Write your name here

| Surname | Other names |
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**Pearson Edexcel**
**International**
**Advanced Level**

Centre Number | | | | | |

Candidate Number | | | | |

# Mechanics M1

## Advanced/Advanced Subsidiary

Wednesday 25 October 2017 – Morning
**Time: 1 hour 30 minutes**

Paper Reference
**WME01/01**

**You must have:**
Mathematical Formulae and Statistical Tables (Blue)

Total Marks

**Candidates may use any calculator allowed by the regulations of the Joint Council for Qualifications. Calculators must not have the facility for symbolic algebra manipulation, differentiation and integration, or have retrievable mathematical formulae stored in them.**

## Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B). Coloured pencils and highlighter pens must not be used.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions and ensure that your answers to parts of questions are clearly labelled.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*
- You should show sufficient working to make your methods clear. Answers without working may not gain full credit.
- Whenever a numerical value of $g$ is required, take $g = 9.8$ m s$^{-2}$, and give your answer to either two significant figures or three significant figures.
- When a calculator is used, the answer should be given to an appropriate degree of accuracy.

## Information

- The total mark for this paper is 75.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*

## Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

*Turn over* ▶

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**1.** A suitcase of mass 40 kg is being dragged in a straight line along a rough horizontal floor at constant speed using a thin strap. The strap is inclined at 20° above the horizontal. The coefficient of friction between the suitcase and the floor is $\frac{3}{4}$. The strap is modelled as a light inextensible string and the suitcase is modelled as a particle. Find the tension in the strap.

**(7)**

## General Principles for Mechanics Marking

| Question Number | Scheme | Marks |
|---|---|---|
| **1** | $T\cos 70^\circ + R = 40g$ | M1A1 |
| | $T\cos 20^\circ = F$ | M1A1 |
| | $F = \frac{3}{4}R$ | B1 |
| | Eliminate $R$ and solve for $T$ | **DM**1 |
| | $T$ = 250 N or 246 N | A1 |
| | | **7** |
| | | |
| | **Notes** | |
| **1** | First M1 for resolving vertically with usual rules (must be using either $20^o$ or $70^o$)<br>First A1 for a correct equation<br>Second M1 for resolving horizontally with usual rules (must be using either $20^o$ or $70^o$)<br>Second A1 for a correct equation<br>B1 for $F = \frac{3}{4}R$ seen (could be on a diagram)<br>Third DM1 dependent on previous two M marks<br>Third A1 for either 250 (N) or 246 (N) | |
| | | |
| | | |
| **2a** | $M(D),\ (1080\times 1)-(400\times 2) = R_C \times 3.5$ | M1 A1 |
| | $R_C = 80$ (N) | A1 |
| | $M(C),\ (1080\times 2.5)+(400\times 5.5) = R_D \times 3.5$ | M1A1 |
| | $R_D = 1400$ (N) | A1 (6) |
| | | |
| | OR $(\uparrow) R_C + R_D = 1480$ | M1A1 |
| | | |
| **2b** | $R_C + (R_C + 520) = 1480$ OR $R_D + (R_D - 520) = 1480$ | M1 A1 |
| | | |
| | $M(D),\ (1080 \times 1) - 400(x-4) = R_C \times 3.5$ | M1 A1 |
| | $x = 2.5$ | A1 (5) |
| | | **11** |
| | **Notes** | |
| **2a** | First M1 for a moments equation or a vertical resolution<br>First A1 for a correct equation ($R_C$ and/or $R_D$ do NOT need to be substituted but if one is, it can be their value found from a previous equation) | |

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**2.**

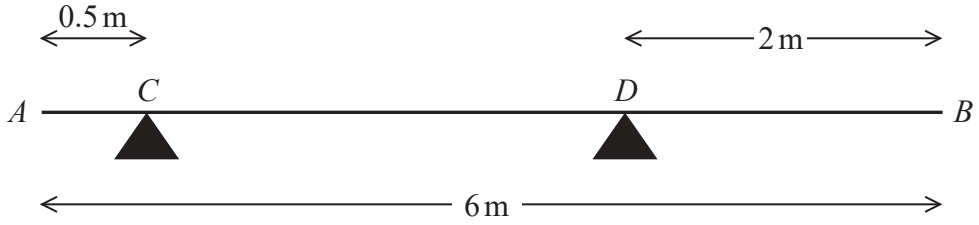


**Figure 1**

A metal girder $AB$, of weight 1080 N and length 6 m, rests in equilibrium in a horizontal position on two supports, one at $C$ and one at $D$, where $AC = 0.5$ m and $BD = 2$ m, as shown in Figure 1. A boy of weight 400 N stands on the girder at $B$ and the girder remains horizontal and in equilibrium. The boy is modelled as a particle and the girder is modelled as a uniform rod.

(a) Find

(i) the magnitude of the reaction on the girder at $C$,

(ii) the magnitude of the reaction on the girder at $D$.

**(6)**

The boy now stands at a point $E$ on the girder, where $AE = x$ metres, and the girder remains horizontal and in equilibrium. Given that the magnitude of the reaction on the girder at $D$ is now 520 N greater than the magnitude of the reaction on the girder at $C$,

(b) find the value of $x$.

**(5)**

## General Principles for Mechanics Marking

| Question Number | Scheme | Marks |
|---|---|---|
| **1** | $T\cos 70^\circ + R = 40g$ | M1A1 |
| | $T\cos 20^\circ = F$ | M1A1 |
| | $F = \frac{3}{4}R$ | B1 |
| | Eliminate $R$ and solve for $T$ | **DM**1 |
| | $T$ = 250 N or 246 N | A1 |
| | | **7** |
| | | |
| | **Notes** | |
| **1** | First M1 for resolving vertically with usual rules (must be using either $20^o$ or $70^o$)<br>First A1 for a correct equation<br>Second M1 for resolving horizontally with usual rules (must be using either $20^o$ or $70^o$)<br>Second A1 for a correct equation<br>B1 for $F = \frac{3}{4}R$ seen (could be on a diagram)<br>Third DM1 dependent on previous two M marks<br>Third A1 for either 250 (N) or 246 (N) | |
| | | |
| | | |
| **2a** | $M(D),\ (1080\times 1)-(400\times 2) = R_C \times 3.5$ | M1 A1 |
| | $R_C = 80$ (N) | A1 |
| | $M(C),\ (1080\times 2.5)+(400\times 5.5) = R_D \times 3.5$ | M1A1 |
| | $R_D = 1400$ (N) | A1 (6) |
| | | |
| | OR $(\uparrow) R_C + R_D = 1480$ | M1A1 |
| | | |
| **2b** | $R_C + (R_C + 520) = 1480$ OR $R_D + (R_D - 520) = 1480$ | M1 A1 |
| | | |
| | $M(D),\ (1080 \times 1) - 400(x-4) = R_C \times 3.5$ | M1 A1 |
| | $x = 2.5$ | A1 (5) |
| | | **11** |
| | **Notes** | |
| **2a** | First M1 for a moments equation or a vertical resolution<br>First A1 for a correct equation ($R_C$ and/or $R_D$ do NOT need to be substituted but if one is, it can be their value found from a previous equation) | |

| Question Number | Scheme | Marks |
|---|---|---|
| | Second A1 for $R_C = 80$ (N)<br>Second M1 for a moments equation or a vertical resolution<br>Third A1 for a correct equation ($R_C$ and/or $R_D$ do NOT need to be substituted but if one is, it can be their value found from a previous equation)<br>Fourth A1 for $R_D = 1400$ (N)<br>Enter marks for equations on ePEN, in the order they appear | |
| **2b** | First M1 for a moments equation or a vertical resolution<br>First A1 for a correct equation ($R_C$ and/or $R_D$ do NOT need to be substituted but if one is, it can be their value found from a previous equation)<br>Second M1 for a moments equation or a vertical resolution<br>Second A1 for a correct equation ($R_C$ and/or $R_D$ do NOT need to be substituted but if one is, it can be their value found from a previous equation)<br>Third A1 for $x = 2.5$<br>Enter marks for equations on ePEN, in the order they appear<br>**N.B.** Equations may contain any or all of $R_C$ , $R_D$ or $x$ for M marks but must contain only **one** of $R_C$ or $R_D$ to earn the A mark.<br>**N.B.** If they assume that $R_D$ = 520, they lose all the marks for part (b).<br>**N.B** If they start with $2R$ = 1480 and then add or subtract (or both) 520 to their $R$ value, M0**.**<br>**N.B.** If brackets are omitted in a moments equation e.g. (520 + $R_C$).4 is written as 520 + $R_C$.4, the M mark can be scored | |
| | | |
| | | |
| | | |
| **3** | $8mu - 4mu = 5mv$ | M1A1 |
| | $v = 0.8u$ | A1 |
| | For $P$: $-I = 4m(0.8u - 2u)$ | M1 A1 |
| | $I = 4.8mu$ | A1 |
| | | |
| | **OR** For $Q$: $I = m(0.8u + 4u)$ | M1 A1 |
| | $I = 4.8mu$ | A1 |
| | | |
| | | **6** |
| | **Notes** | |
| **3** | First M1 for CLM with correct no. of terms, all dimensionally correct, to give an equation in $m$, $u$ and their $v$ only. Condone consistent $g$'s or cancelled $m$'s and sign errors.<br>(N.B. The CLM equation could be obtained by equating the magnitudes of the impulses on each particle)<br>First A1 for a correct equation (they may have - 5$mv$)<br>Second A1 for 0.8$u$ or – 0.8$u$ (as appropriate)<br>Second M1 for using Impulse = Change in Momentum for either $P$ or $Q$ (M0 if *clearly* adding momenta or if $g$ is included or if different mass in the two momentum terms) but condone sign errors. | |

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**3.** Two particles $P$ and $Q$ have masses $4m$ and $m$ respectively. They are moving in opposite directions towards each other along the same straight line on a smooth horizontal plane and collide directly. Immediately before the collision the speed of $P$ is $2u$ and the speed of $Q$ is $4u$. In the collision, the particles join together to form a single particle.

Find, in terms of $m$ and $u$, the magnitude of the impulse exerted by $P$ on $Q$ in the collision.

**(6)**

| Question Number | Scheme | Marks |
|---|---|---|
| | Second A1 for $R_C = 80$ (N)<br>Second M1 for a moments equation or a vertical resolution<br>Third A1 for a correct equation ($R_C$ and/or $R_D$ do NOT need to be substituted but if one is, it can be their value found from a previous equation)<br>Fourth A1 for $R_D = 1400$ (N)<br>Enter marks for equations on ePEN, in the order they appear | |
| **2b** | First M1 for a moments equation or a vertical resolution<br>First A1 for a correct equation ($R_C$ and/or $R_D$ do NOT need to be substituted but if one is, it can be their value found from a previous equation)<br>Second M1 for a moments equation or a vertical resolution<br>Second A1 for a correct equation ($R_C$ and/or $R_D$ do NOT need to be substituted but if one is, it can be their value found from a previous equation)<br>Third A1 for $x = 2.5$<br>Enter marks for equations on ePEN, in the order they appear<br>**N.B.** Equations may contain any or all of $R_C$ , $R_D$ or $x$ for M marks but must contain only **one** of $R_C$ or $R_D$ to earn the A mark.<br>**N.B.** If they assume that $R_D$ = 520, they lose all the marks for part (b).<br>**N.B** If they start with $2R$ = 1480 and then add or subtract (or both) 520 to their $R$ value, M0**.**<br>**N.B.** If brackets are omitted in a moments equation e.g. (520 + $R_C$).4 is written as 520 + $R_C$.4, the M mark can be scored | |
| | | |
| | | |
| | | |
| **3** | $8mu - 4mu = 5mv$ | M1A1 |
| | $v = 0.8u$ | A1 |
| | For $P$: $-I = 4m(0.8u - 2u)$ | M1 A1 |
| | $I = 4.8mu$ | A1 |
| | | |
| | **OR** For $Q$: $I = m(0.8u + 4u)$ | M1 A1 |
| | $I = 4.8mu$ | A1 |
| | | |
| | | **6** |
| | **Notes** | |
| **3** | First M1 for CLM with correct no. of terms, all dimensionally correct, to give an equation in $m$, $u$ and their $v$ only. Condone consistent $g$'s or cancelled $m$'s and sign errors.<br>(N.B. The CLM equation could be obtained by equating the magnitudes of the impulses on each particle)<br>First A1 for a correct equation (they may have - 5$mv$)<br>Second A1 for 0.8$u$ or – 0.8$u$ (as appropriate)<br>Second M1 for using Impulse = Change in Momentum for either $P$ or $Q$ (M0 if *clearly* adding momenta or if $g$ is included or if different mass in the two momentum terms) but condone sign errors. | |

| Question Number | Scheme | Marks |
|---|---|---|
| | Third A1 for $4m(0.8u-2u)$ or $-4m(0.8u-2u)$<br>**OR** for $m(0.8u+4u)$ or $-m(0.8u+4u)$<br>Fourth A1 for 4.8*mu* (must be positive since magnitude) | |
| **4(i)** | $\lvert\mathbf{F}_2\rvert^2 = 8^2+14^2-2\times 8\times 14\cos 30$ | M1 A1 |
| | Solve for $\lvert\mathbf{F}_2\rvert$= 8.1 (N) or better | M1 A1 (4) |
| | | |
| | **OR:** $\lvert\mathbf{F}_2\rvert\cos\alpha = 14\cos 30 - 8$<br>$\lvert\mathbf{F}_2\rvert\sin\alpha = 14\sin 30$ | M1 A1 |
| | Solve for $\lvert\mathbf{F}_2\rvert$= 8.1 (N) or better | M1 A1 (4) |
| | | |
| **4(ii)** | $\frac{\sin\theta}{8} = \frac{\sin 30}{8.12467}$ or $\frac{\sin\phi}{14} = \frac{\sin 30}{8.12467}$ | M1 A1 |
| | Solve: $\theta = 29.49^o$ or $\phi = 120.51^o$ | M1 A1 |
| | Bearing is 149° (nearest degree) | A1 (5) |
| | | |
| | **OR:** $\lvert\mathbf{F}_2\rvert\cos\alpha = 14\cos 30 - 8 = 4.124(355.)$<br>$\lvert\mathbf{F}_2\rvert\sin\alpha = 14\sin 30$ | M1 A1 |
| | Solve: $\alpha = 59.49^o$ | M1 A1 |
| | Bearing is 149° (nearest degree) | A1 (5) |
| | | |
| | **Notes** | |
| **4(i)** | First M1 for use of cos rule with 30°<br>First A1 for a correct equation<br>**OR:** First M1 for 'resolving' in 2 directions with 30° / 60° (**N.B.** M0 here if cos/sin confused)<br>First A1 for TWO correct equations<br>Second M1 for solving for $\lvert\mathbf{F}_2\rvert$, <u>independent</u> *but* must be solving a 'correct cosine formula but with wrong angle' if using method 1<br>**OR** for eliminating $\alpha$ from two equations, <u>independent</u> *but* equations must have the correct structure if using method 2<br>Second A1 for 8.1 (N) or better | |
| **4(ii)** | First M1 for use of sin rule with 30°<br>First A1 for a correct equation (<u>allow 8.12 or better</u>)<br>**OR:** First M1 for 'resolving' in 2 directions with 30° / 60° | |

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**4.** Two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ act on a particle. The force $\mathbf{F}_1$ has magnitude 8 N and acts due east. The resultant of $\mathbf{F}_1$ and $\mathbf{F}_2$ is a force of magnitude 14 N acting in a direction whose bearing is 120°.

Find

(i) the magnitude of $\mathbf{F}_2$,

**(4)**

(ii) the direction of $\mathbf{F}_2$, giving your answer as a bearing to the nearest degree.

**(5)**

| Question Number | Scheme | Marks |
|---|---|---|
| | Third A1 for $4m(0.8u-2u)$ or $-4m(0.8u-2u)$<br>**OR** for $m(0.8u+4u)$ or $-m(0.8u+4u)$<br>Fourth A1 for 4.8*mu* (must be positive since magnitude) | |
| **4(i)** | $\lvert\mathbf{F}_2\rvert^2 = 8^2+14^2-2\times 8\times 14\cos 30$ | M1 A1 |
| | Solve for $\lvert\mathbf{F}_2\rvert$= 8.1 (N) or better | M1 A1 (4) |
| | | |
| | **OR:** $\lvert\mathbf{F}_2\rvert\cos\alpha = 14\cos 30 - 8$<br>$\lvert\mathbf{F}_2\rvert\sin\alpha = 14\sin 30$ | M1 A1 |
| | Solve for $\lvert\mathbf{F}_2\rvert$= 8.1 (N) or better | M1 A1 (4) |
| | | |
| **4(ii)** | $\frac{\sin\theta}{8} = \frac{\sin 30}{8.12467}$ or $\frac{\sin\phi}{14} = \frac{\sin 30}{8.12467}$ | M1 A1 |
| | Solve: $\theta = 29.49^o$ or $\phi = 120.51^o$ | M1 A1 |
| | Bearing is 149° (nearest degree) | A1 (5) |
| | | |
| | **OR:** $\lvert\mathbf{F}_2\rvert\cos\alpha = 14\cos 30 - 8 = 4.124(355.)$<br>$\lvert\mathbf{F}_2\rvert\sin\alpha = 14\sin 30$ | M1 A1 |
| | Solve: $\alpha = 59.49^o$ | M1 A1 |
| | Bearing is 149° (nearest degree) | A1 (5) |
| | | |
| | **Notes** | |
| **4(i)** | First M1 for use of cos rule with 30°<br>First A1 for a correct equation<br>**OR:** First M1 for 'resolving' in 2 directions with 30° / 60° (**N.B.** M0 here if cos/sin confused)<br>First A1 for TWO correct equations<br>Second M1 for solving for $\lvert\mathbf{F}_2\rvert$, <u>independent</u> *but* must be solving a 'correct cosine formula but with wrong angle' if using method 1<br>**OR** for eliminating $\alpha$ from two equations, <u>independent</u> *but* equations must have the correct structure if using method 2<br>Second A1 for 8.1 (N) or better | |
| **4(ii)** | First M1 for use of sin rule with 30°<br>First A1 for a correct equation (<u>allow 8.12 or better</u>)<br>**OR:** First M1 for 'resolving' in 2 directions with 30° / 60° | |

| Question Number | Scheme | Marks |
|---|---|---|
| | First A1 for TWO correct equations (allow 4.12 or better)<br>Second M1, independent, for solving a 'correct sine formula' for $\theta$ or $\phi$<br>**OR** independent for solving two equations, with correct structure, for $\alpha$<br>Second A1 for $\theta =$ AWRT $29^o$ or $\phi =$ AWRT $121^o$<br>**OR** $\alpha =$ AWRT $59^o$ | |
| | Third A1 for Bearing is $149^o$ (nearest degree) | |
| | **N.B.** First M1A1 Could use cos rule to find an angle | |
| | **N.B.** If the resolving method is used and there are no (i) or (ii) labels, only award M1A1 in both cases when an answer is reached. | |
| **5a** | $0 = 14.7^2 - 2 \times 9.8h$ | M1A1 |
| | $h = 11.025$ | A1 |
| | max ht $= 13.5$ or $14$ (m) | A1 (4) |
| | | |
| **5b** | $-1.5 = 14.7t - 4.9t^2$ | M1A1 |
| | $4.9t^2 - 14.7t - 1.5 = 0$ | |
| | $t = \dfrac{14.7 \pm \sqrt{14.7^2 + 6 \times 4.9}}{9.8}$ | **DM**1 |
| | $t = 3.1$ or $3.10$ (s) | A1 (4) |
| | | |
| **5c** | $v^2 = 14.7^2 + 2 \times (-9.8) \times (-2.5)$ | M1 A1 |
| | $v = 16.3$ or $16$ (m s$^{-1}$) | A1 (3) |
| | | **11** |
| | **Notes** | |
| **5a** | **N.B.** If they use $g$ = 9.81, lose first A mark (once for whole question) but all other A marks can be scored.<br>First M1 for a complete method to find the height (Could involve two *suvat* equations) condone sign errors.<br>First A1 for a correct equation (or equations)<br>Second A1 for $h$ = 11 (may be unsimplified) or better (For other methods, give this A1 for any correct (may be unsimplified) intermediate answer)<br>Third A1 for 13.5 or 14 (m) | |
| **5b** | First M1 for a complete method to find the required time (they may find the time up (1.5 s) and then add on the time down. Condone sign errors<br>First A1 for a correct equation or equations<br>Second DM1, dependent, for solving to find required time<br>Second A1 for 3.1 or 3.10 (s) | |

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**5.** A small ball is projected vertically upwards from a point $O$ with speed $14.7\,\text{m s}^{-1}$. The point $O$ is 2.5 m above the ground. The motion of the ball is modelled as that of a particle moving freely under gravity.

Find

(a) the maximum height above the ground reached by the ball,

**(4)**

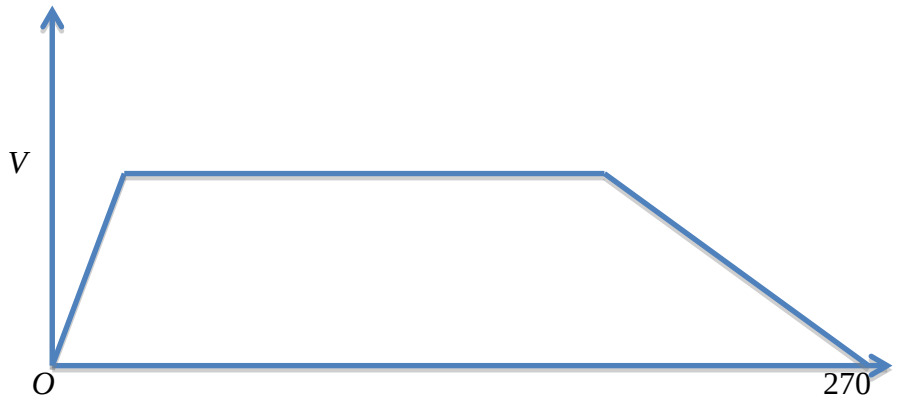
(b) the time taken for the ball to first reach a height of 1 m above the ground,

**(4)**

(c) the speed of the ball at the instant before it strikes the ground for the first time.

**(3)**

| Question Number | Scheme | Marks |
|---|---|---|
| | First A1 for TWO correct equations (allow 4.12 or better)<br>Second M1, independent, for solving a 'correct sine formula' for $\theta$ or $\phi$<br>**OR** independent for solving two equations, with correct structure, for $\alpha$<br>Second A1 for $\theta =$ AWRT $29^o$ or $\phi =$ AWRT $121^o$<br>**OR** $\alpha =$ AWRT $59^o$ | |
| | Third A1 for Bearing is $149^o$ (nearest degree) | |
| | **N.B.** First M1A1 Could use cos rule to find an angle | |
| | **N.B.** If the resolving method is used and there are no (i) or (ii) labels, only award M1A1 in both cases when an answer is reached. | |
| **5a** | $0 = 14.7^2 - 2 \times 9.8h$ | M1A1 |
| | $h = 11.025$ | A1 |
| | max ht $= 13.5$ or $14$ (m) | A1 (4) |
| | | |
| **5b** | $-1.5 = 14.7t - 4.9t^2$ | M1A1 |
| | $4.9t^2 - 14.7t - 1.5 = 0$ | |
| | $t = \dfrac{14.7 \pm \sqrt{14.7^2 + 6 \times 4.9}}{9.8}$ | **DM**1 |
| | $t = 3.1$ or $3.10$ (s) | A1 (4) |
| | | |
| **5c** | $v^2 = 14.7^2 + 2 \times (-9.8) \times (-2.5)$ | M1 A1 |
| | $v = 16.3$ or $16$ (m s$^{-1}$) | A1 (3) |
| | | **11** |
| | **Notes** | |
| **5a** | **N.B.** If they use $g$ = 9.81, lose first A mark (once for whole question) but all other A marks can be scored.<br>First M1 for a complete method to find the height (Could involve two *suvat* equations) condone sign errors.<br>First A1 for a correct equation (or equations)<br>Second A1 for $h$ = 11 (may be unsimplified) or better (For other methods, give this A1 for any correct (may be unsimplified) intermediate answer)<br>Third A1 for 13.5 or 14 (m) | |
| **5b** | First M1 for a complete method to find the required time (they may find the time up (1.5 s) and then add on the time down. Condone sign errors<br>First A1 for a correct equation or equations<br>Second DM1, dependent, for solving to find required time<br>Second A1 for 3.1 or 3.10 (s) | |

| Question Number | Scheme | Marks |
|---|---|---|
| | | |
| **5c** | First M1 for a complete method to find the speed / velocity(Could involve two *suvat* equations) Condone sign errors but must have correct numbers in their equation(s)<br>First A1 for a correct equation (or equations)<br>Second A1 for 16 or 16.3 (m $s^{-1}$) Must be *positive (speed)* | |
| **6a** |  | B1 shape<br>B1 270, *V*<br>(2) |
| **6b** | $\frac{V}{0.6}=\frac{5V}{3}$ **Given answer** | M1A1 (2) |
| **6c** | Time decelerating is $5V$ | B1 |
| | $\frac{1}{2}V\frac{5V}{3}+(270-5V-\frac{5V}{3})V+\frac{1}{2}V.5V=1500$<br>**OR:** $\frac{1}{2}(270+270-5V-\frac{5V}{3})V=1500$ | M1 A2 |
| | $V^2-81V+450=0$ **Given answer** | **DM1**A1 (6) |
| | | |
| **6d** | $V^2-81V+450=0$<br>$(V-6)(V-75)=0$ or $V=\frac{81\pm\sqrt{81^2-4\times450}}{2}$ | M1 solving |
| | $V=6$ or $75$ | A1 A1 |
| | $V=6$ since $(5\times75)>270$ or $V=75$ unrealistic | **B**1 (4) |
| | | **14** |
| | **Notes** | |
| **6a** | First B1 for a trapezium with line starting at the origin<br>Second B1 for 270 and *V* correctly marked | |
| **6b** | M1 for $(t=)\frac{V}{0.6}$; **N.B.** M1A0 for $V=0.6t$ then answer<br>Must see division or intermediate step from $V=0.6t$ e.g. Changing 0.6 into 3/5.<br>A1 for $t=\frac{5V}{3}$ **Given answer** | |

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**6.** An athlete goes for a run along a straight horizontal road. Starting from rest, she accelerates at $0.6\,\text{m s}^{-2}$ up to a speed of $V\,\text{m s}^{-1}$. She then maintains this constant speed of $V\,\text{m s}^{-1}$ before finally decelerating at $0.2\,\text{m s}^{-2}$ back to rest. She covers a total distance of 1500 m in 270 s.

(a) Sketch a speed-time graph to represent the athlete's run.

**(2)**

(b) Show that she accelerates for $\frac{5V}{3}$ seconds.

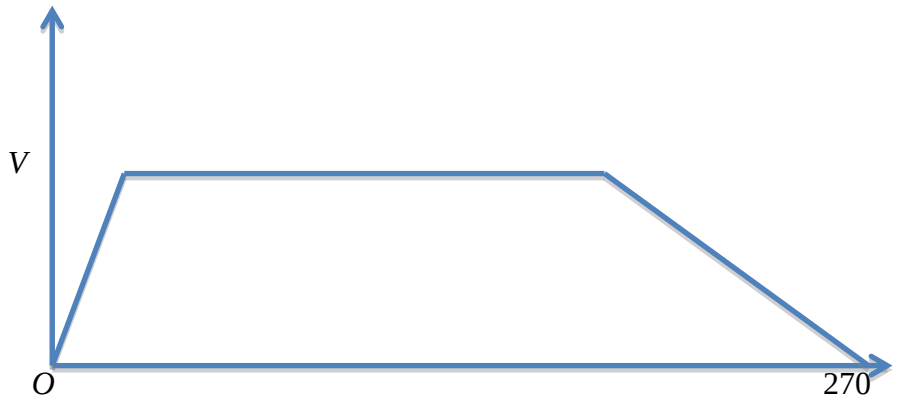
**(2)**

(c) Show that $V^2 - kV + 450 = 0$, where $k$ is a constant to be found.

**(6)**

(d) Find the value of $V$, justifying your answer.

**(4)**

| Question Number | Scheme | Marks |
|---|---|---|
| | | |
| **5c** | First M1 for a complete method to find the speed / velocity(Could involve two *suvat* equations) Condone sign errors but must have correct numbers in their equation(s)<br>First A1 for a correct equation (or equations)<br>Second A1 for 16 or 16.3 (m $s^{-1}$) Must be *positive (speed)* | |
| **6a** |  | B1 shape<br>B1 270, *V*<br>(2) |
| **6b** | $\frac{V}{0.6}=\frac{5V}{3}$ **Given answer** | M1A1 (2) |
| **6c** | Time decelerating is $5V$ | B1 |
| | $\frac{1}{2}V\frac{5V}{3}+(270-5V-\frac{5V}{3})V+\frac{1}{2}V.5V=1500$<br>**OR:** $\frac{1}{2}(270+270-5V-\frac{5V}{3})V=1500$ | M1 A2 |
| | $V^2-81V+450=0$ **Given answer** | **DM1**A1 (6) |
| | | |
| **6d** | $V^2-81V+450=0$<br>$(V-6)(V-75)=0$ or $V=\frac{81\pm\sqrt{81^2-4\times450}}{2}$ | M1 solving |
| | $V=6$ or $75$ | A1 A1 |
| | $V=6$ since $(5\times75)>270$ or $V=75$ unrealistic | **B**1 (4) |
| | | **14** |
| | **Notes** | |
| **6a** | First B1 for a trapezium with line starting at the origin<br>Second B1 for 270 and *V* correctly marked | |
| **6b** | M1 for $(t=)\frac{V}{0.6}$; **N.B.** M1A0 for $V=0.6t$ then answer<br>Must see division or intermediate step from $V=0.6t$ e.g. Changing 0.6 into 3/5.<br>A1 for $t=\frac{5V}{3}$ **Given answer** | |

| Question Number | Scheme | Marks |
|---|---|---|
| **6c** | B1 for $5V$ identified appropriately<br>First M1 for clear attempt to equate the *total* area under graph to 1500.<br>(Must include all 3 parts (if not using the trapezium rule) with $\frac{1}{2}$ seen at least once to give equation in $V$ only; may use (1 triangle + 1 trapezium) or (rectangle - trapezium)<br>(May use *suvat* for one or more parts of the area)<br>A2 for a correct equation, -1 e.e.o.o.<br>Second **DM**1 dependent on first M1 for multiplying out and collecting terms and putting into appropriate form<br>Third A1 for correct equation. **Given answer** | |
| **6d** | First M1 for solving their 3 term quadratic equation for $V$<br>N.B. This M1 can be implied by two correct roots but if either answer incorrect then an explicit method must be shown for this M mark.<br>First A1 for $V = 6$<br>Second A1 for $V = 75$<br>B1 on ePEN but treat as **DM**1, dependent on both previous A marks, for either reason | |
| | | |
| | | |
| **7a** | $T - 3mg\sin\alpha - F = 3ma$ | M1A1 |
| | $4mg - T = 4ma$ | M1A1 (4) |
| | | |
| **7b** | $F = \frac{1}{4}R;\ R = 3mg\cos\alpha$ | B1; M1A1 |
| | $T - 2.4mg = 3ma$<br>$4mg - T = 4ma$ | M1 |
| | $a = \frac{8g}{35}$ **Given answer** | A1 (5) |
| **7c** | Particles have same acceleration | B1 (1) |
| **7d** | $v^2 = 2 \times \frac{8g}{35} \times 1.75$ (= $0.8g$) | M1 A1 |
| | $-3mg\sin\alpha - F = 3ma'$ | M1 |
| | $a' = -0.8g$ | A1 |
| | $0 = 0.8g + 2 \times (-0.8g)s$ | M1 A1 |
| | Total distance = 0.5 + 1.75 = 2.25 (m) Accept 2.3 (m) | A1 (7) |
| | | **17** |
| | | |
| | **Notes** | |
| **7a** | First M1 for equation of motion for $A$ with usual rules<br>First A1 for a correct equation<br>Second M1 for equation of motion for $B$ with usual rules<br>Second A1 for a correct equation<br>**N.B.** If using different tension in second equation, M0 for that equation | |

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**7.**

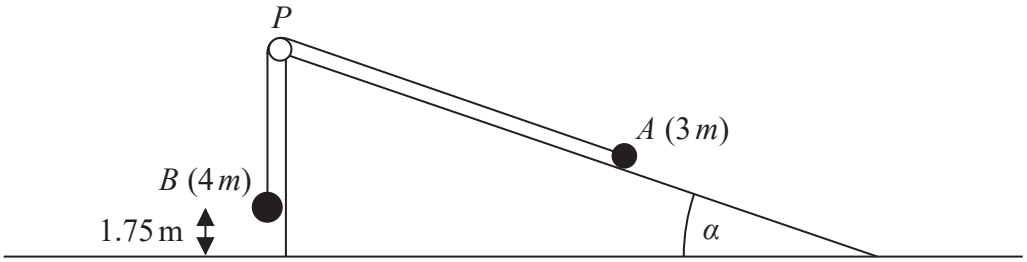


**Figure 2**

Figure 2 shows two particles $A$ and $B$, of masses $3m$ and $4m$ respectively, attached to the ends of a light inextensible string. Initially $A$ is held at rest on the surface of a fixed rough inclined plane. The plane is inclined to the horizontal at an angle $\alpha$ where $\tan\alpha = \frac{3}{4}$. The coefficient of friction between $A$ and the plane is $\frac{1}{4}$. The string passes over a small smooth light pulley $P$ which is fixed at the top of the plane. The part of the string from $A$ to $P$ is parallel to a line of greatest slope of the plane. The particle $B$ hangs freely and is vertically below $P$. The system is released from rest with the string taut and with $B$ at a height of 1.75 m above the ground. In the subsequent motion, $A$ does not hit the pulley.

For the period before $B$ hits the ground,

(a) write down an equation of motion for each particle.

**(4)**

(b) Hence show that the acceleration of $B$ is $\frac{8}{35}g$.

**(5)**

(c) Explain how you have used the fact that the string is inextensible in your calculation.

**(1)**

When $B$ hits the ground, $B$ does not rebound and comes immediately to rest.

(d) Find the distance travelled by $A$ from the instant when the system is released to the instant when $A$ first comes to rest.

**(7)**

| Question Number | Scheme | Marks |
|---|---|---|
| **6c** | B1 for $5V$ identified appropriately<br>First M1 for clear attempt to equate the *total* area under graph to 1500.<br>(Must include all 3 parts (if not using the trapezium rule) with $\frac{1}{2}$ seen at least once to give equation in $V$ only; may use (1 triangle + 1 trapezium) or (rectangle - trapezium)<br>(May use *suvat* for one or more parts of the area)<br>A2 for a correct equation, -1 e.e.o.o.<br>Second **DM**1 dependent on first M1 for multiplying out and collecting terms and putting into appropriate form<br>Third A1 for correct equation. **Given answer** | |
| **6d** | First M1 for solving their 3 term quadratic equation for $V$<br>N.B. This M1 can be implied by two correct roots but if either answer incorrect then an explicit method must be shown for this M mark.<br>First A1 for $V = 6$<br>Second A1 for $V = 75$<br>B1 on ePEN but treat as **DM**1, dependent on both previous A marks, for either reason | |
| | | |
| | | |
| **7a** | $T - 3mg\sin\alpha - F = 3ma$ | M1A1 |
| | $4mg - T = 4ma$ | M1A1 (4) |
| | | |
| **7b** | $F = \frac{1}{4}R;\ R = 3mg\cos\alpha$ | B1; M1A1 |
| | $T - 2.4mg = 3ma$<br>$4mg - T = 4ma$ | M1 |
| | $a = \frac{8g}{35}$ **Given answer** | A1 (5) |
| **7c** | Particles have same acceleration | B1 (1) |
| **7d** | $v^2 = 2 \times \frac{8g}{35} \times 1.75$ (= $0.8g$) | M1 A1 |
| | $-3mg\sin\alpha - F = 3ma'$ | M1 |
| | $a' = -0.8g$ | A1 |
| | $0 = 0.8g + 2 \times (-0.8g)s$ | M1 A1 |
| | Total distance = 0.5 + 1.75 = 2.25 (m) Accept 2.3 (m) | A1 (7) |
| | | **17** |
| | | |
| | **Notes** | |
| **7a** | First M1 for equation of motion for $A$ with usual rules<br>First A1 for a correct equation<br>Second M1 for equation of motion for $B$ with usual rules<br>Second A1 for a correct equation<br>**N.B.** If using different tension in second equation, M0 for that equation | |

| Question Number | Scheme | Marks |
|---|---|---|
| **7b** | B1 for $F = \frac{1}{4}R$ seen e.g. on diagram<br>First M1 for resolving for *A* perp to the plane<br>First A1 for correct equation<br>N.B. These first 3 marks can be earned in (a).<br>Second M1 (Hence) for substituting for *R* and *F* and trig. and solving for *a* (must be some evidence of this) their equations of motion from part (a)<br>Second A1 for **given answer (Not available if not using exact values for trig ratios)** | |
| **7c** | B1 for particles have same acceleration (B0 for same velocity or if incorrect extras given) | |
| **7d** | First M1 for attempt to find speed (or speed$^2$) when *B* hits the ground (M0 if uses *g*)<br>First A1 for a correct expression<br>Second M1 for attempt to find deceleration of *A*<br>Second A1 for correct deceleration<br>Third M1 for using deceleration (must have found a deceleration) with $v = 0$ to find distance (M0 if uses *g*)<br>Third A1 for a correct equation<br>Fourth A1 for 2.25 (m) | |