AQA A-LEVEL PHYSICS · 7408

# PHYSICS



## MARK SCHEME

3.4.1 FORCE, ENERGY AND MOMENTUM · PACK 1

| SCORE | PERCENTAGE |
| --- | --- |
| /217 | % |

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**1.**

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

**OR**

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

($T$ =) 310 (N) ✓

*Expect to see F = 2T cos 75* ***OR*** *80 = T cos 75*

*Condone F = 2 T sin 75* ***OR*** *160 = 2 T sin 75*

*OR F = 2T sin (their acute angle)*

*OR F = 2T cos (their acute angle)*

***OR*** $\frac{80}{\sin 75}$ *seen* ***and*** *83 N on answer line.*

*Condone F = T cos 75* ***OR*** *160 = T cos 75*

***OR*** *(T=)* $\frac{160}{\cos 75}$ *with 620 N on answer line*

*An answer of 83 N due to F and T being interchanged obtains zero marks.*

*Alternative*

*closed triangle (75-75-30) of forces*

*An attempted use of Sine or Cosine Rule seen with correct closed triangle* ***MP1***

*Accept answer correctly rounded to at least 2 sf.*

*Answer = 309 (N) to 3 sf*

*Calculator display= 309.0962644*

**2**

(b) Read off for $F$ = 208 N

**OR**

use of $F = ma$ ✓

*Range for read-off is 208 N to 210 N*

*In use of F = ma:*

*• must see substitution for F and m*

*• condone either POT error in m or F outside range but not both.*

($a$ =) 9900 (m $s^{-2}$) ✓

*Accepted range = 9900 to 10000*

*Penalise 1 x $10^4$ N as a 1 sf answer.*

**2**



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

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

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

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

$s_r$ = 0.385 m✓

*Range for* $s_r$ *between 0.38 m and 0.385 m*

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

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

**2**

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

**OR**

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

*Energy transferred to arrow = 52.48*

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

Use of $E_k = \frac{1}{2} mv^2$✓

*Use of is:*

*• A rearranged expression where m would be subject.*

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

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

$m$ = 0.038 (kg) ✓

*Accept answer correctly rounded to at least 2 sf.*

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

*m = 0.056 kg where incorrect Ek is used (*$\frac{64}{0.82}$ *= 78)*

*(Worth 2 marks) (one error in Ek)*

*Calculator display = 0.03768093075*

**3**

**[9]**

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

*Allow* $g$ *sin30*

*Accept cos60*

**1**



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

**OR**

Uses $\frac{v^2}{2} = g$ 0.3 cos 60 ✓

1.7 $(\text{m s}^{-1})$ ✓

*Do not allow 9.81 for $a$ in suvat equation.*

**2**

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

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

*Do not allow use of approximated shapes.*

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

*May see:*

*Triangle: 0.5 × 0.05 × 1100 = 27.5*

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

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

*Triangle: 0.5 × 0.15 × 1000 = 75*

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

*Treat "400" as a 2 sf answer.*

**2**

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

*For $_1$ ✓ condone 9.81 for $a$.*

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

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

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

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

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

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

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

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

answer that rounds to 0.5 $(\text{m})$ $_3$ ✓

*For $_3$ ✓ accept 0.44 $(m)$.*

**3**



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

72 (kg) or 73 (kg) $_2$ ✓

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

**2**

**[10]**

**3.** C

**[1]**

**4.** (a) arrow between block and belt pointing upwards along the belt

**1**

(b) ($F$ = ) $19g\sin 23°$ to give 72.8 (N) ✓

*Allow 2 sf answer.*

**1**

(c) uses $F = \frac{\Delta(mv)}{\Delta t}$

*Allow for MP1 use of appropriate kinematic equation for $a$ **AND** use of $F = ma$*

$F$ = 12 (N) ✓

their (b) + 12 (N) ✓

*Expect 82 or 85 (N)*

**3**

(d) uses $V$ and $I$ to get total input power or energy ✓

$P_{input}$ *of motor = 110 × 5.0 = 550 W*

$E_{input} = 550 \times \frac{8.0}{0.32} = 13\ 750$ *J*

uses efficiency equation ✓

$P_{useful}$ *to belt = 550 × 0.28 = 150 W*

$E_{useful} = 3850$ *J, from* $154 \times \frac{8.0}{0.32}$ *, or 13 750 × 0.28*

determines power or energy to move one block ✓

$P_{block} = 22$ *or 23 W*

$E_{block} = 560$ *or 580 J*

divides (total) useful power or energy by individual power or energy to give answer of 6 blocks ✓

*Allow ecf for MP4 only for their (c)*

**4**

**[9]**



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**5.** (a) Use of $p = mv$ **or** estimates walking speed = 1 or 2 m/s✓

*Allow use of where $m$ has been made the subject and $p$ has been substituted.*

Accept any answer in range $2 \times 10^6$ to $10 \times 10^6$ (kg) ✓

*Range on answer:*

*(Using speeds in range 0.5 $ms^{-1}$ to 2.5 $ms^{-1}$)*

*Accept 1 significant figure answer*

**2**

(b) **Max 4**

There is a force on the water (from the propeller) and this produces an equal force on the propeller (from the water in the opposite direction) ✓
Correctly links to Newton's 3 rd law ✓

This force on the ship equals the drag force on the ship✓ Correctly links to Newton's 1st law ✓

Force is needed to change the water's momentum ✓ Correctly links to Newton's 2nd law✓

*Must link correct law to at least one correct statement for all 4 marks*

**4**

(c) (When system is enabled,) drag decreases by more than thrust

**Or**

(When system is enabled,) decrease in work done (per second) against drag (at any speed) is greater than the decrease in the work done by the propeller (at any rotational speed)✓

*Work done (per second) by drag decreases and work done (per second) by propeller decreases (at any rotational speed) ✓*

To maintain constant momentum then drag must equal thrust✓

Propeller can operate at lower rotational speed so that thrust again equals drag

**Or**

Engine does less work (and less fuel needs burnt) ✓

*3rd MP: Accept answer in terms of power = $Fv$*

**3**

**[9]**



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**6.** (a) Closed triangle of forces drawn ✓

Appropriate scale ✓

$\theta$ = 23 to 27 (°) ✓

$U$ = 77 to 81 (N) ✓

*Accept scale where 10 N is represented by at least 1 cm.*




*Treat each marking point independently.*

*Do not accept answers for $U$ and $\theta$ without a scale diagram.*

*Maximum of 3 marks for a free-body diagram where forces have been drawn to scale. (Check figure 8)*

**4**

(b) $V$ is vertical / Force at **Y** is now vertical / $V$ does not have a horizontal component / $V = S + 31$ / $V$ is perpendicular to the pole / $V$ is of greater magnitude than $U$ / Force at **Y** has increased in magnitude✓

(Because) $S$ and weight (or *mg*) are both vertical (in **Fig 3**)✓

(Because) greater moment of weight (about **Y**) in **Fig 3** / smaller moment of weight (about **Y**) in **Fig 1** / (Because) $S$ is larger in magnitude than $D$ (to produce a greater moment (about **Y** because they are equal distances from Y)✓

**3**

**[7]**

**7.** (a) (Work done = lost KE = ½ $mv^2$ =) 0.019 (J) ✓

**1**



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(b) Use of $W = Fs$ ✓

($F$ =) 0.66 ($N$) ✓

*Condone POT error in substitution*

*ECF from* ***(a)***

***Alternative:***

*Use of an appropriate suvat equation* ***and*** *use of* $F = ma$ ✓

*($t$ = 9.8 x $10^{-6}$ $s$)*

*($a$ = 6.0 x $10^{8}$ $m\ s^{-2}$)*

*Condone POT error in substitution*

*No ECF from 3.1 this route ($F$ =) 0.66 ($N$)* ✓

**2**



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(c) Use of Volume = Thickness x area of cross-section✓

*Condone POT errors apart from final answer (V =) 8 × $10^{-4}$ × 0.03*
*Or (V =) 2.4 × $10^{-5}$*

(Average density =) $\frac{50+5}{2} = 27.5$ ✓

Use of density = $\frac{\text{mass}}{\text{volume}}$ ✓

*Condone use of their density and volume*

(mass =) 6.6 × $10^{-4}$ (kg) ✓ c.a.o

**Alternative:**

Use of Volume = Thickness x area of cross-section✓

*Condone POT errors apart from final answer*

*(V =) 8 x $10^{-4}$ × 0.03 Or (V =) 2.4 × $10^{-5}$*

Use of density = $\frac{\text{mass}}{\text{volume}}$ / (mass =) 1.2 x $10^{-3}$ or 1.2 x $10^{-4}$✓

(Average mass =) $\frac{1.2\times10^{-3}+1.2\times10^{-4}}{2}$ ✓

= 6.6 × 10– 4 (kg) ✓ c.a.o

*Condone use of their density and volume (50 kg $m^{-3}$ =1.2 x $10^{-3}$)*

*(5 kg $m^{-3}$ =1.2 x $10^{-4}$)*

**Alternative:**

Condone POT errors apart from final answer

Attempts to determine the area under the graph:

Formula for area of a rectangle added to the formula for area of a triangle seen / formula for the area of trapezium seen✓

$5 \times 0.03 + \frac{(50-5)\times0.03}{2} = 0.825\ (kg\ m^{-2})$
***or*** $\frac{50+5}{2} \times 0.03 = 0.825\ (kg\ m^{-2})$✓

Multiplies their area by 8 x $10^{-4}$✓

Mass = 6.6 × $10^{-4}$ (kg) ✓ c.a.o

**4**



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(d) **Q** has a larger volume (for the same mass and KE) /

**Q** has a larger surface area (for the same mass and KE) ✓

**Q** will experience a greater resistive force (at any given speed) / **Q** will displace more matter per unit distance✓

**Q** will do more work per unit distance / **Q** will transfer more of its kinetic energy per unit distance / **Q** will experience a greater deceleration✓

*Must have **Q** will travel a shorter distance for all 3 marks.*

**3**

**[10]**

**8.** D

**[1]**

**9.** C

**[1]**

**10.** B

**[1]**

**11.** D

**[1]**

**12.** C

**[1]**

**13.** (a) Use of time = angle / angular speed ✓

To get 3.5 (s) ✓

*Alternative for MP1: Accept distance ÷ speed when circumference has been calculated.*

*Accept answers that round to 3.49*

**2**

(b) Arrow towards centre of turntable. ✓

**1**

(c) Use of $F = mrw^2$ ✓

OR

determination of centripetal acceleration and then $F = ma$ ✓

To give 0.097 N ✓

*Shown by substitution.*

*Condone use of diameter or radius halved in MP1.*

*Accept negative answer.*

*Calculator value: 0.0972*

**2**



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(d) States block is (constantly) changing direction ✓

Uses appropriate Newton law of motion to link evidence (to show that a force acts) ✓

*Alternative 1*

Block constantly changing direction (at constant speed) ✓

Uses N1 to show that a force must apply ✓

*Alternative 2*

Changing direction shows (centripetal) acceleration ✓

Uses N2 to show that a force must apply ✓

*Reference can be to the name of the law or to a description of what the law says.*

*Condone lack of "resultant force" in N1 and N2.*

*Use of "changing velocity" without reference to direction is not enough for MP1.*

**2**

(e) Use of pendulum equation by substitution or manipulation ✓

To give 1.55 $\mathrm{m}$ ✓

*Allow 2+ sf*

*Allow answer that rounds to 1.55*

*Use of $g = 10\ N\ kg^{-1}$ gives 1.58 − do not allow for MP2*

**2**

(f) *Amplitude* – the pendulum shadow amplitude becomes less than the block shadow amplitude ✓

*Phase* – time period decreases/changes OR frequency increases/changes (as pendulum amplitude gets less) therefore phase changes ✓

*Must see a comparison for MP1*

*Condone:*

*the time periods/ frequencies remain identical therefore the shadows remain in phase*

**2**

**[11]**

**14.** B

**[1]**

**15.** A

**[1]**



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**16.** C

**[1]**

**17.** C

**[1]**

**18.** D

**[1]**

**19.** (a) Volume of A = area × length = $4.16 \times 10^{-4}$ $m^3$

OR

Mass of A = $W/g$ = 3.6 kg ✓

*Condone POT error in MP1*

Use density equation ✓

*Do not allow use of weight in density equation*

Compares

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

OR

the calculated density of A with density of brass

*Do not accept $8.3 \times 10^3$ for density of A .*

OR

the calculated mass of A with the calculated mass of brass

*Award zero marks for an unsupported answer "Brass"*

and therefore brass ✓

*Only award MP3 if answer "brass" given.*

Example:

Volume of A = area × length = $4.16 \times 10^{-4}$ $m^3$ ✓
Mass if brass = density × volume = 3.58 $kg$ ✓

Weight = 3.58 × 9.81 = 35 $N$ (which is weight of A) and therefore brass is correct.

**3**

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

**2**



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(c) Angle (to horizontal) decreases ✓

(Weight/tension in rope remains constant at 35 $\mathrm{N}$ )

So horizontal components (from tension in rope) increase ✓

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

(Therefore tension in cable must increase)

*Do not allow "tension increases" for credit.*

**2**

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

= 41 cos (90−12) / 41 sin (12)

= 8.5 $\mathrm{N}$ ✓

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

*Alternative:*

*Perpendicular distance = 0.95 sin (12)*

*= 0.198 $m$ ✓*

*Moment = 41 × 0.198 = 8.1 ✓*

Allow ecf from their value of weight component .

*Allow ecf from their value of perpendicular distance.*

*(Calculator value is 8.098 160 3)*

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

**2**



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(e) ALTERNATIVE 1

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

Increases tension (and therefore moment) ✓

ALTERNATIVE 2

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

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

*Any 2 alternatives*

ALTERNATIVE 3

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

Increases tension (and therefore moment). ✓

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

ALTERNATIVE 4

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

Increases perpendicular distance (and therefore moment). ✓

**4**

**[13]**

**20.** B

**[1]**

**21.** B

**[1]**

**22.** C

**[1]**

**23.** A

**[1]**

**24.** D

**[1]**

**25.** B

**[1]**

**26.** A

**[1]**



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**27.** B

**[1]**

**28.** C

**[1]**

**29.** B

*B*

**[1]**

**30.** A

$\frac{mg}{k}$

**[1]**

**31.** (a) (±) 0.04 (m) ✓

*Correct answer only*

**1**



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(b) $G_{max}$ line ruled through bottom of first error bar and through top of fifth error bar **OR** $G_{min}$ line ruled through top of first error bar and through bottom of sixth error bar$_1$✓

*$_1$✓ requires at least one line to be well-drawn i.e. thin, single, continuous*

$G_{max}$ between 10.7 and 10.9 $_2$✓

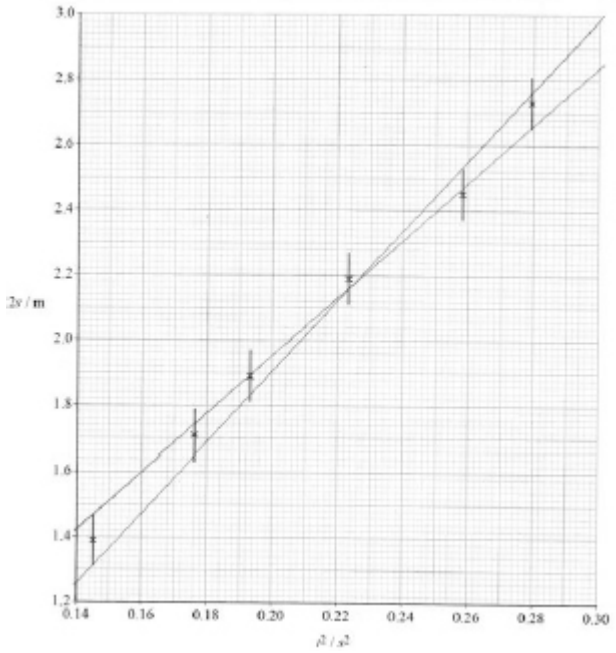
*For $_2$✓ expect a 3 sf value. Accept 2 sf value only if it comes from expected range. Condone 4 sf value.*

$G_{min}$ between 8.7 and 8.9 $_3$✓

*For $_3$✓ accept 2 or 3 sf values only*

*For $_{23}$✓ <u>at least one</u> $\Delta t^2$ step ≥ 0.08 ($s^2$) (i.e. half width of grid)*

*Ignore any unit given with $G_{max}$ or $G_{min}$*




**3**

(c) uses $g = \frac{G_{max} + G_{min}}{2}$ with their values from part (b) $_1$✓

evaluates mean of their $G_{max}$ and $G_{min}$ to 2 sf $_2$✓

*If no other mark given, allow 1 mark for a value of 9.7 (m $s^{-2}$) from a well-drawn best-fit line.*

*Give no credit for an unsupported answer.*

*Treat "10" as a 2 sf answer.*

**2**



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(d) absolute uncertainty in $g$ $_1$✓

*Mark each point independently. If no other mark given, allow 1 mark for a percentage uncertainty (1 or 2 sf) based on the full range (rather than half the range).*

*For $_1$✓ must use their $G_{max}$* ***AND/OR*** *their $G_{min}$ e.g.*

$\Delta g = \dfrac{G_{max} - G_{min}}{2}$ ***OR*** *$G_{max}$ − their g* ***OR*** *their g − $G_{min}$*

*May be seen in working for percentage uncertainty e.g.*

$\left(\dfrac{G_{max} - g}{g}\right) \times 100$ OR $\left(\dfrac{g - G_{min}}{g}\right) \times 100$

OR $\left(\dfrac{G_{max} - G_{min}}{G_{max} + G_{min}}\right) \times 100$

percentage uncertainty in $g$ = $\dfrac{\text{their } \Delta \text{ g}}{\text{their g}}$ × 100 $_2$✓

*For $_2$✓ allow 1 or 2 sf*

**2**

(e) systematic error ✓

*'zero error' is neutral*

**1**

(f) points/line displaced to right owtte

**OR**

line moves down

**OR**

(vertical) intercept is decreased / now has negative intercept ✓

*Must refer to a property of the graph; comments about error bars are neutral; ignore (new) calculated values of $t^2$.*

*Accept 'gradient is decreased' / 'graph (or line) becomes a curve of decreasing gradient' owtte.*

*No credit for 'points move down' / 't2 values are increased'.*

*Allow answers in form of their own diagram or on* ***Figure 2****.*

**1**

**[10]**



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**32.** (a) attempted use of principle of moments:

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

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

full use of principle of moments ✓

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

($d$ =) 2.4 (m) ✓

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

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

*1150 × 3.6 = 1800 × 1.8 + 750 $x$*

**Alternative**

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

**OR**

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

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

250 $\mathrm{N}$ : 500 $\mathrm{N}$ = 3.6 − $d$ : $d$ ✓ (principle of moments)

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

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

*750 × $d$ + 1800 × 1.8 = 1400 × 3.6*

*Alternative for MP1 and MP2:*

*Moments about worker's centre of gravity:*

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

*MP1 for one correct side of equation seen.*

*MP2 all correct terms seen (condone one error).*

($d$ =) 2.4 (m) ✓

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

**3**



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

*Use of $\varepsilon = \frac{\Delta L}{L}$ is by rearrangement to make $\Delta L$*

*the subject **and** 6 × 10$^{-5}$ × 3 seen (condone use of $L$ = 3.6 $m$ here).*

*Condone POT error on extension*

($d$ =) 1.8 m ✓

*Some supporting use of graph for read-off seen*

*Allow range of 1.75 $m$ to 1.85 $m$*

**2**

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

**1**

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

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

Straight line passes through (0, 0.46) ✓

*Within 1/2 square*

Straight line passes through (3.6, 0.26) ✓

*Within 1/2 square*

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

**3**

**[9]**

**33.** (a) (component of total weight parallel to slope =) 640 sin $\theta$ ✓

*Allow $mg$ sin $\theta$ or 65g sin $\theta$ or 638 sin $\theta$*

*or 637.7 sin $\theta$ or 637.65 sin $\theta$*

*Condone labelling this component as $W$ in statements such as*

$W$ = 640 sin $\theta$

*Do not accept*

$W$ sin $\theta$ *unless $W$ is defined as $mg$*

**1**



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(b) use of $P = Fv$ ✓

*Ecf from part (a) for MP1 and MP2*

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

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

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

($\theta$ =) 17(.4) (°) ✓

*(Calculator displays: 17.35298907 for mg sin $\theta$ and 65g sin $\theta$ and 637.65 sin $\theta$)*

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

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

*Common ecf:*

*(65gcos$\theta$ = 190) = 72.6 (°) or 73(°) scores MP1 and MP2*

*(65 tan$\theta$ = 190) = 71.1 (°) or 71(°) scores MP1 and MP2*

*Use of $W = Fs\cos\theta$ is only acceptable as an ecf where $F$ = 65g and component of weight is given as 65gcos$\theta$ (or equivalent) in part (a)*

*Alternative MP1:*

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

***OR***

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

**2**



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(c) Less (useful) power output ✓

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

Gains less (gravitational) potential energy every second ✓

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

Effective $\theta$ has decreased / $mg$ sin $\theta$ has decreased / component of the weight parallel to the slope has decreased ✓

*General marking principle:*

*MP1 less (useful) power output*

*MP2 basic point*

*MP3 explains consequences of basic point in terms of power (MP3 is an extension of MP2, quoting*

$P = \frac{\Delta W}{\Delta t}$ *without linking to an appropriate explanation is insufficient).*

Smaller force does less work per second ✓

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

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

*Loses MP1: where conflicting statements made about (useful) power output / states more power output / total power output is same.*

*Loses MP3 for conflicting statements made in support of explanation.*

*Accept $\theta$ as the effective angle to the slope.*

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

**OR** (distance travelled)

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

*Treat 'inputs more energy' or 'does more work' as neutral.*

*Condone P = $E/t$ has decreased as MP3*

**3**



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

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

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

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

*Condone one read-off error.*

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

(acceleration =) 0.21 ($\mathrm{m\ s^{-2}}$) ✓

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

*Accept 2 or 3 significant figures only.*

***MAX 1 mark***

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

**3**

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

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

**MAX 3** from:

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

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

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

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

*The answer must be written in terms of energy transfers*

**4**

**[13]**

**34.** A

*19*

**[1]**



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**35.** B

*the kinetic energy of the mass*

**[1]**

**36.** D

$\frac{v^2}{rg}$

**[1]**

**37.** C

*The acceleration is unchanged.*

**[1]**

**38.** C

*7.50 m s$^{-1}$*

**[1]**

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

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

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

Use of $\rho = \frac{m}{V}$ ✓

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

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

*Answer seen to at least 2 sf.*

*Calculator display = 0.3890548342*

**3**



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

**OR**

Use of $W=mg$

**OR** statement:

Upward force = weight ✓

*Possible ECF from **(a)** where their m rounds to 0.4 kg.*
*W = 3.72m seen or 3.72m as the subject of a force equation.*
*Do not allow 3.72 x 0.4 as use of W=mg*
*.*

Applies condition for equilibrium by setting $F = mg$

**OR**

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

($m$ =) 1.80 (kg) ✓

*Accept answer correctly rounded to at least 2 sf.*
*F= 6.88 N where* $\frac{m}{t} = 0.4$
*m=1.85 kg or 1.8 kg*

**3**



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(c) Use of $E = Pt$

OR

converts kWh to J ✓

*(E =) 340 × 39* ***or*** *13260 (J)*

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

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

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

*Or equivalent e.g W mins*

*Do not accept incorrect unit.*

*Do not accept incorrect subject.*

***MP2***

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

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

(=) 11% ✓

*Accept answer correctly rounded to at least 2 sf.*

*Calculator display = 10.5238*

**2**



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(d) Incorrect:

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

**OR**

Incorrect:

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

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

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

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

*Accept lift or thrust or upward force.*

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

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

**3**

(e) Use of an appropriate equation of motion:

$v = u + at$ ✓

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

($t$ =) 0.15 (s) ✓

*Accept answer correctly rounded to at least 2 sf.*

*Calculator display = 0.14784946236559*

**2**



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

**OR**

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

**OR**

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

($h$ =) 0.61 (m) ✓ **ECF**

***MP1*** *(Downward journey)*

*Allow s = 0.65m*

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

***OR***

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

***OR***

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

*MP1 (Upward journey)*

*Allow s=0.041 m obtained from*

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

***OR***

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

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

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

*Accept answer correctly rounded to at least 2 sf.*

*Calculator display = 0.60987903225806*

**2**



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(g) Student is correct:

Weight is the only force acting on the helicopter.

**OR**

Acceleration = (-)3.72 $ms^{-2}$✓

Due to **Newton's 2 nd law**, the acceleration acts in the **same direction** as the weight (which is always downwards).

**OR**

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

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

*Where acceleration is quoted must have correct unit.*

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

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

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

*Neutral for statements that refer to deceleration / acceleration.*

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

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

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

**2**

**[17]**

**40.** C

*displacement and momentum*

**[1]**



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**41.** (a) Equates resultant force to *ma*

and shows *a* proportional to *y,* as *Aρmg* are all constant✓

*In MP1:*

*Condone upthrust/buoyancy force for resultant force*

*F = ma = -Aρyg*

$\rho = -\frac{A\rho yg}{m}$

*Condone missing minus signs in MP1.*

Minus sign included and explained:

(restoring) force/acceleration directed to centre of oscillation ✓

(hence SHM)

*In MP2:*

*Minus because force/acceleration is in opposite direction to y*
*OWTTE*

**2**

(b) ($T = 2\pi/\omega$) so $\omega = \sqrt{\frac{g}{l}}$ ✓ (= 10.74 rad $s^{-1}$)

($a_{max} = -\omega^2 y_{max} = \frac{g}{l} \times y_{max} = (9.81 \div 0.085) \times 0.005$ )

*Alternative for MP1:*

*calculates time (0.58(5) s) AND then uses ω from this time*

0.58 (m $s^{-2}$) ✓ from some correct working

*MP2 for correct calculation of acceleration.*

**2**

(c) Idea that (at resonance) frequency of forced vibrations equals natural/resonant frequency $_1$✓

Idea that amplitude (of vibrations/oscillations) is at a maximum $_2$✓

*Accept fully labelled graph of amplitude vs driving frequency with resonance frequency clearly labelled$_1$✓ and an amplitude peak. $_2$✓*

*Condone 'wave frequency' for 'driving frequency'*

*Ignore references to phase*

**2**



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(d) stopped: wave frequency ($=\frac{v}{\lambda}$)= 0.12 Hz $_1$✓

moving: when ship continues at 8 m $s^{-1}$, forcing frequency will be further from resonant frequency $_2$✓

Moving option is better with reason,

eg for stopped option wave/forcing frequency very close to natural frequency, (so amplitude of oscillations will be high)

**OR**

for moving option resonance does not occur $_3$✓

*[1]✓is for calculation of (driving) frequency when stopped. Condone reference to 'frequency of waves'.*

*If no reference to ship being stopped, evidence can come from the substitution. Reject simple "0.12 (Hz)"*

*[2]✓ is for a relevant comment about the moving situation*

*OR*

*calculation of forcing frequency with the ship moving (giving 0.05 Hz)*

*For $_2$✓ accept incorrect calculation from adding speeds provided comment that this frequency is further from resonant frequency.*

*[3]✓ is for statement of why moving is the better option*

*Allow answer for $_3$✓ that mentions that damping will be highly likely, so amplitudes may not reach high enough values to prevent operation*

3

**[9]**

**42.** C

*45 m*

**[1]**

**43.** D

*force mass × displacement*

**[1]**

**44.** B

*4 m $s^{-1}$*

**[1]**



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

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

*Some evidence that Figure 1 is used:*
*calculation based on a point on line between 75 MPa and 125 MPa*
*OR calculation from point on straight line extended*
*OR*
*Use of triangle from more than half of the linear section.*

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

*Allow 2 sf answer 1.4 × $10^{11}$ (Pa).*

**1**

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

*Reject idea that there is **no** increase in strain.*
*Condone 'extension' or '(plastic) deformation' for 'strain'.*
*Condone 'shortly after' for 'beyond'*
*Accept: does not show 'necking' before fracture*
*Accept: fracture occurs very near the limit of proportionality (condone 'elastic limit').*
*Accept references to a particular value of strain e.g. 9 x $10^{-4}$ to 12.7 x $10^{-4}$*

**1**

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

(halves load)

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

$\Delta L$ = 1.1(4) × $10^{-3}$ (m) ✓

*Total load = (4.4 + 16.0) × 9.8(1) = 200(.1) N*
*Allow 'g' for 9.8(1)*

*Expect to see F = 100 N and*
*A = 5.03 × $10^{-7}$ $m^2$. Condone use of d in calculation of cross-sectional area A in MP2.*
*Or separate calculations using σ = F÷A, E = σ÷strain, strain = ΔL÷L*
*Condone POT error in MP2.*

**3**



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

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

Calculates $F_s$ or $F_a$ $_3$✓

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

Distance = 1.18 m ✓$_5$

*$\Delta L$ = {FL÷AE} steel = {FL÷AE} aluminium {F÷d²E} steel = {F÷d²E} aluminium $_1$✓*

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

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

*$1.33\ F_s + F_s = 200$ N*

*$F_s = 86$ N, $F_a = 114$ N $_3$✓*

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

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

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

*ECF for MP2 and MP3 in MP4*

**5**

**[10]**

**46.** A

*10 μm s$^{-1}$ 100 s*

**[1]**

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

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

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

(because)

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

**OR**

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

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

**2**



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

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

***OR***

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

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

*Allow 9.81 or 9.8 instead of g.*

**2**

(c) max two from: ✓ ✓

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

answer that rounds to 1.5 or 1.6 (N) ✓

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

*Expect to see 160 g for mass of spoon.*

*Allow credit for an algebraic solution to get m:*

*e.g. when m = M,* $\frac{m}{M} = \frac{(12-x)}{x} = 1$

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

**3**

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

(because) as *M* increases:

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

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

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

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

**3**

**[10]**

**48.** D

*work done.*

**[1]**



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

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

OR

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

*Expect to see 4.69 s*

OR

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

*Expect to see 9.42 s*

OR

Calculates unknown speed ✓

*Expect to see 340.3 m $s^{-1}$*

Answer that rounds to 4.73 (s) ✓

*Do not accept 2sf for final answer.*

**2**

(b) speed from graph: 450 m $s^{-1}$ ✓

*Accept 445 - 455 m $s^{-1}$*

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

*Expect to see 6.6 × $10^{8}$ (J)*

**2**

(c) **MAX three** from: ✓✓✓

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

Final answer between 16% and 17%✓

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

*Evidence for gradient may be on figure*

*Allow ECF from (b)*

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

*Reject power that is calculated assuming a constant speed.*

**4**



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(d) Identifies distance decelerating

**AND**

max velocity = (470 ±5) m $s^{-1}$ ✓

Uses *suvat* equation(s)

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

*allow 7000 m to 7600 m*

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

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

*For MP2 allow calculation of*

*gradient × average speed to give*

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

**2**

**[10]**

**50.** B

*800 N*

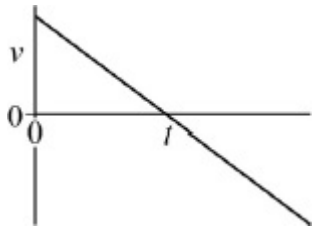
**[1]**

**51.** A

*0.40u*

**[1]**

**52.** A




**[1]**

**53.** C

$v\sqrt{2}$

**[1]**

**54.** D



**[1]**

**55.** (a) 4.5 × $10^{-2}$ ✓

*CAO*

**1**



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(b) (short $T_1$)

so images are not blurred (or wtte)

*must refer to quality / property of images, eg 'images are sharp' / 'focused' / 'clear' / 'defined';*

*allow '(images of) ball are circular' / 'spherical' / 'not elongated' or wtte: accept sketch*

*'increasing distance between images' / 'image is accurate' are neutral*

OR

to determine position of the ball (in each image or wtte) ✓

*allow 'to see (point) where ball is' / idea that (centre of) ball needs to be a 'single point' / 'ball does not move during each flash ( $T_1$)'*

*comments about the motion / trajectory of ball eg 'see a clear pattern' are neutral*

*comments about the duty cycle / flash rate are neutral*

**1**



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(c) correct rearrangement to a three-term equation;

**1**

$\frac{H-h}{n}$ as the subject eg $\frac{H-h}{n}=\frac{u_0}{f}+\frac{gn}{2f^2}$ $_1$✓

valid suggestion for quantity plotted on *x*-axis;

allow use of $y = mx + c$ aligned with $\frac{H-h}{n}=\frac{u_0}{f}+\frac{gn}{2f^2}$

suitably annotated to identify *x* $_2$✓

explains how *g* found using the gradient for **their** *x*-axis;

insist on *g* as subject whether explanation is in words or expressed as an equation $_3$✓

*for* $_1$✓ *condone* $\frac{H-h}{n}=\frac{u_0}{f}+\frac{g}{2n}\left(\frac{n}{f}\right)^2$

$_3$✓ *is contingent on* $_2$✓*;*

*for a correct equation or if no equation is seen mark* $_2$✓ *and* $_3$✓ *as below:*

| for $_2$✓ | for $_3$✓ |
|---|---|
| $n$ | $g$ = gradient × $2f^2$ |
| $\frac{n}{2}$ | $g$ = gradient × $f^2$ |
| $\frac{n}{f}$ | $g$ = gradient × $2f$ |
| $\frac{n}{2f}$ | $g$ = gradient × $f$ |
| $\frac{n}{f^2}$ | $g$ = gradient × 2 |
| $\frac{n}{2f^2}$ | $g$ = gradient |

*for an incorrect equation with n in the 'mx' term allow ECF for* $_2$✓ *and* $_3$✓

**2**



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(d) $n = 17 \pm 1$ $_1$✓

*$^1$✓ expect integer n = 17 ± 1 but see valid unusual approach below*

**1**

use of $H = \frac{u_0 n}{f} + \frac{g}{2}\left(\frac{n}{f}\right)^2$

OR

use of $H = u_0 t + \frac{1}{2} g t^2$ (eg with $t$ from $\frac{n}{31}$) $_2$✓

$u_0$ correctly evaluated to (minimum) 2 sf $_3$✓

*for $_2$✓ either approach 'use of' means full substitution without error (with h = 0 shown or implied by omission) so that $u_0$ is the only unknown;*

*condone g = ± 9.79 OR ± 9.8(1);*

*condone POT error / mixed units for H and g*

**1**

valid alternative method:

use of **Figure 1** to determine non-zero $h$ for integer $n > 0$

for $_1$✓ a valid $h$ for their integer $n$ (≤ 16)

eg when $n = 5$, $h = \frac{89\ (\text{mm})}{99\ (\text{mm})} \times 1550\ (\text{mm}) = 1393\ (\text{mm})$

for $_2$✓ full sub including a valid $h$ for their $n$

for $_3$✓ $u_0$ correct for their $n$ and $h$

eg for $n = 5$ and $h = 1393$, $u_0 = 0.18(4)\ (\text{m s}^{-1})$ $_3$✓

*for $_3$✓ see table for $u_0$ with n = 16 OR 18 AND/OR for the (intermediate) rounding of t;*

*accept > 3 sf that rounds to values in table:*

| | subs $n$, $f$ | truncates $t$ | |
|---|---|---|---|
| expected | $t$ = 17/31 | 3 sf | 2 sf |
| $t$ / s | (0.548387) | 0.548 | 0.55 |
| $u_0$ / m s$^{-1}$ | 0.14 | 0.15 | 0.13 |

| ECF | $t$ = 16/31 | 3 sf | 2 sf |
|---|---|---|---|
| $t$ / s | (0.516129) | 0.516 | 0.52 |
| $u_0$ / m s$^{-1}$ | 0.48 | 0.48 | 0.44 |

| ECF | $t$ = 18/31 | 3 sf | 2 sf |
|---|---|---|---|
| $t$ / s | (0.580645) | 0.581 | 0.58 |



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| | | | |
|---|---|---|---|
| $u_0$ / m s$^{-1}$ | -0.17 | -0.18 | -0.17 |

**1**

(e) calculates the horizontal velocity;

divides a valid horizontal displacement $s_2 - s_1$ by a time $_1$✓

*for $_1$✓ $s_2 - s_1$ in range 490 to 1000 (mm);*

*expect time to be found from counting intervals between flashes but allow use of **their (f)** result;*

*condone use of distance between contacts with time of $\frac{19}{31}$ and $\frac{20}{31}$;*

horizontal velocity in range 1550 and 1650 (mm s$^{-1}$) $_2$✓

*$_2$✓ is not contingent on $_1$✓*

*allow 2 sf 1.6 × 10$^3$ (mm s$^{-1}$)*

**2**



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(f) determines $h_{max}$ (at top of bounce) using an annotation to **Figure 3** $_1$✓

eg

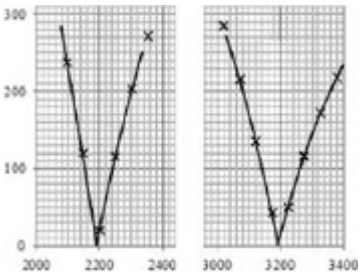


valid attempt to find time $t$ between contacts by using *suvat* with $u = 0$, eg time = $(2\times)\sqrt{\frac{2\times \text{their } h_{max}}{9.81 \text{ OR } 9.79}}$ $_2$✓

OR

determines $s$ for <u>both</u> contacts OR determines $s_2 - s_1$ using annotations to **Figure 3** $_1$✓

eg




valid attempt to find $t$ by = $\frac{\text{their } s_2 - s_1}{\text{their horizontal velocity in 01.5}}$ $_2$✓

time in range 0.61(0) to 0.65(0) (s) $_3$✓

*for $_1$✓ annotation should be a smooth curve through (at least) top 4 points, n = 51 to 54; don't insist on seeing a horizontal line to the h axis*

*for $_2$✓ accept mixed units / POT in substitution / time to maximum height calculated / valid working in **(e)***

*OR*

*for $_1$✓ annotation should be at least one smooth (allow straight) line to define each contact;*

*eg (at least) through n = 41/42 OR 43/44 to h = 0 AND through n = 61/62 OR 63/64 to h = 0*

*for $_1$✓or $_2$✓ accept valid working in **(e)**;*

*accept use of horizontal distance = 1000 (mm)*

*for $_2$✓do not condone use of integer number of intervals, eg $t = \frac{19}{31}$ = 0.61(3) OT*

*$t = \frac{20}{31}$ = 0.645*

*$_3$✓ is contingent on $_2$✓;*

*exception: award $_3$✓ for t in range if obtained by estimating a **non**-integer number of intervals, eg $t = \frac{19.5}{31}$*



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3

**[13]**



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## Examiner reports

**1.**

(a) 43% of students scored two marks with a further 20% gaining one mark. Many students tried to resolve 160 N rather than *T*; this made the calculation considerably more challenging, and these students typically scored zero marks. Many were unsure whether to use sine or cosine or failed to appreciate that $F$ was shared between the two horizontal components of the tensions acting at P.

(b) 51% of students obtained two marks with a further 33% obtaining one mark. Many students did not score the second mark because they:

- did not change the mass into kg
- converted the mass into weight.

Some students attempted to use an equation of motion due to their inability to assimilate the information provided. This showed a limited development of exam technique through limited awareness of the purpose of the stimuli provided.

(c) This part proved inaccessible to most students with over 94% of students achieving zero. Many attempted to use $W = Fs$ even though the force was not constant over the distance shown in **Figure 3**. Another significant proportion of students used $W=\frac{1}{2}F\Delta L$, again scoring zero due to the non-linear relationship between $F$ and $s$ shown in **Figure 3**. Over 60% of students achieved at least one mark in this part. Grade A students typically achieved all three marks with grade E students able to make some progress. One mark was usually obtained for a correct conversion of km $h^{-1}$ to m $s^{-1}$ but quite often this was the only credit-worthy work seen in the working.
Common errors seen included:

- incorrect re-arrangement of $E_k = \frac{1}{2} m v^2$
- forgetting to use 82% of the available energy as the kinetic energy.

Many students attempted to use $P = Fv$ because they thought that efficiency was a reference to power in this context.

**2.**

(a) A surprisingly large number of students struggled with this relatively simple '*show that* question. This was used to establish that the motion down, and up, the rail occurred under the condition of constant acceleration.

(b) About 40% of students gained full marks by realising that the answer could be obtained using a '*suvat* equation or by considering the transfer from stored gravitational potential energy to kinetic energy. About 40% of the cohort made no relevant progress. Students are reminded not to give final answers in surd form as they will not gain the mark.

(c) Most students knew that they needed to obtain the area of the graph between **B** and **C**. The graph was deliberately constructed without curves so that students could obtain this area by geometry. Crude attempts to count the squares were not rewarded. A significant number of students thought they could use $F\Delta t$, even though the value of $F$ varies throughout the time period.

(d) Only about 15% of students gained any credit in this question. The rest of the cohort failed to realise that this could be solved using '*suvat* equations. Students who were successful commonly used $s = \frac{1}{2}at^2$ with half the duration from **C** to **D**, and then doubled their answer.



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(e) A large number of students did not attempt this question or made no valid point. The questions followed the sequence of the leg jump from **A** to **E**, and students were expected to use a reading from the graph beyond **E** to determine the mass.

**3.** This was one of the easiest questions in this 2022 paper.

**8.** This was one of the hardest questions in this 2022 paper. It had distractors that were more popular than the correct answer.

In this question, all four options were similarly popular. It was clear that many students did not spot the word 'extra' in the question, for example.

**11.** This was one of the hardest questions in this 2022 paper. It had distractors that were more popular than the correct answer.

This question was a difficult multi-step calculation. Most students chose B, and the next most popular was D, the correct answer.

**12.** This was one of the hardest questions in this 2022 paper. It had distractors that were more popular than the correct answer.

Responses to this question indicated how poorly Newton's third law of motion is understood. The correct answer was the least popular option. Clearly many students do not realise that the pair of forces act on different objects and are the same type of force.

**13.** The question was based on a practical demonstration of the relationship between simple harmonic motion (shm) and circular motion.

The calculations in (a), (c) and (e) were very straightforward and caused little trouble for most students.

(b) was more challenging. Examiners were lenient in their interpretation of the arrow, but several students lost the mark through carelessness. When drawing a direction such as this students should use a ruler and avoid ambiguity in the construction.

In order to answer (d) correctly students had to be clear about the evidence on which their answer was based. Stating that the velocity is changing, without any mention of direction, was not interpreted by examiners as evidence. Many students invoked Newton's 3 $^{rd}$ law without success.

Answers to (f) were often incomplete. Examiners were expecting to see a comparison, but many students only discussed the effect on the pendulum. In order to gain the phase mark some supporting discussion was needed. This was partly because both no change and an in-phase change were acceptable, depending on the depth of the student's discussion.

**19.** Most students were able to answer (a) correctly and obtain full marks. Partial credit was available for students who got the wrong answer, but answers needed to be set out with sufficient clarity for any mark to be awarded. Students should be encouraged to make each step in their calculations clear.

The relatively poor performance of students in (b) and (c) demonstrated much misunderstanding about the components of forces. It was made clear in the question that the tension in the rope was the same throughout, but many students showed little awareness of this.



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The moment calculation in (d) proved to be much more accessible. Partial credit was available to students who made one error in their answer.

There were many alternative answers to (e) and all of them were given credit. Students often failed to gain marks by making vague statements that failed to set out clearly the physics behind their suggestions. Several students suggested, incorrectly, that shortening the rope so that A was higher would make a difference.

**21.** Generally, students were less successful in answering this question than the other questions in this 2022 paper.

**22.** Generally, students were more successful in answering this question than the other questions in this 2022 paper.

**24.** Generally, students were less successful in answering this question than the other questions in this 2022 paper.

**26.** Generally, students were less successful in answering this question than the other questions in this 2022 paper.

**27.** Generally, students were more successful in answering this question than the other questions in this 2022 paper.

**29.** This question was the most demanding; fewer than 40% of students got it right and the correct answer was not the most popular choice.

This question was about the equilibrium of forces. The most popular answer was A. Drawing the weight of the trapdoor and the tension in the rope on the diagram would have shown their lines of action. This would have indicated B as the only force with a line of action that would pass through a common point and therefore give no turning effect.

**31.** (a) The most common response was 0.08, with a large majority of students failing to appreciate that the *y*-axis was a plot of $2s$ and so the absolute uncertainty had been doubled.

(b) Students were more successful in drawing the line for the minimum gradient than for the maximum gradient. A common mistake was to draw the line for the maximum gradient through the bottom of the error bar for the first plot and through the top of the error bar for the final plot. This bypassed the fifth plot and was, consequently, incorrect.

(c) Examiners marked this question based on the student's values for (b). A value to 2 sf was expected.

(d) Very few students used their value for $g$ from (c), with many opting to make a comparison using 9.81.

(e) About 60% of students gave the correct answer.

(f) Just under half the cohort gave a correct description of how the graph would change. Those who simply stated what would happen to the values, rather than to the plotted points or line, did not get credit.



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**32.**

(a) Over 25% of the students obtained all three marks. Many of these students had labelled **Figure 1** with distances and forces and gave clear working that was easy to follow. A common incorrect answer was 1.2 m. This was usually caused by incorrect use of $d$ in the moments equation.

(b) Most students gained at least one mark in this calculation. The reasons seen for failing to gain the second mark included: use of 3.6 m for $L$, thinking that the extension was the answer, and an inaccurate read-off from **Figure 2**. These errors reflect a lack of exam technique; students did not cope well in situations where key information was provided in the opening stem of the question.

Students should be encouraged to use a ruler to draw straight lines on diagrams to ensure an appropriate degree of accuracy in reading data from graphs.

(c) Over 70% of students gained this mark. This calculation was much simpler than the previous question with both pieces of data provided close to the question. The best answers seen typically followed the steps of writing the equation, substituting the data, re-arranging to make the stress the subject, and placing the answer to an appropriate number of significant figures on the answer line.

(d) Most students gained at least one mark by drawing an appropriate line with a negative gradient. Just over 20% gained two marks; these students appreciated that that extension had doubled and were able to determine the new extension for $d$ = 0 but then incorrectly drew a line parallel to the original line.

**33.**

(a&b) Almost 40% of students scored one mark in (a) and 36% scored two marks in (b). A significant number of students who could not do (a) were able to do the calculation in (b). This suggests that these students knew the process involved in determining the component of the weight parallel to the slope but were unaware of the technical term used to describe it. Many students were able to use $P = Fv$ in question (b) to determine the force but were unable to relate this force to the component of the weight parallel to the slope.

(c) Less than 10% of the cohort obtained two or more marks. Students did not seem to have any real-world appreciation of this 'zig-zag' path being easier than the direct path in **Figure 2**. They thought that the cyclist had travelled further, had encountered more resistive forces, and had done more work with a greater power output. These students offered efficiency-type arguments to explain why they thought that the useful power output had changed. Many of those who did appreciate that the effective angle had been diminished thought that the power output had increased by omitting the idea that the cyclist maintained the same steady speed.

(d) Students had more success here with 32.7% of them able to score all three marks. However, over 45% of the students were unable to score any marks. Many of these students attempted to use $v = u + at$ thus not appreciating that motion was non-uniform or that this equation can only be applied to situations where the acceleration is constant.



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(e) This question proved too challenging for this cohort of students. Less than 5% of the students were able to obtain more than three marks. The answers seen were typical of work at GCSE level. The marks scored were limited to statements that air resistance increased with speed or that the gravitational potential energy was being converted into kinetic energy. Many students disregarded the instruction to outline the energy transfers and instead answered in terms of resultant forces and accelerations. The type of analysis that one would expect from more able AS students was rarely seen. A significant number of students stated that the cyclist was losing kinetic energy even though the velocity did not decrease.

**39.**

(a) Students performed well in this part with 47% of students achieving all three marks. Those who made more limited progress were unfamiliar with how to determine the volume of air displaced each second and instead used $2\pi rh$ or $\frac{4}{3}\pi r^3$. Here again, realising that this is a "show that" question was crucial; students must ensure that their working clearly demonstrates *all* the steps they have made to produce the answer. Some students presented a one significant figure answer and this limited them to a maximum of two marks.

(b) This part of the question expected students to appreciate that the displacement of the gas produced an upwards force equal to the weight of the helicopter. This was beyond the knowledge and understanding of most. Fewer than 16% of students scored three marks and certainly demonstrated A-grade performance. Over 70% of students scored zero in this part. Many students thought that the mass of gas displaced per second was equal to the mass of the helicopter. Many attempted to use conservation of energy to obtain an answer by setting gravitational potential energy equal to kinetic energy. It was very common to see 0.4 × 3.72 as the only working presented.

(c) This part of the question was more accessible with almost 60% of students obtaining at least one mark. However, many students demonstrated a limited appreciation of the context and divided the energy stored in the battery by 39 s to find a power. This was incorrect as it assumed that all of the energy stored in the battery was transferred in 39 s. Many poorer performing students were unable to convert kilowatt-hours into joules.

(d) Almost 60% of students were able to score at least one mark. However, fewer than 10% of students were able to make further progress and not even 1% scored all three marks. Most realised that the helicopter was now heavier and that more work was required to keep it in the air. However, they were unable to describe how the helicopter produces the extra lift required. Also, they were unable to connect the increased amount of work done to power and therefore were unable to explain why the flight time would not double. Students would often make statements without being able to support them with an explanation that demonstrated their knowledge and understanding of the underlying physics.



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(e) 58% of students obtained both marks. Almost 8% did not even attempt this calculation. Mistakes seen included dividing the acceleration by the change in velocity and using an inappropriate equation of motion.

(f) 11% of students did not attempt this calculation. 32% of students scored one mark, usually for determining the maximum height above the ground or the distance travelled upwards from the position shown in **Figure 3** to the maximum height. These students presented 0.65 m or 0.041 m as their answer without appreciating how this applied to this context.

(g) The lack of quality of the students' technical language was often the reason for limited progress in this part. Many thought that constant acceleration was the same as constant velocity and developed arguments based on acquisition of a terminal velocity. Many others offered Newton's third law as a reason to support equilibrium and Newton's first law.

**40.** This question was the easiest with over 75% of students getting it right.

**41.** This question included some parts that many students found very challenging but also parts that were quite accessible.

(a) It was clear that many students had little idea about how the equation for SHM can be obtained. Commonly students simply stated the conditions for SHM without relating it to the context.

(b) The calculation was much more straightforward with over half of students getting both marks. The mark scheme allowed those who could go no further to gain one mark for using a value of $\omega$ or similar. Common errors included adding the amplitude when calculating the period, or using the total distance submerged as the amplitude when calculating the acceleration.

(c) This proved to be quite challenging. Students who made no reference to the amplitude being a maximum at resonance were limited to one mark. Other answers showed some difficulty with the idea of driving frequency. Some good answers were seen that made use of a labelled sketch graph.

(d) This part discriminated very well. More than 60% of students were able to get at least one mark, usually for working out the wave frequency. Nearly 40% of students were able to go further, often for stating that this was close to the natural frequency and therefore the boat should move. Full marks were given for those who also made some reference to what happened to the driving frequency when the boat was moving. This is another example of a question that tests assessment objective AO3. Students should be encouraged to practise answering questions of this kind in preparation for this examination in the future.

**42.** This question was the most demanding; fewer than 40% of students got it right and the correct answer was not the most popular choice.

This question was about the displacement of a projectile. The most popular answer was A, followed by B. These answers suggested that students did not identify that displacement, and not distance, was required.

**44.** Part (a) was the one with popular distractors.



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**45.** This question included parts with a range of difficulty, giving most students the opportunity to pick up some marks.

(a) A straightforward calculation that required students to use an appropriate section of the graph to obtain the Young modulus. Power of ten errors prevented some students obtaining the mark.

(b) A range of responses was acceptable but the idea that there was no increase in strain beyond the linear section of the graph did not get the mark. These answers implied that students knew what brittle meant but did not apply it to **Figure 1**.

(c) The calculation was reasonably accessible with nearly half of the students getting full marks. This part discriminated well, giving students who got the wrong value some credit provided their answer was set out sufficiently clearly to show what they were doing. A common error was using 200 N for the load; this gave access to two of the three marks.

(d) This was also one of the most discriminating on the paper. Over half of the students were able to get at least one mark, usually for providing evidence of a moment equation. Students who did not see that for AB to be horizontal the extensions of the two wires had to be equal made little further progress. The mark scheme produced a range of marks, rewarding students who set out their work sufficiently clearly to obtain intermediate marks. Using the value of extension from part(c) gave partial credit to some of these students.

**46.** This question was the easiest with over 75% of students getting it right.

**47.** (a) Students struggled to make comments about moments that related specifically to this context. Generic statements about balanced moments were insufficient. Students regularly failed to comment on the relevant forces, eg weight of the food, when describing moments.

(b) This relatively simple derivation was not attempted well by a large majority of the cohort. Few students started with an expression of moments and commonly omitted $g$ in their working.

(c) There was a good spread of marks here, although many students failed to connect the equation from part (b) and therefore gained no credit. A large number tried to obtain a gradient.

(d) Very few students gained any credit. Most students presented arguments in terms of a percentage uncertainty. This, they argued, would decrease as $M$ increased because the absolute uncertainty in $M$ would be constant. This is not the case: the absolute uncertainty in a value of $x$ is constant but, as **Figure 3** shows, this leads to an increasing uncertainty in $M$.

**49.** There was a range of demand to the parts of question 2 that meant it produced a good spread of marks.

(a) There were several alternative routes available for the first mark, and the majority of students were able to pick up credit for one of them. The second mark proved to be more difficult, with only about half of the students getting both marks. Almost all of the students who worked out the answer correctly realised that a two significant figure (s.f.) answer was inappropriate in the context.



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(b) Few students had any difficulty calculating the kinetic energy. This proved to be one of the most accessible questions on the paper.

(c) This four-mark part of the question was answered correctly by almost half of the students. It was clear that, although the graph was unusual, the support given here allowed students to access the marks. The mark scheme was designed to credit each step in the calculation separately. Students who set out their answers logically and clearly benefited from this.

(d) This was much more demanding with only about one in six students receiving both marks. The assessment objective for this part required some flexibility in the approach students could use. Students should be encouraged to develop their skills in answering AO3 questions of this kind.

**54.** Generally, students were more successful in answering this question (this had a success rate of at least 65%).

**55.** In this question, based on required practical activity 3, students were required to explain how *g* could be determined by a free-fall method using evidence from a strobe photograph.

There was no expectation that students should have direct experience of using a stroboscope but that does not preclude the use of photographic images, made with the aid of a stroboscope, to analyse the motion of a falling object. Mobile phones can produce videos of objects in free fall that perform a similar function. Many students showed through their working that they were well aware of the independent effect of motion in horizontal and vertical directions.

(a) Over half of the students gave the correct response.

(b) Students were asked why the duration of each flash should be short. Some stated that this increases the number of images produced, but we expected them to comment on the quality of each image or to explain that this allowed the position of the ball in each image to be determined.

(c) Much of the work was easy to follow, even though some used the space on page 4 to show a rearranged equation. There were many possible valid solutions, the most popular of which was to suggest that $\frac{n}{2f^2}$ was plotted on the $x$-axis so that $g$ was the gradient. Students must make sure that they avoid ambiguous statements such as "we need to find the gradient to get $g$". They also had to make sure to explain clearly how $g$ was obtained; a statement in which $g$ was not the subject, such as "the gradient of the graph is $\frac{g}{2f^2}$", was not accepted.

(d) We expected students to use **Figure 1** to identify $N$, the image number at the instant the ball hits the floor for the first time. We accepted $N$ = 17 ± 1 but many missed the intention of the question and tried to substitute $n$ = 0 or 5 into $H - h = \frac{u_0 n}{f} + \frac{g}{2}\left(\frac{n}{f}\right)^2$. It should have been obvious that the $n$ = 0 approach could not work. The $n$ = 5 approach led to attempts to measure $h$ directly from **Figure 2** and, in some instances, this worked, but many failed to recognise the broken dimension convention and wrongly concluded that $h$ was $\frac{H}{2}$.



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(e) We expected them to determine the horizontal velocity by dividing the distance between two suitable images by the corresponding time; we accepted the use of their distance between the second and third contacts (usually 1000 mm) and their time from 01.6.

Comparatively few added suitable annotation to **Figure 3**. Rather than take the expected route of dividing the distance by their (e) result, some used $s = \frac{1}{2}at^2$ with $s$ = 495 mm and g = 9.79 m s$^{-2}$ but apart from those who forgot to multiply their $t$ by 2 or who failed to cope with the mixed units, this approach worked well. Some credit was given for determining the time by estimating a non-integer number of intervals between the contacts.



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