answers made any reference as to why cylinder P would fall without opposition.

Full marks were regularly awarded in part (d), where it was usually seen that the time for P would be unaffected (an explanation was needed for the mark) but that for Q would be shorter. Some candidates thought that the increased resistance of the tube would cause a reduced emf; these answers were subjected to a two mark maximum.

40. (a) Candidates were generally very successful on these questions.

(b) Candidates were generally very successful on these questions.

(c) Most candidates were successful. However, a few used $t = s / v = 54 / 33$ instead of a kinematics equation.

(d) As with previous papers, candidates lacked the depth of knowledge necessary to describe energy transfers. Perhaps some teachers assume candidates already know this from GCSE. More practice on this type of question is necessary. Too few candidates are able to make the link between potential and kinetic energy.

41. Most candidates were able to draw a reasonable vector diagram. Scales could often have been larger and a minority of candidates failed to state the scale factor. Few showed the direction of the resultant – for which they were penalised unless it was clear from the directions of the two velocities being added. Those correctly calculating the resultant were penalised by a mark, however most attempted calculations were incorrect.

42. More than one third of the candidates incorrectly chose distractor C in this Question, where an average force has to be calculated by applying $F = \Delta mv / \Delta t$. Just over half of them correctly chose alternative D. Undoubtedly the error of so many candidates was to fail to appreciate the vector nature of velocity and momentum. Distractor C would have been the correct answer had the change in velocity been $35 – 30 = 5$ m s^{-1}.

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43. This question concerned the significance of the area under a force-time graph. When this question was pre-tested just over half of the students gave the correct answer. The responses in the examination shows that candidates prepare much more seriously for real examinations than for pre-testing sessions, because it proved to be the easiest question in the paper.

44. This question tested the vector nature of momentum, the scalar nature of kinetic energy and the meaning of an elastic collision. Just over two thirds of the candidates realised that the exact reversal of momentum meant a change of $2mv$ and that an elastic collision meant no change in kinetic energy. Almost 20% of them chose distractor C, thinking there is no change in momentum.

45. (a) Most were successful but a significant number did not multiply by g, perhaps not understanding the difference between weight and mass.

(b) A common error was to not half the force (or double the area). However, a high percentage did realise that you had to do more than simply substitute the numbers given.

(c) (i) Most correctly calculated the load on one of the cables but many did not realise they needed to double their result to get the complete load.

(ii) A lot of rounding errors were evident. 0.06 recurring was often rounded to 0.06 rather than 0.067. Many used their value for weight but did not halve it. Some candidates therefore lost a mark because even though they got the correct answer, they had not halved that weight and this was a physics error.

(iii) Many did not understand that they should use the weight and the extension previously calculated. Many thought that the total load divided by the extension of one cable would give only half of the total stiffness constant. This is not the case because the extension of each cable is the same.

46. (a) This was quite well done. A few used $v = s / t = 1.5 / 0.43$ and there was some use of $a = 9.81$. Those who had practiced less of these questions got confused because u was not zero. Incorrect rearranging of the equation was also quite common.

(b) A common error was to use cos25 rather than sin25 for resolving along the slope.

(c) This was very poorly answered. It was expected that candidates would realise that kinetic energy was not changing, and therefore, the transfer could be easily summed up as gravitational potential energy transferred to internal / thermal energy. Most did not pick up the more subtle points that the GPE ultimately all ends up as internal / thermal energy and the KE stays constant.

It was not enough to say that some of the GPE transfers to KE and some to heat. That doesn't answer the question and could apply to many situations. Candidates should always name the forces. 'Resistive forces' did not score the mark, 'friction' or 'drag' was needed.

Many candidates have learnt that 'loss of GPE is equal to the gain in KE' and they believe this applies to all situations.

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47.

(b) (i) Most candidates got this correct. Only a few dropped a mark for the unit, e.g. with N / m rather than Nm.

(ii) A very large number of candidates thought that $W = Fs\cos\theta$ had to be used and needlessly multiplied by cos25.

(iii) This tended to be 3 marks or zero. Some lost marks due to errors in the powers of ten. Other than that, a large number didn't know how to do a simple moments calculation.

(c) The majority were very successful on this question.

48.

The definition in part (a)(i) was well known. Because the quantity concerned is called gravitational field *strength*, there was frequent confusion as to whether it is a vector or a scalar, with many answers being crossed out and changed. Part (a)(ii) was also generally very rewarding. The main problem was a failure to show how the terms from the data booklet equations (m_1, m^2 and r) translated into the terms in the question (m, M, R and h). In the derivation, some students cancelled M instead of m. However, others had so little confidence in their use of algebra that they could make little progress even in a simple derivation such as this.

Part (b)(i) caused few problems and marks were generally high. Sometimes incorrect values had been extracted from the data booklet for the mass and radius of the Earth. Three significant figures were expected in the answer; therefore a minimum of three significant figures should also have been used in the substitution and working. When $h = 1.39 \times 10^7$ was used as the radius of the orbit one mark was lost and the value of the force thus obtained was carried forward to make most marks available in part (b)(ii). Part (b)(ii) offered a very wide range of approaches to enable students to show that the satellite would make three transits of Earth in every 24 hours. Apart from the three alternatives given in the mark scheme (all of which were frequently seen) a very concise calculation showed that a satellite with an angular speed of 2.19×10^{-4} rad s^{-1} would move through an angle of 18.9 rad in one day, equating to ($18.9 / 2\pi =$) 3.01 transits.

Use of polar orbiting satellites for monitoring the Earth (weather forecasting, spying, surveying, etc.) were well known in part (c), although some students confused the application with an equatorial geosynchronous satellite. Explanations of the application were often less satisfactory: reference to the rotation of Earth beneath the orbit, allowing the whole surface to be scanned, was the key here. The ability to provide regular updates of the information obtained was also an acceptable explanation. Students who mentioned the use of the polar satellite for communications gained the first mark but were usually unable to point out its limitations, caused by intermittent contact.

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49. Most of the candidates made significant progress in part (a) and there were some very good explanations of thermionic emission. The most common omission was in not describing the role of the electric field between the anode and cathode in accelerating the electrons in the beam.

Many candidates calculated the acceleration correctly and a significant number set out their work clearly and well. Some attempted to use the work done by the electric field between and others tried to use just the equations of motion.

Parts (b) (ii) and (b) (iii) were well done by many candidates.

In part (b) (iv), a significant number of candidates did not know how to proceed but the majority made some progress either by using ratios or equations of motion. For those that made significant headway, the most frequent mistake was to omit to add on the vertical distance that had already been travelled by the time the beam reached the end of the plates.

50. Most candidates correctly took ratios to obtain the value for d in (a). Many then went on to calculate the acceleration, time or kinetic energy before substituting to find the force (from $F = ma$, $Ft = \Delta(mv)$ or $W = Fs$ respectively).

An unexpectedly large number of candidates failed to refer to the kinetic energy and skidding distance equation in (c) and consequently were unable to take their answers forward. The best answers showed the proportional relationship between skidding distance and kinetic energy and stated that the kinetic energy was entirely transferred into the internal energy of the tyres / road ('heat' was condoned for 'internal energy' here).

51. This question has been used to test candidates in earlier years. The former one showed an improvement in facility and the latter one a deterioration. This question was about the magnetic forces that act on a coil which is free to rotate in a uniform magnetic field. 58% of the responses were correct. The most popular incorrect answer was distractor B. Candidates who chose this response had not spotted the fact that when the coil lies with its plane perpendicular to the field, the two forces on its sides act in opposite directions along the same straight line. Therefore they do not constitute a couple.

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52. (a) (i) This was generally well done but a few used t = s / v. Some rounded 0.4946 to 0.495 and then rounded again to 0.50. This was penalised.

(ii) A large majority of candidates used a 'suvat' equation for this. Unusually, quite a few did so correctly with $a = 0$ and $u = v = 8.5$.

Many teachers encourage the 'suvat' equations to be applied for constant velocity situations and this is fine if the candidates know what to do. Nevertheless, the most common error was the use of 'suvat' with either $a = 9.81$ or $u = 0$.

For constant velocity situations, it is simply necessary to use, $s = vt$.
Those who did choose $v = s / t$, sometimes rearranged as $s = v / t$.

(b) (i) Uniform deceleration was implied in this question so a 'suvat' approach was appropriate with $s = 0.35$ m, $u = 8.5$ ms^{-1} and $v = 0$. Most errors were due to use of $t = s / v$ or using 9.81 for the acceleration.

A very large number of candidates rounded to 2 dp (0.08). This was forgiven here but it is not good practice. 2sf would be appropriate here (0.082). Many students clearly do not understand the difference between decimal places and significant figures.

(ii) Extensive use of $a = 9.81$ to calculate a horizontal force was seen. Very many candidates clearly did not fully understand the context. They identified a suitable equation but substituted the wrong values. There were many errors such as confusing distance with time, speed with acceleration. Not many used KE / displacement and most of those that tried tended to make errors. Quite a few candidates didn't attempt to answer this question.

53. This question required candidates to realise that change of momentum is equal to the impulse of a force, and that the answer is therefore represented by the area enclosed between the force-time graph and the time axis. 80% of them were able to do this correctly. Possibly it was inability to calculate the area of a triangle that caused 12% to choose distractor D.

54. This question was a numerical test of "force × time = change in momentum". This topic was not examined in Section B. Outwardly this question is more demanding than the previous one, but an even higher percentage of the answers were correct. Consequently this was the easiest question in the test. The ability of a question to distinguish the ablest students usually suffers when the facility is high (97% in this case); hence this was also the least discriminating question in the test.

55. Most candidates dealt with the simple calculation in part (a)(i) but many lost a mark by simply forgetting to square the velocity.

Part (a)(ii) gave the average horizontal force with no indication that the force, and therefore acceleration, was constant. Therefore, candidates who used suvat equations, apart from s = ½(u+v)t, were awarded only 1 mark. Just under 20% of candidates got the answer using a valid method, with most opting to equate the work done to the change in kinetic energy.

Part (b) proved to be the most challenging question in the paper with barely one-sixth of candidates gaining any marks at all. The majority of candidates failed to see that a sin component of either displacement or velocity was required and instead used W=F.s(cosθ) when dealing with the angle.

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56. Overall this question proved difficult to many candidates, with many failing to grasp the underlying physics in each part. Candidates would have aided their comprehension of this question by sketching diagrams to highlight the relevance of the information.

In part (a)(i) barely one-quarter of candidates could interpret the data given to work out the extension of the rope, and in part (a)(ii) most candidates only went so far as to calculate one of the forces acting on the jumper. A free-body diagram would have helped candidates elucidate both forces and then more likely identify the resultant force. This would have also helped candidates answer part (b), which was clearly poorly understood, with many candidates multiplying the mass by zero, rather than setting the resultant force as zero.

Part (c) was very poorly answered with very few answers showing an appreciation that there were 3 energies (kinetic, elastic potential and gravitational potential) involved in the calculation. Most candidates ignored the potential energy in the rope and treated the question as a simple conversion of gravitational potential energy to kinetic energy. The introduction of new data confused many candidates.

Despite part (d) directing candidates to consider the kinetic energy of the jumper, very few did. It was extremely rare to see answers that appreciated the kinetic energy remained unchanged and most candidates gave answers in terms of impulse and momentum. Candidates needed to consider the fact that the work done to reduce the kinetic energy to zero would occur over a shorter distance and so the force on the jumper would increase.

57. (a) Most candidates were successful on this one but a few divided by 9.81 rather than multiply.

(b) There was significant use of mass rather than weight for this moment calculation and 12 m was occasionally used rather than 5 m.

Incorrect units were often seen. Nm^{-1} and NM being the most common errors.

(c) Most candidates got this one right but a few attempted to use trigonometry to resolve the weight of the ship. A few used a distance of 12 − 5 = 7 m, perhaps thinking the pivot was at the centre of mass.

(d) Quite a few candidates did not attempt to resolve T and did 2.5 × T = 8.0 × F, but nearly all had a correct moments equation, which was credited.

58. This question was the first of two questions in this test that required candidates to select an incorrect statement, a type of question which often challenges their logical reasoning. In the perfectly elastic collision at right angles between a molecule and the side of a container, the velocity of the molecule is exactly reversed. The change in momentum is therefore $mu - (-mu) = 2mu$. 70% of the candidates were aware of this, but almost a quarter of them thought the change in momentum would be zero (and therefore chose distractor A). Very few candidates chose the other two distractors.

59. This question was answered correctly by almost 95% of the students, who clearly recognised that the area under the graph was “force × time = impulse = change in momentum”. The surprising feature of this question is that when in was pre-tested in 2008 fewer than 60% of the students gave the correct response.

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