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| Candidate surname | Other names |
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Centre Number | Candidate Number

# Pearson Edexcel International Advanced Level

## Tuesday 7 May 2024

Afternoon (Time: 1 hour 30 minutes)

**Paper reference** **WME01/01**

# Mathematics

## International Advanced Subsidiary/Advanced Level
## Mechanics M1

**You must have:**
Mathematical Formulae and Statistical Tables (Yellow), calculator

Total Marks



**Candidates may use any calculator permitted by Pearson regulations. 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).
- **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 $g = 9.8\text{ m s}^{-2}$, and give your answer to either 2 significant figures or 3 significant figures.

### Information

- A booklet 'Mathematical Formulae and Statistical Tables' is provided.
- There are 8 questions in this question paper. 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.
- If you change your mind about an answer, cross it out and put your new answer and any working underneath.

*Turn over*

**1.** Two particles, $A$ and $B$, have masses $m$ and $3m$ respectively. The particles are connected by a light inextensible string. Initially $A$ and $B$ are at rest on a smooth horizontal plane with the string slack.

Particle $A$ is then projected along the plane away from $B$ with speed $U$.

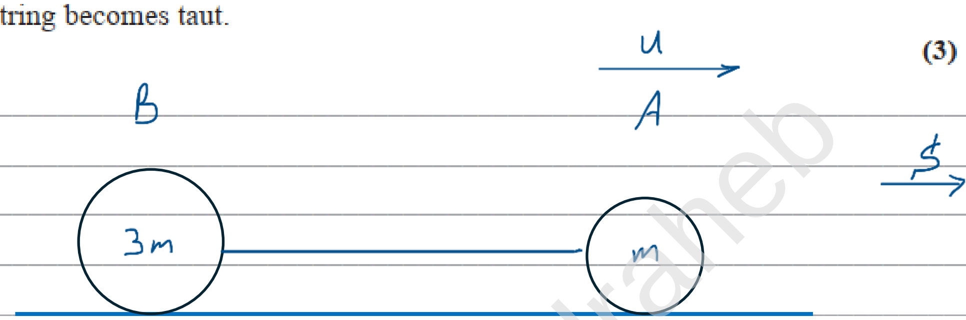
Given that the common speed of the particles immediately after the string becomes taut is $S$

(a) find $S$ in terms of $U$.

**(2)**

(b) Find, in terms of $m$ and $U$, the magnitude of the impulse exerted on $A$ immediately after the string becomes taut.

**(3)**




(a) $m_1 u_1 + m_2 u_2 = (m_1 + m_2) V$

$mu + 0 = (4m) S \quad \div m$

$4S = u \qquad S = \frac{1}{4} u$

(b) $I = m(v - u)$

$= m(S - u) = m\left(\frac{1}{4}u - u\right) = -\frac{3}{4} mu$

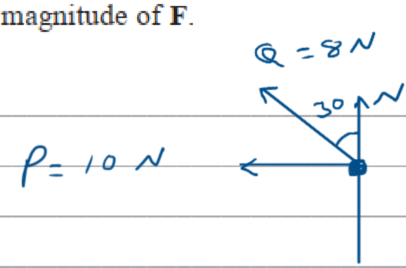
Magnitude of the impulse $= \frac{3}{4} mu$

2. Two forces, **P** and **Q**, act on a particle.

- **P** has magnitude 10 N and acts due west
- **Q** has magnitude 8 N and acts on a bearing of 330°

Given that **F** = **P** + **Q**, find the magnitude of **F**.

**(4)**




$\leftarrow$ X: $10 + 8\sin 30 = 14$

$\uparrow$ Y: $8\cos 30 = 4\sqrt{3}$

Magnitude of F $= \sqrt{(14)^2 + (4\sqrt{3})^2} = 2\sqrt{61}$ N

**3.**

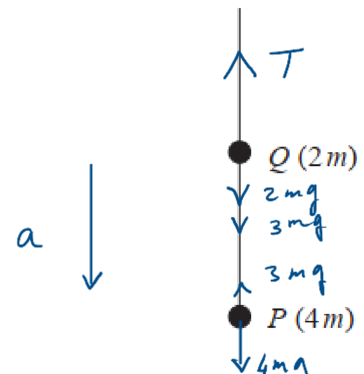



**Figure 1**

Two particles, $P$ and $Q$, have masses $4m$ and $2m$ respectively. The particles are connected by a light inextensible string. A second light inextensible string has one end attached to $Q$. Both strings are taut and vertical, as shown in Figure 1.

The particles are **accelerating** vertically **downwards**.

Given that the tension in the string connecting the two particles is $3mg$, find, in terms of $m$ and $g$, the tension in the upper string.

**(6)**

$4\cancel{m}g - 3\cancel{m}g = 4\cancel{m}a$ — (1) $\div m$

$5mg - T = 2ma$ — (2)

from (1) $4a = g$ $\quad a = \frac{1}{4}g$

in (2) $5mg - T = \cancel{2}m \cdot \frac{1}{\cancel{4}\,2} g$

$T = 5mg - \frac{1}{2}mg$

$T = 4.5mg$

**4.**

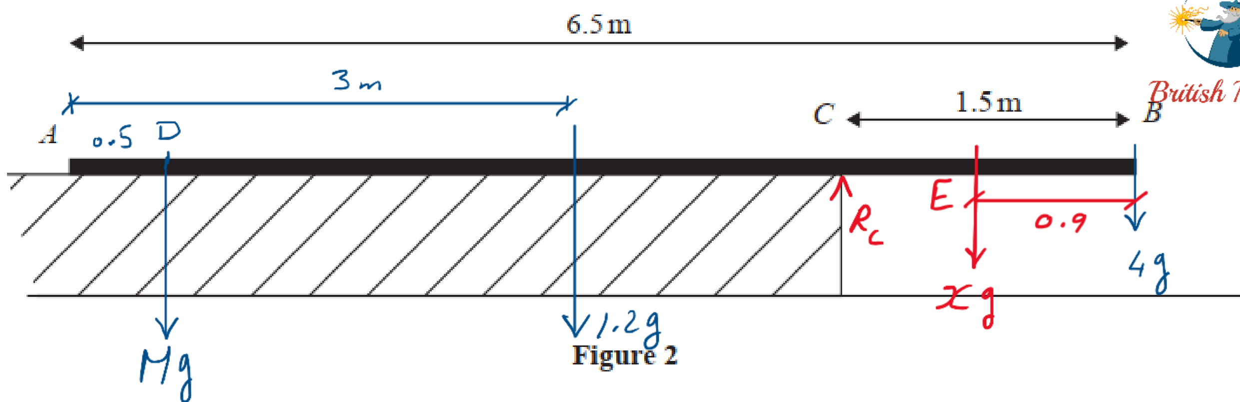



**Figure 2**

A non-uniform rod $AB$ has length 6.5 m and mass 1.2 kg. The centre of mass of the rod is 3 m from $A$. The rod rests on a horizontal step and overhangs the end of the step $C$ by 1.5 m, as shown in Figure 2.

The rod is perpendicular to the edge of the step.

A particle of mass 4 kg is placed on the rod at $B$ and another particle, whose mass is $M$ kg, is placed on the rod at $D$, where $AD = 0.5$ m.

The rod remains in equilibrium in a horizontal position.

(a) Find the smallest possible value of $M$.

**(3)**

The particle at $B$ **and** the particle at $D$ are now **removed**.

A new particle is placed on the rod at the point $E$, where $EB = 0.9$ m.

The rod remains in equilibrium in a horizontal position but is on the point of tilting about $C$.

(b) Find the magnitude of the force acting on the rod at $C$.

**(3)**

(a) $M_C$: $4\cancel{g}\times 1.5 = M\cancel{g}\times 4.5 + 1.2\cancel{g}\times 2 \quad \div g$

$4.5M + 2.4 = 6$

Smallest $M = 0.8$ Kg

(b) Let mass of new particle at $E = x$

$M_C$: $x\cancel{g}\times 0.6 = 1.2\cancel{g}\times 2 \quad \div g$

$0.6x = 2.4$

**Question 4 continued**

$x = 4 \text{ Kg}$

$R_c = 4g + 1.2g = 5.2g \text{ N}$







**(Total for Question 4 is 6 marks)**

**5.** A parachute is used to deliver a box of supplies. The parachute is attached to the box.

- the parachute and box are dropped from rest from a helicopter that is hovering at a height of 520 m above the ground
- the parachute and box fall vertically and freely under gravity for 5 seconds, then the parachute opens
- from the instant the parachute opens, it provides a resistance to motion of magnitude 3200 N
- the parachute and box continue to fall vertically downwards after the parachute opens
- the parachute and box are modelled throughout the motion as a particle $P$ of mass 250 kg

(a) Find the distance fallen by $P$ in the first 5 seconds.
**(2)**

(b) Find the speed with which $P$ lands on the ground.
**(7)**

(c) Find the total time from the instant when $P$ is dropped from the helicopter to the instant when $P$ lands on the ground.
**(3)**

(d) Sketch a speed-time graph for the motion of $P$ from the instant when $P$ is dropped from the helicopter to the instant when $P$ lands on the ground.
**(2)**

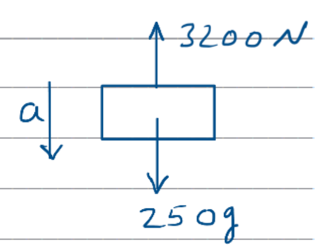




$t_1 = 5\,s$ , $R = 3200\,N$ , $M_p = 250\,Kg$

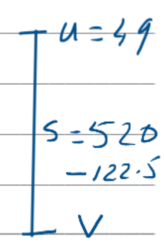
(a) $s = ut + \frac{1}{2}gt^2 = 0 + \frac{1}{2} \times 9.8 \times 5^2 = 122.5 = 123\,m$

(b) $250g - 3200 = 250a$




$a = \dfrac{250 \times 9.8 - 3200}{250} = -3\,m\,s^{-2}$

After the first 5 s $\quad v = u + gt$
$= 0 + 9.8 \times 5 = 49\,m\,s^{-1}$




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

$= 49^2 + 2(-3)(520 - 122.5)$

$= 16$

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**Question 5 continued**

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speed $= \sqrt{16} = 4\ m\ s^{-1}$

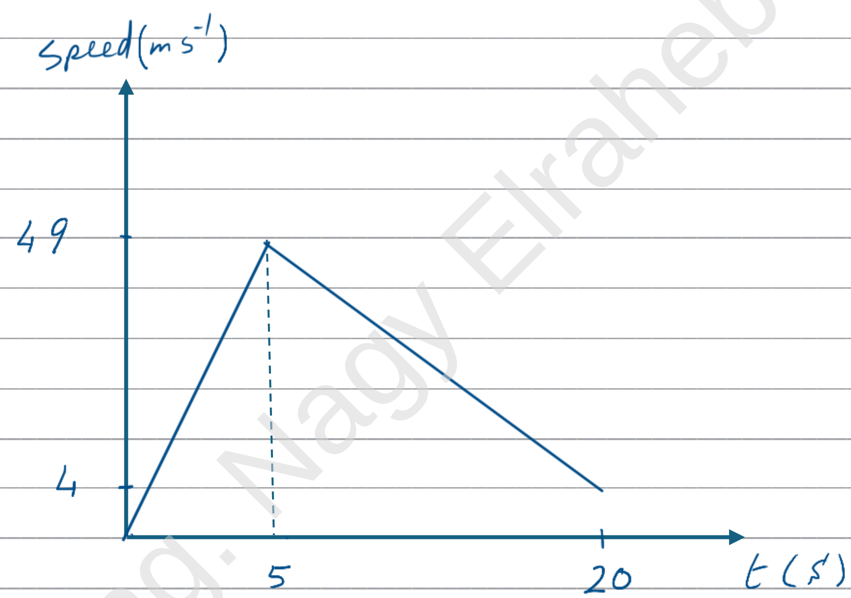
(c) For second part $v = u + at$

$4 = 49 - 3t$

$t = \dfrac{4-49}{-3} = 15\ s$

Total time $= 15 + 5 = 20\ s$

(d)






**(Total for Question 5 is 14 marks)**

**6.**

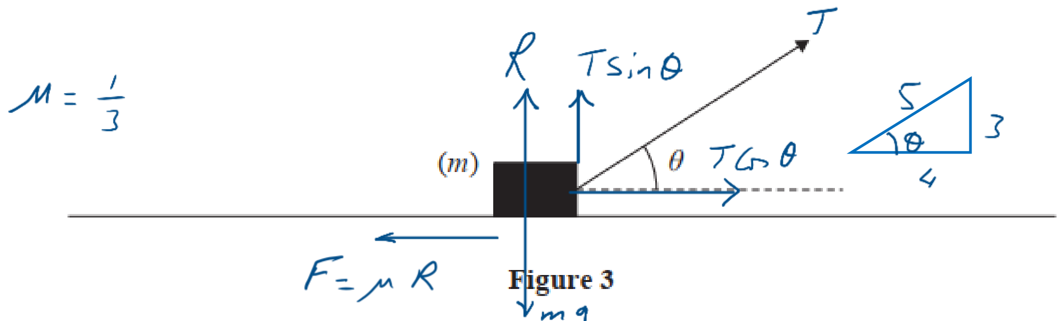



**Figure 3**

A box of mass $m$ lies on a rough horizontal plane. The box is pulled along the plane in a straight line at **constant speed** by a light rope. The rope is inclined at an angle $\theta$ to the plane, as shown in Figure 3.

The coefficient of friction between the box and the plane is $\frac{1}{3}$

The box is modelled as a particle.

Given that $\tan\theta = \frac{3}{4}$

(a) find, in terms of $m$ and $g$, the tension in the rope.

**(7)**

The rope is now removed and the box is placed at rest on the plane.
The box is then projected horizontally along the plane with speed $u$.

The box is again modelled as a particle.

When the box has moved a distance $d$ along the plane, the speed of the box is $\frac{1}{2}u$.

(b) Find $d$ in terms of $u$ and $g$.

**(5)**

(a) $R + T\sin\theta = mg$

$R + \frac{3}{5}T = mg$ $\qquad$ $R = mg - \frac{3}{5}T$

Friction $F = \mu R = \frac{1}{3}mg - \frac{1}{5}T$

$T\cos\alpha = F$

$\frac{4}{5}T = \frac{1}{3}mg - \frac{1}{5}T$ $\qquad$ $T = \frac{1}{3}mg$

(b) $R_1 = mg$ $\qquad$ $F_1 = \mu R_1 = \frac{1}{3}mg$

$-F_1 = ma$ $\qquad$ $-\frac{1}{3}\cancel{m}g = \cancel{m}a$

**Question 6 continued**

$a = -\frac{1}{3}g$

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

$\left(\frac{1}{2}u\right)^2 = u^2 + 2\left(-\frac{1}{3}g\right)d$

$\frac{1}{4}u^2 - u^2 = -\frac{2}{3}gd$

$\cancel{-}\frac{3}{4}u^2 = \cancel{-}\frac{2}{3}gd$

$d = \frac{9u^2}{8g}$

**(Total for Question 6 is 12 marks)**

7. [*In this question, the horizontal unit vectors* **i** *and* **j** *are directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]



Two speedboats, $A$ and $B$, are each moving with constant velocity.

- the velocity of $A$ is $40\,\text{km}\,\text{h}^{-1}$ due east
- the velocity of $B$ is $20\,\text{km}\,\text{h}^{-1}$ on a bearing of angle $\alpha$ ($0° < \alpha < 90°$), where $\tan\alpha = \frac{4}{3}$

The boats are modelled as particles.

(a) Find, in terms of **i** and **j**, the velocity of $B$ in $\text{km}\,\text{h}^{-1}$

**(2)**

At noon

- the position vector of $A$ is $20\mathbf{j}$ km
- the position vector of $B$ is $(10\mathbf{i} + 5\mathbf{j})$ km

At time $t$ hours after noon

- the position vector of $A$ is $\mathbf{r}$ km, where $\mathbf{r} = 20\mathbf{j} + 40t\mathbf{i}$
- the position vector of $B$ is $\mathbf{s}$ km

(b) Find an expression for $\mathbf{s}$ in terms of $t$, **i** and **j**.

**(2)**

(c) Show that at time $t$ hours after noon,

$$\overrightarrow{AB} = [(10 - 24t)\mathbf{i} + (12t - 15)\mathbf{j}]\,\text{km}$$

**(2)**

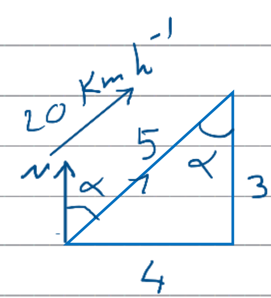
(d) Show that the boats will never collide.

**(3)**

(e) Find the distance between the boats when the bearing of $B$ from $A$ is 225°

**(4)**

$V_A = 40\ Km\ h^{-1}$




(a) $V_B = 20 \sin\alpha\ i + 20 \cos\alpha\ j$

$= 20 \times \frac{4}{5}\ i + 20 \times \frac{3}{5}\ j$

$= 16i + 12j \quad Km\ h^{-1}$

(b) $r_A = r_{A0} + V_A t = 20j + 40t\,i$

**Question 7 continued**

$r_B = r_{B_0} + V_B t = 10i + 5j + (16i + 12j)t$

$S = (10 + 16t)i + (5 + 12t)j$

(c) $\vec{AB} = \vec{B} - \vec{A} = (10+16t)i + (5+12t)j$

$- (20j + 40ti)$

$= (10 - 24t)i + (-15 + 12t)j$

$= (10 - 24t)i + (12t - 15)j$

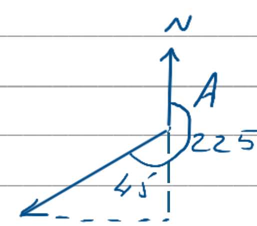
(d) For the boats to collide $\vec{AB} = 0i + 0j$

$10 - 24t = 0$ at $t = \frac{10}{24} = \frac{5}{12}$

$12t - 15 = 0$ at $t = \frac{15}{12} = \frac{5}{4}$

So not the same time.
The boats will not collide

(e) $225 - 180 = 45°$




direction of $\vec{AB} = -i - j$

$\frac{12t - 15}{10 - 24t} = \frac{-1}{-1}$

$12t - 15 = 10 - 24t$

$36t = 25$ $t = \frac{25}{36}$ h

dist. of $AB = \sqrt{\left(10 - 24 \times \frac{25}{36}\right)^2 + \left(12 \times \frac{25}{36} - 15\right)^2} = \frac{20\sqrt{2}}{3}$ km

**(Total for Question 7 is 13 marks)**

**8.**

$\mu = \frac{11}{36}$

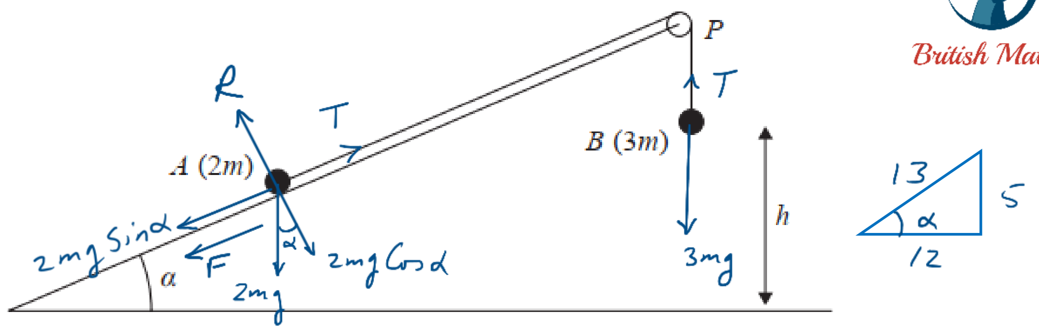



**Figure 4**

One end of a light inextensible string is attached to a particle $A$ of mass $2m$. The other end of the string is attached to a particle $B$ of mass $3m$. Particle $A$ is held at rest on a rough plane which is inclined to horizontal ground at an angle $\alpha$, where $\tan\alpha = \frac{5}{12}$

The string passes over a small smooth pulley $P$ which is fixed at the top of the plane. Particle $B$ hangs vertically below $P$ with the string taut, at a height $h$ above the ground, as shown in Figure 4.

The part of the string between $A$ and $P$ lies along a line of greatest slope of the plane. The two particles, the string and the pulley all lie in the same vertical plane.

The coefficient of friction between $A$ and the plane is $\frac{11}{36}$

The particle $A$ is released from rest and begins to move up the plane.

(a) Show that the frictional force acting on $A$ as it moves up the plane is $\frac{22mg}{39}$ **(3)**

(b) Write down an equation of motion for $B$. **(2)**

(c) Show that the acceleration of $A$ immediately after its release is $\frac{1}{3}g$ **(4)**

In the subsequent motion, $A$ comes to rest before it reaches the pulley.

(d) Find, in terms of $h$, the total distance travelled by $A$ from when it was released from rest to when it first comes to rest again. **(6)**

(a) $R = 2mg\cos\alpha = 2mg \times \frac{12}{13} = \frac{24}{13}mg$

Frictional force $F = \mu R = \frac{11}{36} \times \frac{24}{13}mg = \frac{22mg}{39}$

(b) $3mg - T = 3ma$



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**Question 8 continued**

(c) $T - 2mg \times \frac{5}{13} - \frac{22mg}{39} = 2ma$

$T - \frac{4}{3}mg = 2ma$ — (1)

$3mg - T = 3ma$ — (2)

$\frac{5}{3}\cancel{m}g = 5\cancel{m}a \quad \div m \qquad a = \frac{1}{3}g$

(d) For B $\quad v^2 = u^2 + 2as$

$= 0 + 2 \times \frac{1}{3}gh$

B hits the ground at $v = \sqrt{\frac{2}{3}gh}$

B moves through two parts.

part 1 = h

Part 2 : $T = 0$ in (1) $\quad 2\cancel{m}a = -\frac{4}{3}\cancel{m}g \quad \div m$

$a = -\frac{2}{3}g$

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

$0 = \frac{2}{3}\cancel{g}h + 2\left(\frac{-2}{3}\cancel{g}\right)s' \qquad \div g$

$\frac{4}{\cancel{3}}s' = \frac{2}{\cancel{3}}h$

$s' = \frac{1}{2}h$

Total dist travelled by $A = h + \frac{1}{2}h = \frac{3}{2}h$

(Total for Question 8 is 15 marks)

**TOTAL FOR PAPER IS 75 MARKS**

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