AQA A-LEVEL PHYSICS · 7408

PHYSICS



MARK SCHEME

3.4.1 FORCE, ENERGY AND MOMENTUM · PACK 3

SCORE	PERCENTAGE
/158	%

STEMUP

These questions belong to AQA, not to us.

The examination questions, mark schemes and examiner reports in this pack were written and published by AQA. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with AQA and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. AQA has not endorsed, approved or been involved in the production of it. AQA and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

AQA publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at aqa.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Mark schemes

1. D

[1]

2. B

[1]

3. C

[1]

4. (a) force is at right angles / horizontal to wall (and so no component along the wall) ✓

1

(b) arrow drawn upwards from point of contact with ground ✓ between ladder and vertical which when extended would pass through 'on ladder' part of label ✓

Must be vertical or pointing to right for first mark

1
1

(c) *(use of sum of clockwise moments = sum of anticlockwise moments)*
EITHER
$F \times 8.0\sin 60$
OR
$390 \times 4.0 \cos 60$ ✓
$F = 390 \times 4.0 \cos 60 / 8.0 \sin 60 = 110\ (113)$ N ✓

Either moment correct gets first mark (does not have to be evaluated)

1
1

(c) **ANY 3**
(vertical reaction) force from ground increases ✓
direction of arrow of resultant force from ground changes (as ladder is ascended) ✓
friction force / horizontal component of G between ladder and ground would increase ✓
the (reaction) force from the wall increases ✓
weight (of system) / load on ladder increases ✓
as person climbs they exert a force along the ladder ✓

MAX 3

[8]

STEMUP.CO.UK

5. (a) arrow parallel to slope labelled (M+2m)gsin35 and label parallel to slope labelled tension OR T ✓



Ignore arrows not parallel to ground e.g. weight

Ignore friction

W not acceptable for (M +2m)g

1

(b) T – Mgsin35 = Ma
AND (M+2m)gsin35 – T = (M+2m)a ✓

add two equations

(M + 2m)gsin35 – Mg sin35 = Ma + (M +2m)a ✓

HENCE
(a= mgsin35 / (M+m))

OR
(M +2m)gsin35 – Mgsin35 ✓ (= (2M+2m)a)

a = 2mgsin35 /(2M +2m) ✓

HENCE
(a= mgsin35 / (M+m))

1
1

(c) SECOND MARK CONDITIONAL ON FIRST
mass / impulse / acceleration (of trollies) is the same ✓
momenta (trolley A and B) the same

SECOND MARK CONDITIONAL ON FIRST

both have same speed / magnitude of velocity but different masses
✓

(hence) momentum of A is greater / momenta in opposite directions
✓

1
1

STEMUP.CO.UK

(d) $\text{acceleration} = \frac{1}{4} \times \frac{30 \times 9.81 \times \sin 35°}{(30 + 95)} = 0.338$ ✓

(use of $v^2 = 2as$)

$v = \sqrt{(2 \times 0.338 \times 9.0)} = 2.47$ ✓

$t = \frac{2.47}{0.338} = 7.3\text{s}$ ✓

OR
(use of $s = 1/2at^2$)
$9 = ½ \times 0.338 \times t^2$ ✓
$t = 7.3$ s ✓

CE from acceleration calculation
If used g for acceleration then no marks awarded

1
1
1

(e) number of journeys = (1800/(12 + 7.3) = 93 or 94 ✓

number of blocks = 2 × 93 = 186 or 2 × 94 = 188 ✓

Allow CE from 06.4
Allow between 93 to 94
Allow CE from incorrect number of journeys
Allow 186 to 188

1
1

[10]

STEMUP.CO.UK

6. (a) EITHER

calculate value for constant using two calculations ✓

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

need to see table to look for any working

OR

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

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

e.g. 0.5/0.8 = √110/√140

OR

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

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

no comment needed with this alternative

2

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

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

use of consistent *m* and *f* Substituted in $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ including g but condone powers of 10 error ✓

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

0.67 m ✓

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

3

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

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

2

[7]

7. A

[1]

8. B

[1]

STEMUP.CO.UK

9. A

[1]

10. C

[1]

11. D

[1]

12. B

[1]

13. A

[1]

14. D

[1]

15. A

[1]

16. C

[1]

17. (a) Calculation of energy = $12 \times 7.2 \times 10^4 = 8.64 \times 10^5$ J

Or time = 12000 / 1.5 = 8000 s ✓

Calculation of other quantity and substitution in power = useful energy / time taken ✓

Power = 110 (108 W) ✓

Or

Time = 8000 s ✓

Allow ecf for current or time

Current = charge / time = 9 A ✓

Power = VI = 108 (W) ✓

3

STEMUP.CO.UK

(b) Attempt to use Power / velocity ✓

Allow use of 100W for P

73 N ✓

Ignore inclusion of KE in calculation

If 108 used then answer is 72 N

If 100 used then answer is 67 N

or

work done = $F \times 12000$ ✓

equates to 110×8000 so $F = 73$ N ✓

allow ecf from 3.1

2

(c) Force parallel to slope = $120 \times 9.81 \times \sin 4.5 = 92$ N ✓

1

(d) Total resistive force = ans to (c) + ans to **(b)** (= 165 N) ✓

Allow ecf for incorrect F

$$\text{Speed} = \left(\frac{100}{165} =\right) 0.61\ \text{m s}^{-1}$$

Allow 0.66 / 0.67 if 108 W or 110 W used

2

(e) **Increasing the mass**

Reward discussion of compression of tyres

Reduces the range ✓

increases the friction on the bearings/tyres

OR More energy / power is used accelerating the user to the final speed

OR user and wheelchair have higher KE/ more energy to move ✓

Increasing the speed

Reduces the range ✓

Air resistance increases with speed ✓

Treat as independent parts

If not explicit about increasing / decreasing lose the first mark in each part

Within each part, second mark is dependent on the first

Allow opposite answers for decreasing mass / speed

4

[12]

STEMUP.CO.UK

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

3.1×10^{-3} (m) ✓

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

2

(b) (500 = Tcos 65)

T = 1200 N ✓

1

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

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

(Incident and reflected) waves interfere / superpose ✓

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

4

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

1

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

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

Third harmonic = 7.4 (Hz) ✓

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

2

(f) Diagram showing three approximately equally spaced loops

Condone single line

1

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

Permenant deformation / Does not return to original length ✓

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

2

[13]

19. C

[1]

STEMUP.CO.UK

20. D

[1]

21. (a) (Total) kinetic energy ✓

1

(b) Attempt to apply conservation of momentum ✓

NB This is a 'show that' so all stages must be seen

1

16 000 × 2.8 – 12 000 × 3.1 = 28 000 v ✓

Must see substitution

1

v = 0.27(1) (m s^{-1}) ✓

Correct equation (watch signs) gets first and second marks

1

(c) Impulse = 16 000(2.8 – 0.271) or 12 000(3.1 + 0.271) = 4.0(5) × 10^4 ✓

If 0.3 m s–1 used then impulse will be 4.0 × 10^4 or 4.08(4.1) × 10^4

1

N s or kg m s^{-1} ✓

1

(d) Trucks move in opposite directions/rebound ✓

1

Velocity of **B** is greater than that of **A** because total momentum is to the right OR **B** has lower mass ✓

OR

Momentum of **B** after collision is same as that of **A** before the collision (and vice versa)

1

[8]

22. D

[1]

23. B

[1]

24. A

[1]

25. D

[1]

STEMUP.CO.UK

26. (a) Tangent drawn at $t = 2.0 \pm 1$ s ✓

Use of suvat loses first 2 marks

Guidance- take tangent point to be half-way between where the line clearly leaves the curve

1

Mean deceleration from use of tangent using correct coordinates (correct Δv and Δt) and answer in range (-)2.5 to (-)2.9 (m s^{-2}) ✓

Ignore minus sign

=15/5.5 = 2.7(3) m s^{-2}

Allow if answer rounds to these values

1

Use of $F = ma$ using their a with answer

i.e. Force $=1.8 \times 10^4 \times$ their a from an attempt at a tangent or trying to use *suvat* equation✓

Answers from best attempts at tangent in range 4.7 to 4.9 × 10^4 N

1

(b) Attempt to estimate area under the graph ✓

Use of suvat equation = 0

1

Correct square count 21 to 23 10 mm squares

(525-575 small squares)

OR

distance per square = 2.5 m or 0.1 m✓

For attempt to find area using trapezium rule expect use of 1 s intervals for this mark

1

Value in range 50 m to 60 m **and conclusion**

that escape lane would be long enough✓

1

(c) KE of lorry :

to KE of gravel (as it is pushed aside/moved)✓

OR

PE of gravel (as it may be ejected upwards)✓

Ignore losses due to friction

Not KE of the ground

1

transfer to thermal energy /internal energy/heating of gravel /ground/lorry

STEMUP.CO.UK

OR

work done on the gravel/vehicle increasing internal energy/raising temperature✓

Must refer to what is heated

1
Max 2

(d) Appreciates that KE converted into PE

OR

May be stated or by attempt to use of $mgh = ½ mv^2$

OR

Calculates initial KE of lorry $½1.8 \times 10^4 \times 17.5^2 = 2.76 \times 10^6$ (J) ✓

1

Height needed in escape lane = $2.76 \times 10^6/(1.8 \times 10^4 \times 9.81) = 15.6$ m

OR

Length of lane required = 15.6/sin25 = 37 m (compare with 85 m)

OR

vertical height of ramp = 35.9 m (compare with height needed 15.6 m)

OR

maximum change in PE possible = $85 \sin 25 \times 9.81 \times 1.8 \times 10^4 = 6.3 \times 10^6$ (J)

(compare with initial KE) ✓

Allow max 2 if height = 85 tan 25
or length of lane = 15.6/tan 25
i.e. allow these incorrect values when drawing conclusion

1

Comparison and conclusion that escape lane would be long enough. This must follow from correct working✓

.....

Deceleration produced by slope = 9.8(1) sin 25 or

4.15 (4.1 or 4.2) m s^{-2} seen✓

Distance to stop from $v^2 = 2as$ give $s = 37$ m (compare with 85 m)✓

Arriving at 37 m gets first two marks

STEMUP.CO.UK

OR

Minimum deceleration needed = $17.5^2/2 \times 85 = 1.8$ m s^{-2} (compare with 4.15 m s^{-2})

Comparison and conclusion that escape lane would be long enough This must follow from correct working✓

1

(e) The straight road of uniform gradient because:

The deceleration (condone acceleration) is uniform ✓

with the gravel the initial deceleration is larger/may vary ✓

Travelling through gravel could make the vehicle unstable/bounce erratically(owtte) ✓

Gravel because:

On the ramp the lorry would roll backwards after stopping (as it has no brakes)

Do not allow deceleration less when on gravel(It is greater initially)

Do not allow answers that (average) force using gravel lane is less than decelerating force on the ramp (due to increased stopping distance or stopping time)

Or because stopping time is longer

MAX 1

[12]

27. B

[1]

28. A

[1]

29. D

[1]

30. C

[1]

31. A

[1]

32. C

[1]

33. D

[1]

STEMUP.CO.UK

34. (a) Mass of alpha particle = $\frac{2\times1.6\times10^{-19}}{4.81\times10^{7}}$ =6.6(53) × 10^{-27} (kg)

Allow mass = 2 × m_p + 2 × m_n = 6.696 × 10^{-27} kg

Allow mass = 4 × 1.66 × 10^{-27} kg = 6.64 × 10^{-27} kg

Allow mass = 4 × 1.67 × 10^{-27} kg = 6.68 × 10^{-27} kg

Allow slight rounding on mass (must be correct to 2 sf)

OR

Correctly re-arranged k.e. equation (with v^2 or v as subject) with 8.1 × 10^{-13} (J) substituted correctly$_1$✓

1.56 × 10^7 seen $_2$✓

*Condone **incorrect mass** in otherwise correct substitution **with v or v^2 recognisable** as subject .*

Alternative approaches are:

$$v=\sqrt{\frac{E_k\times\text{specific charge}}{e}}$$

$$v=\sqrt{\frac{2\times E_k}{m_\alpha}}$$

Must see answer to at least 2 sf

Must see attempt to use one of the alternative approaches to support correct answer

2

(b) Use of $W = Fs$, F = 8.1 × 10^{-13} ÷ 3.5 × 10^{-2} $_1$✓

(F=) 2.3 × 10^{-11} (N) $_2$✓

Condone POT error

Correct answers gets 2 marks

OR

Use of an appropriate equation of motion to find a **and** $F = ma$

(allow their mass and their velocity in this sub) $_1$✓

Condone POT error

(F=) 2.3 × 10^{-11} (N) $_2$✓

Condone POT

STEMUP.CO.UK

OR

Use of an appropriate equation of motion to find t **and** $F = \Delta mv/t$

(allow their mass and their velocity in this sub) $_1$✓

(F=) 2.3×10^{-11} (N) $_2$✓

[answer is

$$\frac{(\text{their speed})^2 \times (\text{their } m_\alpha)}{0.070}$$

Using 2×10^7 m s^{-1} yields(5.71×10^{15} × their m_∞) – allow 1 sf answer in this case

Expect to see 3.8×10^{-11} (N) or 4×10^{-11} (N)]

2

(c) (Number of ions formed over range =)

$5.1 \times 10^4 \times 3.5$ seen **or** 1.785×10^5 (ions) seen

OR

8.1×10^{-13} converted to eV seen $_1$✓

$8.1 \times 10^{-13} \div 1.785 \times 10^5$

OR

$5.06 \times 10^6 \div 1.785 \times 10^5$ seen $_2$✓

Condone POT error in first mark

Ignore units

$8.1 \times 10^{-13} \div (5.1 \times 10^4 \times 3.5)$ is worth 1st and 2nd marks

Condone POT errors in second mark

Correct answer obtains 3 marks

28 (.4) (eV) $_3$✓

99(.3) (eV) scores 1 mark

3

(d) (Q =) $0.85 \times 10^{-3} \times 1.2 \times 10^{-9} = 1.02 \times 10^{-12}$

OR

n = (their Q) $\div 1.6 \times 10^{-19}$ $_1$✓

$n = 6.4 \times 10^6$ (c.a.o.) $_2$✓

Condone one POT error for one mark

2

(e) At 3.5 cm the pd drops / the current begins

STEMUP.CO.UK

OR

When the source is 10 cm away no ionisation occurs in the air gap (because the alpha particles have insufficient range to reach the air gap)

OR

When the radioactive source is close enough (approx. 5 cm) ionisation occurs ✓

OR

When beyond 3.5 cm no change in pd / current equals zero

Must be sense of abrupt change

MAX 3

When ionisation occurs / charge carriers are liberated in the air gap:

Allow more ionisation for second mark

resistance has decreased

OR

current increases (from zero)

OR

the potential difference decreases (with a maximum current) (to its minimum value) (across the air gap)✓

From 10 cm separation until 5 cm (approx) separation nothing changes / appreciates that pd is 4500 V / pd across gap = 4500 V until ionisation occurs ✓

Current is produced: the pd across 5 MΩ resistor is 4250 V / most pd is across the 5 MΩ resistor / small pd across air gap ✓

Current is produced and the pd across the air gap is 250 V✓

Current is produced and the pd across the air gap is 250 V✓

3

[12]

35. C

[1]

STEMUP.CO.UK

36. (a) (u =)0.2(0) or 20 or 200 **and** (v =)0.25 or 25 or 250 $_1$✓;

Both *velocities seen / allow seen in* $(a =)\frac{v-u}{t_3}$ */ condone (possible) powers of ten (POT) error for 1st mark and 2nd mark in their* v *and* u *and any substitution* v *and* u *into* $(a =)\frac{v-u}{t_3}$

Where t_3 *has been substituted must be* t_3 *= 1.19 (s)*

substitution of their u and v in $(a =)\frac{v-u}{t_3}$ ✓

Where t_3 has been substituted must be t_3 = 1.19 (s)

Values for:

u *(0.20 (m s*$^{-1}$*) or 20 (cm s*$^{-1}$*)200 (mm s*$^{-1}$*)) and*

v *(0.25 (m s*$^{-1}$*) or 25 (cm s*$^{-1}$*) or 250 (mm s*$^{-1}$*))*

Correctly combined with t_3 *(1.19) will earn 1st and 2nd marks*

Where u *and* v *are not correct, they must be identifiable as their* u *and* v *(2nd mark is only mark available except where error is POT)*

Allow their $\frac{\Delta v}{1.19}$ *(=* a*) where clear it is their* Δv

a = 4.2 × 10^{-2} (m s^{-2}) $_3$✓

Correct result for a *will earn three marks;*

Accept 420 mm s^{-2} *or 42 cm s*$^{-2}$ *if m s*$^{-2}$ *has been replaced on the answer line*

2 sf answer only

3

(b) (set **B** because) it has a greater time / takes longer (to travel between gates) (hence distance between gates is larger) $_1$✓

(and) set **B**'s <u>average velocity</u> is greater / set **B**'s <u>velocity</u> at <u>gate 1</u> is greater / Set **B**'s <u>velocity</u> is greater at both gates

Two calculations for gate separation s *using either*

OR

(and) set **A**'s <u>average velocity</u> is smaller / set **A**'s <u>velocity</u> at <u>gate 1</u> is smaller/ Set **A**'s <u>velocity</u> is smaller at both gates $_2$✓

Alternative Method

values of u and v are calculated (condone POT error) and corresponding values for each s determined; $_1$✓

<u>a comparison of ***their*** distances</u> leading to <u>conclusion</u> that set **B** produced when s is largest

STEMUP.CO.UK

OR

ratio $\left(t_3 \times \frac{t_1 + t_2}{t_1 \times t_2}\right)$ is <u>proportional to distance</u> s and **B**'s <u>ratio is greater</u> $_2$✓

$(s =)\left(\frac{u+v}{2}\right) \times t_3$ ***OR*** $(s) = \frac{v^2 - u^2}{2a}$; ***OR*** $(s =) t_3 \times \frac{t_1 + t_2}{t_1 \times t_2}$

	u/ms^{-1}	v/ms^{-1}	s/m	$v^2 - u^2$/ m^2s^{-2}
Set A	0.164	0.238	0.356	0.0297
Set B	0.181	0.270	0.476	0.0401

	$t_3 \times \frac{t_1 + t_2}{t_1 \times t_2}$
Set A	7.12
Set B	9.54

Allow ecf for acceleration where used to find s

Using a = 0.042: s_A = 0.354 and s_B = 0.478

Treat a larger change in velocity as neutral

2

(c) Continuous, <u>ruled</u> straight best fit line through 1st and last points $_1$✓

n=4 point below and n=7 above, other points cut by line of best fit

Line must not be thicker than half a square grid

Line must have no variation in thickness

Do not accept more than one line drawn, do not accept discontinuities

Gradient from $\frac{y \text{ step}}{x \text{ step}}$ **seen**

and

G = 0.045 range (0.042 to 0.053) $_2$✓

Steps at least half the height and half the width of the grid; (at least 3 squares horizontally and at least 5 squares vertically)

Allow $\frac{\text{change in y}}{\text{change in x}}$ *where points are on line and are at least half drawn line apart ($\Delta x \geq 3$ and $\Delta y \geq 0.175$)*

Ignore any units given for G

Allow 1 sf answers of 0.04 or 0.05 where correct working is shown

2

STEMUP.CO.UK

(d) $\frac{\text{their } G}{4.9}$ ✓

($h = 9.2 \times 10^{-3}$ m)

*Ecf from part **(c)***

***Expect 2 sf normally**. Penalise 3 or more sf*

*Condone 1 sf answers where correct working is shown in part **(d)** **and** where their G is quoted to 1sf*

In this case, allow use of their rounded G or full carry value

1

(e) idea that the intercept can be found by calculating $a - Gn$ where a and n are values read-off (from a point on the line) and G is the gradient ; intercept compared to 0, 0 (OWTTE in a general y=mx +c description)

Simply explaining how to find the intercept does not fully answer the question and gets no credit must describe the comparison aspect; do not accept idea of extrapolation off the grid or re-plotting on axes that include (0, 0)

OR

Read-off points (of line of best fit for) x_1 and x_2 compare with corresponding y_1 and y_2 , compares the ratio of the x terms to the ratio of the y terms; if equal then directly proportional

OR

Determine the constant of proportionality for at least two points (on line of best fit) and compare, where constant exists then directly proportional ✓

Idea that a and n will share a common factorial increase

1

[9]

37. (a) (use of $\rho = M/V$)

$M = 4.0 \times 10^{-6} \times 920 = 3.68 \times 10^{-3}$ (kg) ✓

weight $= 3.68 \times 10^{-3} \times 9.81 = 3.6 \times 10^{-2}$ (N) ✓

Ecf for second mark

1 sig.fig. -1 mark

1
1

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

Ecf 5.1 from mass calculation

1

STEMUP.CO.UK

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

1
1
1
(MAX 3)

[6]

38. C

[1]

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

1
1

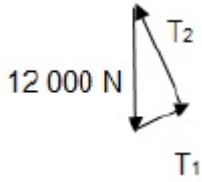
(b) EITHER
the point through which (the line of action of) a force has no turning effect/causes no rotation/ no torque ✓
OR
where the mass of the body can be considered to be concentrated OR where the weight can be considered to act ✓
NOT where mass can be considered to act
Ignore reference to force of gravity

1

(c) so there is not a resultant moment/turning effect / turning force OR moments do not balance OR (beam) does not rotate / oscillate / swing ✓
about A / because A is pivot ✓
Allow moments balanced for no resultant moment

1
1

(d)



$T_1 = 12\ 000 \cos 53$ ✓
$T_1 = 7200\ (7221)$ (N) ✓
$T_2 = 12\ 000 \sin 53$ ✓
$T_2 = 9600\ (9583)$ (N) ✓

STEMUP.CO.UK

OR

$T_1 \cos 53 + T_2 \cos 37 = 12\,000$ ✓
$T_1 \sin 53 = T_2 \sin 37$ ✓
$T_2 = T_1 \sin 53/\sin 37$
hence
$T_1 \cos 53 + T_1 \sin 53 \cos 37/\sin 37 = 12\,000$
$T_1 = 7200$ (7221) (N) ✓
$T_2 = 7221 \sin 53/\sin 37 = 9600$ (9583) (N) ✓

If T_1 and T_2 are the wrong way round get 3 out of 4
If scale drawing 2 max +/- 300(N)
If values out by a factor of 10 then -1 (i.e. confusion over g)

1
1
1
1

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

No attempt to calculate area scores zero
Wrong area (e.g. d^2 or $2\pi r$ or $2\pi rl$) maximum 1 mark unless diameter used for radius in πr^2 then maximum 2 marks
Accept 4.0×10^{-3}
If 4×10^{-3} then -1 as 1 sig. fig.

1
1
1

[12]

40. D

[1]

41. A

[1]

42. (a) *(use of gain in E_k = loss in E_p)*
$1/2mv^2 = mgh$
$1/2v^2 = 9.81 \times 8.0$ ✓
$(v = \sqrt{(2 \times 9.81 \times 8.0)}) = 13$ (12.5) (m s^{-1}) ✓

Bald correct answer scores 1 mark
If use $v^2 = u^2 + 2as$ then zero
Unless resolved g along slope
If use 10 for g (–1)
Gets second mark if answer rounds to 13

1
1

STEMUP.CO.UK

(b) THREE FROM:
acceleration of truck in Fig.1 is constant ✓
In Fig.2
acceleration is greater/greatest at start/top ✓
acceleration decreases ✓
reference to zero acceleration/uniform velocity between C and D ✓
because the component of weight/acceleration parallel to the slope changes ✓

1
1
1
(3 max)

(c) the loss of (gravitational) potential energy is the same
hence gain in kinetic energy is the same ✓

1

(d) THREE FROM:
rain has no (initial) horizontal momentum ✓
vertical momentum of rainwater decreases ✓
there is no external (horizontal) impulse/force on the truck (and water system) ✓
mass (of truck) increases but speed/velocity decreases ✓
horizontal momentum of water increases (but horizontal momentum of truck decreases by same amount) ✓
(so) no change in (horizontal) momentum of truck and collected water/total momentum ✓

If say: 'vertical momentum/velocity of rain drops/water changes to horizontal (momentum/velocity)' score 2 marks

Cannot score last mark if stated that speed/velocity of truck does not change

1
1
1
(3 max)

[9]

43. D

[1]

44. C

[1]

45. (a) Radius of orbit = 5 tan 28.5 + 1 = 3.71 m ✓

1

Speed = 2 × 3.14 × 3.71/5.2 = 4.49 () ✓

For second mark only allow

Use of sin 28.5 gives orbit radius 3.39 m and speed = 4.1 m s^{-1}

Or

Forgets to add 1 giving radius 2.71 and speed 3.27 m s^{-1}

1

STEMUP.CO.UK

(b) Centripetal force = 85 × $4.49^2/3.71$ = 460 N ✓

470 N if using 4.5 m s^{-1} leads to 1000 N

1

Centripetal force = T sin 28.5 ✓

Allow the following as ecf:

Forgetting to add the 1 m (using r = 2.71 m) leads to centripetal force = 630 N T = 1300 N)

*Using r =3.39 m as ecf from part **(e)** which leads to*

Centripetal force = 510 N giving T = 1070 N

1

T = 950 - 970 N ✓

1

OR

Weight = 85 × 9.8(1) 0r 834 N seen ✓

Weight = T cos 28.5 ✓

T = 950 (949) (N) ✓

OR

Centripetal force = 85 × $4.5^2/3.71$ = 464 N ✓

Weight = 834 N ✓

$T = \sqrt{464^2 + 834^2}$ = 950 – 970 N ✓

Allow ecf for incorrect weight or centripetal force

Allow the following as ecf:

Forgetting to add the 1 m (using r = 2.71 m) leads to

Centripetal force = 630 N, T = 1050 N

Using r = 3.39 m leads to

Centripetal force = 510 N giving T = 980N

(c) Vertical (compressive) force **on the pole** increases ✓

1

Increases mass <u>increases weight</u> and hence tension in the rope(for the same angle) $_1$✓

1

<u>Centripetal Force</u>

on the acrobats/masses would be different/not equal

STEMUP.CO.UK

OR

Would be greater <u>on the more massive acrobat</u>(travelling at the same speed/same angle to vertical) $_1$✓

Unbalanced (horizontal) forces/resultant force exists (on the pole) ✓

OR

Unbalanced moments acting (on pole)/resultant torque acting (on pole) ✓

Causing the pole to sway/bend/move/ or tilt/topple the platform <u>toward more massive acrobat</u> $_1$✓

1
Max 3

[8]

STEMUP.CO.UK

Examiner reports

3. 56.7% correct

4. Responses to this question on statics proved to be quite patchy.

Question (a) was generally well answered, with the majority appreciating that friction was negligible because the resultant force was a right angle to the wall.

Question (b) was less well done: very few students appreciated that the arrow for force G, the weight and the resultant force from the wall when extended would intersect at one point. G was often drawn vertically upwards or along the ladder; this did score 1 mark providing the arrow started from the point of contact with the ground. The calculation caused problems for over half of the students because they did not appreciate that they had to apply the principle of moments. The last part of the question generated some very good answers with some quite detailed analysis seen. Three-quarters of students were awarded at least two marks. There were some misconceptions such as that the force G decreases as the person climbs the ladder or that the resultant force from the wall only increases when the person is over half-way up the ladder.

5. The responses to this question showed significant variation with students performing significantly better in the quantitative parts than they did in the qualitative.

The majority of students failed to identify the forces acting on the trolley that were parallel with the slope. It was rare to see the component of the combined weights of trolley and blocks identified. Also, the majority of diagrams included forces which were not required such as the reaction force.

Question (b) involved an algebraic derivation of the acceleration of the trolley – this proved quite a challenge for some and responses had to be scrutinised carefully to see if they were valid. Many provided a correct formula for the resultant force on trolley A but then incorrectly stated that the tension was equal to the component of trolley B's weight along the slope. The more successful answers treated the trollies as a system with a resultant force acting equal to (M + 2m) gsin35 – Mgsin35 and a combined mass of 2M + 2m.

There was a typographical error in question (c) which led candidates to assume that loaded trolley A was being compared with loaded trolley B. The question originally intended to ask students to compare loaded trolley A with unloaded trolley B (as shown in Figure 2). We judged that both interpretations should be allowed and revised the mark scheme to permit the two different approaches. Either approach could achieve 0, 1 or 2 marks according to the accuracy of the answer. Student responses to this question were carefully scrutinised to assess the impact of the typographical error, and there was no evidence that students were unable to generate meaningful responses to this question.

The conclusion mark of how the momenta compared was then conditional on the first mark being awarded. The multi-step calculations in (d) and (e) were well done, with a high proportion of students scoring at least 3 of the 5 marks available.

STEMUP.CO.UK

6. Question (a) required students to analyse the data given and demonstrate that it was consistent with the given relationship. Just over half of students were able to do this. Common errors were confusion between linear and proportional relationships, and attempts to derive the expression algebraically without using the data.

The calculation in question (b) proved to be one of the more challenging in the paper. The main reason for this was a lack of appreciation of how to find the mass per unit length of the nylon string; this did limit them although they were able to pick up a mark for a correct substitution of tension and frequency in the appropriate formula.

The explanation, required in (c), of why the result might be different if much larger masses were used, was not well answered. The majority did not appreciate that the nylon would get thinner and this would reduce the mass per unit length. Common responses tried to invoke Hooke's law notwithstanding the fact that nylon does not obey this law.

7. Less than 50% of students selected the correct answer. Distractor B was the most frequently selected incorrect response. In selecting distractor B, students did not take account of the horizontal motion of ball **X**.

8. Most students selected the correct answer. A significant number of students selected distractor D, believing this statement was incorrect. **X** has a greater breaking stress since the force applied to it is greater than the force applied to **Y** at the point of breaking.

9. Almost 50% of students selected distractor B. Students were unable to see that the force was the same on both masses. Students often have difficulty in distinguishing between force and acceleration, as was the case here. The smaller mass will experience a greater acceleration but this is due to its inertia and not the size of the force it experiences. As momentum is conserved, then the momentum lost by one object is equal to the momentum gained by the other. The magnitude of the momentum change is the same for both objects. The forces acting between the objects can only act while they are in contact, therefore the time over which the momentum change occurs is the same for each.

Momentum change = impulse = force × time

$$\text{Same force} = \frac{\text{same momentum change}}{\text{same contact time}}$$

Alternatively, these forces are internal forces in a two-body system, constituting an example of Newton's third law, and must be equal in magnitude.

10. This moments calculation proved to be very challenging, with only 17% of students selecting the correct answer. Distractors A and B were the most popular incorrect answers with each being selected by approximately 35% of students. This error was caused by students disregarding the weight of the uniform metre rule.
Students should be encouraged to read the question carefully and include all forces and their respective distances to the pivot before undertaking any moments calculation.

11. Most students were able to determine the momentum gained by the object. Each of the distractors gained about 15% of student responses.

12. 91% of students selected the correct answer.

STEMUP.CO.UK

13. 27% of students selected the correct answer here. Most students attempted to use equations of motion but failed to appreciate the direction of the acceleration and were unable to resolve to find the component of the weight parallel to the slope. Those who were successful most frequently used the principle of conservation of energy to find the work done by the frictional force.

14. This was an accessible question with 87% of students selecting the correct response. The most frequent incorrect response was distractor A, with weaker students unable to recognise the vector nature of momentum.

15. 45% of students selected the correct answer, with 33% of students incorrectly selecting distractor B. Students seemed unwilling to consider the total momentum as being zero despite this application of momentum conservation being clearly stated in the specification content.

16. 70.2% correct

17. This question required students to apply their knowledge and understanding of physics to a battery-powered wheelchair. It gave students an opportunity to demonstrate knowledge and understanding in a range of areas including electrical and mechanical energy, power and force.

(a) This was a fairly accessible question with more than half of the students gaining all three marks. There was more than one route students could choose to answer this question, with the calculation of the current proving to be a popular alternative. 'Show that' questions provide students with an answer that can be used later should they be unable to do the calculation. It has become relatively common to see students attempting to use the value to perform the calculation backwards. It was more common to see answers that manipulated the numbers in the stem to obtain 100W. Students should be reminded that examiners will only give credit to the final answer in a 'show that' calculation if it is given to at least one more significant figure than the value in the question.

(b) Students were given full credit if they chose to use the value of 100 W from 03.1. Despite this, many students were unable to make at least some attempt at an answer, with over 10% making no attempt at all. It may be that many students were unfamiliar with questions that move from one area (such as electricity) to another (such as force), which could have led to the confusion of v (velocity) with V (pd) that was seen. Teachers should understand that this combination of topics within a question is a requirement of this specification, and the full A-level, that is certain to continue to appear in the examination papers. Errors were also seen in the answers that were provided. For example, asking for a 'mean' value of a quantity inevitably encourages some students to divide their answer by 2, an error that was seen a surprising number of times.

(c) Again, it may have been the context of this question that meant that this relatively straightforward calculation was only correctly performed by a minority of students. It may also have been partly due to the fact that only one mark is available and yet there are several opportunities for error, such as missing out 'g' and using the wrong trigonometrical function.

(d) The fact that a large number of students did not attempt this question is partly related to the need to use information from 03.2, which was not well answered. It could also suggest that students expect calculations involving speed (or velocity) to require the use of the "suvat" equations, for example, and that they are therefore confused when none of the familiar information is provided. However, it is acknowledged that this is a conceptually demanding question, requiring students to appreciate that, at the maximum speed, the driving force = the total friction/drag force for example, and then apply that to P = Fv.

(e) Another common feature of this new specification is the assessment of a student's ability to reach a reasoned judgement. In this question students were required to decide which effect (increase or decrease) they were going to consider, and whether this would increase or decrease the range. This was a point missed by many students. Fully correct answers were rare, with many students failing to make the link between the speed and drag forces for example.

18. This question applied both the idea of standing waves and the behaviour of materials to the context of a radio aerial. Despite this combination of topics, several parts of the question proved to be very accessible.

(a) It is clear from the large proportion of students who obtained both marks for this question that the application of the Young modulus is well understood. This question was made even more accessible by providing the area, and by giving all the data in units that did not require conversion.

(b) This one mark calculation was poorly answered, with few students being able to obtain the correct value for the tension. It may be that many students missed the relevant data or could not picture which forces were needed. It would doubtless have helped some students had they drawn the forces on the diagram provided.

(c) It is clear that many students learn about the formation of standing waves in general terms and answers focusing on this were incomplete in several respects. In particular, many students missed out the initial formation of the wave, and many failed to adequately explain the reason for production of specific frequencies. Consequently it was common to see answers obtaining only 2 of the 4 marks.

(d) This calculation proved to be very accessible with a large majority of students obtaining the single mark for it.

(e) However, this calculation proved to be less accessible despite an error for the mass per unit length in part (d) being carried forward. Credit was also given for students making it clear that the fundamental frequency had to be multiplied by 3.

(f) The drawing of three 'loops' was generally awarded the mark, unless the length of each loop was too unequal to be acceptable.

(g) Whilst it was common to see answers that made some attempt to describe what happens to the wire if it is stretched too much, poor use of the correct terminology, such as failure to mention an elastic limit or equivalent, tended to limit the mark awarded to many answers.

20. 43.0% correct

21. (a) That kinetic energy would be conserved in an elastic collision was well known (64.5% correct).

(b) Most students knew how to arrive at the answer (75.3% fully correct), but responses were often completely unstructured and consisted of a mass of figures and calculations with no indication of what the calculation represented. In questions where the command word is 'calculate' this may often be accepted, but in 'show that' items communication of the processing of data needs to be clear.

STEMUP.CO.UK

(c) The same impulse on each of the trucks is equal and opposite so students needed to focus on one or other of the trucks involved. There were many who misread the data and associated the initial velocities with the wrong trucks. Many gave the impulse as the difference between the final momenta of the two trucks.

(d) It was necessary here to have a qualitative appreciation of the application of conservation of momentum and kinetic energy in the elastic collision. It is not possible to conserve both unless the trucks travel in opposite directions after the collision, and many appreciated this point. Many students, however, went on to state that the speed of each truck would be the same as before but in the opposite direction; others wrote that B would have the speed that A had and vice versa. The first conserves kinetic energy but not momentum (total momentum would be reversed) and the second would only be true if they had the same mass. If A were to stop, as suggested by many students, then to conserve momentum B would need to travel at a lower speed than either of the trucks (since the initial total momentum was 7600 Ns to the right, B's speed would need to be 0.63 Ns). This would not conserve kinetic energy. 38.5% of students were successful here.

22. 38.1% correct

23. 67.6% correct

24. Students found this question challenging; there was a success rate of just over 20%. The most common incorrect response seen was distractor C. Quite often this was selected without any evidence of supporting calculations.

25. This question was demanding, with only 18.8% of students able to select the correct answer. The most frequently selected incorrect answer was distractor A. The two approaches used were to realise the significance of the area under the force-time graph or alternatively to realise the significance of the gradient of the momentum-time graph.

26. (a) It was important to realise that this was not uniform deceleration so that application of the suvat equation was not appropriate. Many students unfortunately used this approach and therefore could only access the final mark for application of $F = ma$. A significant proportion used the instantaneous values at 2 s to find acceleration and these students were denied access to the final mark. Students who realised that a tangent was required were able to progress and were rewarded, provided that the tangent was not at a point too far from 2.0 s. The accepted range was determined to allow for the acceptable limits. Just over 30% of students scored all three marks.

(b) The use of the suvat equations led to no marks being awarded in this part. A majority of the students realised that the area under the graph was needed and there were many very sound responses (though 65% of students ultimately scored zero). Counting squares was the most popular approach. Use of the trapezium rule was often spoiled by choice of time intervals that were too large.

(c) Students here needed to think of the context and respond accordingly. There were many who produced the very low level response of 'heat and sound', which gained no credit. It was essential to state what was heated. Only the more thoughtful students commented on the transfer of KE of the lorry to KE of the gravel, or work done moving it, which contributed to the greatest energy transfer in the context. 4.6% of students gained both marks here.

STEMUP.CO.UK

(d) There were a number of different routes that led to the conclusion that the escape lane was long enough and they were seen in fairly even numbers. The easiest and possibly most straightforward were a comparison of the initial KE of the lorry and height at which the KE would be totally transferred, or comparison of the initial KE with the PE of the lorry if it were to reach the top of the ramp. Whilst the appropriate calculations were often seen, it was disappointing that many did not provide any comments of what each calculation represented and final statements in conclusion were often not well argued. However, over a quarter of students were able to score maximum credit.

(e) This was an open-ended question that could be argued either way with appropriate comment. The most common approach was to discuss the problem of rolling back down the slope after stopping on the ramp. Comments relating to comparisons of acceleration were not appropriate as this usually led to students writing that the deceleration was lower on the gravel. These were comparing the instantaneous deceleration at 2 s with the uniform deceleration on the ramp; the initial deceleration on the gravel was considerably larger. 52.5% of students answered this successfully.

27. Students demonstrated a limited understanding of the difference between acceleration and velocity, with the most popular answer selected being distractor A. Students found it difficult to realise that objects are still accelerating even when their instantaneous velocity is zero. 26.9% of students arrived at the correct answer.

28. A considerable number of students had difficulty in resolving vectors, with many choosing distractor B as their answer. Students who selected the correct answer (42.6%) had quite often drawn a vector triangle around the wind's velocity and this helped them to identify the correct component.

29. The most common incorrect response seen was distractor A. These students mixed up the acceleration of free-fall conditions with the conditions experienced under terminal velocity. There was a success rate of 38.7% on this item.

30. The most popular answer here was the correct answer (41% of students); certainly higher achieving candidates seemed confident with this calculation.

31. Most students thought that the transit time would either be halved or doubled, selecting B or C in almost equal numbers. Only 24% of students identified A as the correct answer and in doing so realised the transit time was unaffected by doubling the width of the core.

32. Almost 40% of students were able to select the correct answer. The most common wrong answer selected was B; here students used a simple 2:1 ratio approach for the distance based on the information provided about the tensions.

33. The majority of students (58.1%) were able to identify the correct ranking of the prefixes. The most common incorrect response was B showing these students were unable to recall the values for pico- and femto-.

STEMUP.CO.UK

34. (a) There were a number of stages to this "show that" question. Because of its level of demand the mark scheme was less stringent than usual about how "show that" calculations should be presented. However, students should be encouraged to ensure they have fully demonstrated how the answer is obtained. These pieces of advice should be considered:

- any equations used should be written with subjects seen at each stage of the calculation;
- mid-calculation rounding should be avoided;
- the answer should be quoted to more significant figures than the value they have been asked to find.

(b) The main error seen, when using F = ma and equations of motion, was not taking into account speed changing when calculating the time to stop. Students who identified the questions as being set up for a "work done = change in kinetic energy" generally obtained all marks (27.3%).

(c) Good students were able successfully to complete this calculation (23.1%) whereas lower performing students appeared to have little appreciation of the problem and were able to make only limited progress, by perhaps finding the number of ions or converting the energy into electron volts.

(d) Students failed to gain marks here for a number of the following common reasons: dividing the current by the time, using $2 \times 1.6 \times 10^{-19}$ for each charge carrier rather than 1.6×10^{-19}, and misremembering the prefix nano- as 10^{-12}.

(e) This question proved to be inaccessible to all but the very best students. Only 10.7% of students managed to score anything on this item. The number of factors they had to consider proved too challenging for most. Where students realised that ionisation occurred when the alpha source was close enough, they often got confused about the effect this had on the current in the circuit and the resistance and potential difference across the air gap. Many students thought that an increase in current could only occur when the potential difference across the air gap increased.

36. (a) Many students incorrectly assumed the air-track glider's velocity was zero at the first light gate. Other common mistakes seen included using the total travel time of 2.09 s rather than 1.19 s and assuming that the distance travelled was 10.0 cm. Nevertheless, nearly a quarter of students scored all three marks.

(b) There were lots of undeveloped statements; students implied that a longer time equalled a greater distance. In many cases, the supporting arguments presented were flawed with many students stating that with the same acceleration a greater time would result in a larger distance. There was some good analysis of the data but such an approach was usually only taken by higher grade students. Only 12.8% of students gained both marks.

(c) The lines of best fit seen were generally of good quality. Many students demonstrated best practice for determining the gradient. Large gradient triangles were drawn with the read-off co-ordinates and corresponding differences clearly seen. Mistakes that occurred most frequently included not taking the false origin into account and drawing a gradient triangle that was too small. Very nearly 90% of students scored at least one mark here.

(d) Appropriate use of significant figures is particularly important in Section A. Calculated quantities should be shown to the number of significant figures of the data with the least number of significant figures. 53.4% of students gained this mark.

STEMUP.CO.UK

(e) A significant number of students disregarded the instruction “without drawing another graph” and chose to describe how to test the relationship by drawing a graph. They did not appreciate the significance of the term “directly proportional” and could only apply it to descriptions of the graph one would expect for such a relationship. Students were unable to describe how such a relationship could be tested by non-graphical means. A common error presented was that a linear relationship was the same as a directly proportional one. This was evidenced by statements such as “constant gradient”, “straight line”, “as a increases, n increases”. Disappointingly, only 6.9% of students scored the mark.

37. This question involved use of the density formula.

(a) The majority of students (74.4%) had few problems with this calculation. Of those who did, conversion from mass to weight was the common problem.

(b) As with the previous question, this was well answered. The only common issue was the use of weight rather than mass in the density formula.

(c) Students found this question very challenging and only a small minority (4.3%) managed to come up with complete solutions. Setting up an expression that enabled the volume of iron to be calculated is clearly a procedure that is unfamiliar to many students. A reasonable proportion did appreciate that a mass needed to be divided by the density of iron and picked up the first mark, but got no further because they did not appreciate that the volume of the ice is less than the volume of the cube because part of the volume is occupied by the piece of iron.

39. This question required students to understand the conditions for equilibrium and apply these in a multi-step calculation. They were also required to understand the significance of the centre of mass..

(a) A pleasing proportion of students (nearly two-thirds) were able to identify one of the conditions for equilibrium; the resultant force being zero being the common answer. Only more able students were able to provide the second condition.

(b) There was some confusion over how centre of mass is defined. A significant proportion of students stated what is meant by the centre of gravity. This was given credit but it is clear that the distinction between these two is not well understood.

(c) Very few students (2.9%) managed to score both marks for this question. Nearly a quarter of students appreciated that this was to prevent rotation, but did not then give a complete explanation by referring to no resultant moment about A as the line of action of the forces passes through A when the beam is in equilibrium.

(d) This is not an unusual calculation at this level but it was clear that a significant proportion of students were unsure how to analyse the forces on the beam. The best students managed complete solutions whilst weaker students did manage to access some of the intermediate marks.

(e) The calculation in this question proved to be much more accessible and far more students were able to access the marks. Over half managed to score at least two marks. The most common error was failing to calculate the cross-sectional area correctly; the predominant mistake was using the diameter for radius. Weaker students often used surface area of the cable instead of cross-sectional area.

42. This question required an understanding of the vector nature of acceleration and momentum and also how using energy considerations can lead to a simpler analysis due to it being a scalar quantity.

(a) This was a straightforward calculation but a lot of students were caught out because they used $v^2 = u^2 + 2as$ instead of energy considerations. This meant that they did not get credit for their answer unless they allowed for the different directions of *v*, *a* and *s*.

(b) Some good responses were seen to this question although it was not uncommon for contradictory statements to be made. Most students were able to state that acceleration was constant in figure 1 but analysis of figure 2 proved more of a challenge. It was quite common to see answers that referred to speed rather than acceleration decreasing as the truck moved down the ramp. Also, a significant proportion of students thought that the truck decelerated between C and D. A quarter of students managed to gain all three marks.

(c) Only more able students could give a satisfactory explanation for the speeds being the same (19.8% correct).

(d) This was a challenging question that required a good understanding of momentum conservation in closed systems and also the importance of direction in momentum considerations. Very few students managed to give complete discussions. The commonest answer was that as mass went up momentum increased, with students failing to appreciate that with no external horizontal forces acting, this could not be the case. Better students did appreciate that the total horizontal momentum remains constant and so as mass increases speed must decrease. It was very rare for there to be a discussion of how the momentum of the rain water changes from vertical to horizontal. Nearly three-quarters of students failed to score on this question.

43. Most students correctly identified D as the correct answer here, but B also proved to be popular with about 25% of the students. They may have realised that the amplitude decreases with damping, without taking into account peak broadening.

44. This was answered correctly by less than half of the students. D was the most popular distractor, with some students probably calculating the number of oscillations of B. A and B were also relatively popular.

45. (a) Many students (59%) completed this part fully successfully. This and part (b) exposed weaknesses in the understanding of some students when using sine, cosine and tangent. Many who arrived at 2.71 m did not add the extra metre for the platform to deduce the radius of the circular path followed by the acrobats.

(b) The simplest and most common route to the answer was to consider the vertical forces. There were other routes to the answer too. The most common of these was to realise that the horizontal force due to the tension provided the centripetal force. Examiners allowed the error carried forward from part (a) for the radius of the path for those who solved the problem this way.

STEMUP.CO.UK

(c) There were some very good responses to this part and many students provided at least part of the necessary analysis. A high proportion of students wrote that there would be unbalanced forces on the acrobat, but in the subsequent explanation of how this imbalance occurred many answers were spoiled when students wrote about effects of weight when they should have referred to mass and vice versa. Most responses concentrated on the unbalanced horizontal force or considered the moments of the forces. Few made any comment of the increased vertical force on the pole.

STEMUP.CO.UK