Please check the examination details below before entering your candidate information

Candidate surname StemUp Model Solution | Other names

**Pearson Edexcel**
**International Advanced Level**

Centre Number | Candidate Number

**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 $g = 9.8\,\text{m}\,\text{s}^{-2}$, 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.
- Good luck with your examination.

*Turn over* ▶

P65266A

©2021 Pearson Education Ltd.

1/1/1/1/1/

P 6 5 2 6 6 A 0 1 3 2

Pearson

Leave blank

**1.** A particle $P$ has mass $3m$ and a particle $Q$ has mass $5m$. The particles are moving towards each other in opposite directions along the same straight line on a smooth horizontal surface. The particles collide directly.

Immediately before the collision the speed of $P$ is $ku$, where $k$ is a constant, and the speed of $Q$ is $2u$.

Immediately after the collision the speed of $P$ is $u$ and the speed of $Q$ is $3u$.

The direction of motion of $Q$ is reversed by the collision.

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

**(2)**

(b) Find the two possible values of $k$.

**(5)**

(a) Take the original direction of motion of P as positive.

Impulse on Q: $I = m(v - u) = 5m(3u - (-2u))$

$I = 5m \times 5u$

Magnitude of impulse $= 25mu$

(b) CLM, with P moving on in the same direction (velocity $+u$):

$3m(ku) + 5m(-2u) = 3m(u) + 5m(3u)$

$3mku - 10mu = 3mu + 15mu$

$3k = 28 \Rightarrow k = \frac{28}{3}$

CLM, with the direction of P reversed (velocity $-u$):

$3m(ku) + 5m(-2u) = 3m(-u) + 5m(3u)$

$3mku - 10mu = -3mu + 15mu$

$3k = 22 \Rightarrow k = \frac{22}{3}$

Two possible values: $k = \frac{28}{3}$ or $k = \frac{22}{3}$

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 1 continued**

**Q1**

**(Total 7 marks)**

Leave blank

**2.** A car moves along a straight horizontal road with constant acceleration $a\,\text{m s}^{-2}$ where $a > 0$

The car is modelled as a particle.

At time $t = 0$, the car passes point $A$ and is moving with speed $u\,\text{m s}^{-1}$

In the first three seconds after passing $A$ the car travels 20 m.

In the fourth second after passing $A$ the car travels 10 m.

The speed of the car as it passes point $B$ is $20\,\text{m s}^{-1}$

Find the time taken for the car to travel from $A$ to $B$.

**(8)**

First 3 s: $s = ut + \frac{1}{2}at^2 \Rightarrow 20 = 3u + \frac{1}{2}a(3)^2$

$20 = 3u + \frac{9a}{2}$ (1)

First 4 s: $s = 20 + 10 = 30 \Rightarrow 30 = 4u + \frac{1}{2}a(4)^2$

$30 = 4u + 8a$ (2)

From (1): $u = \frac{20}{3} - \frac{3a}{2}$

Sub into (2): $30 = 4\left(\frac{20}{3} - \frac{3a}{2}\right) + 8a$

$30 = \frac{80}{3} - 6a + 8a \Rightarrow 2a = \frac{10}{3}$

$a = \frac{5}{3}\ m\ s^{-2}$

$u = \frac{20}{3} - \frac{5}{2} = \frac{25}{6}\ m\ s^{-1}$

A to B: $v = u + at$

$20 = \frac{25}{6} + \frac{5}{3}t$

$\frac{5}{3}t = \frac{95}{6} \Rightarrow t = \frac{95}{6} \times \frac{3}{5}$

Time taken from A to B = 9.5 s

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 2 continued**

Leave blank

**Question 2 continued**

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 2 continued**

**Q2**

**(Total 8 marks)**

Leave blank

**3.** [*In this question* **i** *and* **j** *are perpendicular horizontal unit vectors.*]

Three forces, $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, are given by

$$\mathbf{F}_1 = (5\mathbf{i} + 2\mathbf{j})\text{N} \quad \mathbf{F}_2 = (-3\mathbf{i} + \mathbf{j})\text{N} \quad \mathbf{F}_3 = (a\mathbf{i} + b\mathbf{j})\text{N}$$

where $a$ and $b$ are constants.

The forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ act on a particle $P$ of mass 4 kg.

Given that $P$ rests in equilibrium on a smooth horizontal surface under the action of these three forces,

(a) find the size of the angle between the direction of $\mathbf{F}_3$ and the direction of $-\mathbf{j}$.

**(4)**

The force $\mathbf{F}_3$ is now removed and replaced by the force $\mathbf{F}_4$ given by $\mathbf{F}_4 = \lambda(\mathbf{i} + 3\mathbf{j})\text{N}$, where $\lambda$ is a positive constant.

When the three forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_4$ act on $P$, the acceleration of $P$ has magnitude 3.25 $\text{m s}^{-2}$

(b) Find the value of $\lambda$.

**(5)**

(a) Equilibrium: $F_1 + F_2 + F_3 = 0$

$(5i + 2j) + (-3i + j) + (ai + bj) = 0$

$F_3 = -2i - 3j \quad (a = -2, \ b = -3)$

$F_3$ has components 2 in the $-i$ direction and 3 in the $-j$ direction,

so the angle $\theta$ with $-j$ satisfies $\tan\theta = \frac{2}{3}$

$\theta = 33.690...° = 33.7°$

(b) Resultant force $R = (5i + 2j) + (-3i + j) + \lambda(i + 3j)$

$R = (2 + \lambda)i + (3 + 3\lambda)j$

N2L: $R = 4a$, so $|R| = 4 \times 3.25 = 13$

$(2 + \lambda)^2 + (3 + 3\lambda)^2 = 13^2$

$4 + 4\lambda + \lambda^2 + 9 + 18\lambda + 9\lambda^2 = 169$

$10\lambda^2 + 22\lambda - 156 = 0$

$5\lambda^2 + 11\lambda - 78 = 0$

$(\lambda - 3)(5\lambda + 26) = 0$

$\lambda = 3 \quad$ or $\quad \lambda = -\frac{26}{5} \quad$ (reject since $\lambda > 0$)

$\lambda = 3$

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 3 continued**

Leave blank

**Question 3 continued**

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 3 continued**

**Q3**

**(Total 9 marks)**

Leave blank

**4.**

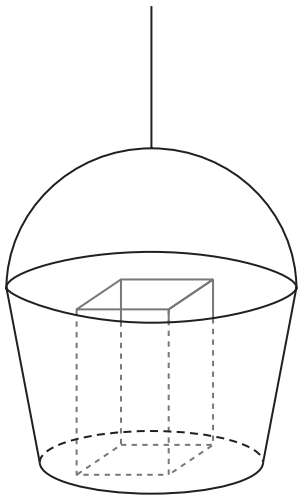


**Figure 1**

Figure 1 shows a large bucket used by a crane on a building site to move materials between the ground and the top of the building. The mass of the bucket is 15 kg.

The bucket is attached to a vertical cable with the bottom of the bucket horizontal. The cable is modelled as light and inextensible.

When the bucket is on the ground, a bag of cement of mass 25 kg is placed in the bucket.

The bucket with the bag of cement moves vertically upwards with constant acceleration $0.2\,\text{m s}^{-2}$. Air resistance is modelled as being negligible.

(a) Find the tension in the cable.

**(3)**

At the top of the building, the bag of cement is removed. A box of tools of mass 12 kg is now placed in the bucket.

Later on the bucket with the box of tools is moving vertically downwards with constant deceleration $0.1\,\text{m s}^{-2}$. Air resistance is again modelled as being negligible.

(b) Find the magnitude of the normal reaction between the bucket and the box of tools.

**(3)**

(a) Bucket and cement together, mass 15 + 25 = 40 kg

N2L (↑): $T - (15g + 25g) = (15 + 25) \times 0.2$

$T - 392 = 8$

Tension = 400 N

(b) Box of tools only, mass 12 kg. Moving down and decelerating,

so its acceleration is 0.1 m $s^{-2}$ upwards.

N2L (↓): $12g - R = 12 \times (-0.1)$

$117.6 - R = -1.2 \Rightarrow R = 118.8$

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 4 continued**

Normal reaction = 119 N

Leave blank

**Question 4 continued**

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 4 continued**

**Q4**

**(Total 6 marks)**

Leave blank

**5.** [*In this question* **i** *and* **j** *are perpendicular horizontal unit vectors.*]

A particle $P$ is moving with constant acceleration. At 2 pm, the velocity of $P$ is $(3\mathbf{i} + 5\mathbf{j})$ km h$^{-1}$ and at 2.30 pm the velocity of $P$ is $(\mathbf{i} + 7\mathbf{j})$ km h$^{-1}$

At time $T$ hours after 2 pm, $P$ is moving in the direction of the vector $(-\mathbf{i} + 2\mathbf{j})$

(a) Find the value of $T$.

**(6)**

Another particle, $Q$, has velocity $\mathbf{v}_Q$ km h$^{-1}$ at time $t$ hours after 2 pm, where

$$\mathbf{v}_Q = (-4 - 2t)\mathbf{i} + (\mu + 3t)\mathbf{j}$$

and $\mu$ is a constant.

Given that there is an instant when the velocity of $P$ is equal to the velocity of $Q$,

(b) find the value of $\mu$.

**(3)**

(a) $a = \frac{v - u}{t} = \frac{(i + 7j) - (3i + 5j)}{0.5}$

$a = \frac{-2i + 2j}{0.5} = (-4i + 4j)$ km h$^{-2}$

$v_P = (3i + 5j) + (-4i + 4j)t$

$v_P = (3 - 4t)i + (5 + 4t)j$

At $t = T$, $v_P$ is parallel to $(-i + 2j)$:

$5 + 4T = -2(3 - 4T)$

$5 + 4T = -6 + 8T$

$4T = 11$

$T = \frac{11}{4}$ $(= 2.75)$

(b) $v_P = v_Q$: $(3 - 4t)i + (5 + 4t)j = (-4 - 2t)i + (\mu + 3t)j$

$i$: $3 - 4t = -4 - 2t \Rightarrow 2t = 7 \Rightarrow t = 3.5$

$j$: $5 + 4t = \mu + 3t \Rightarrow \mu = 5 + t = 5 + 3.5$

$\mu = 8.5$

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 5 continued**

Leave blank

**Question 5 continued**

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 5 continued**

**Q5**

**(Total 9 marks)**

Leave blank

**6.** A fixed rough plane is inclined at an angle $\theta$ to the horizontal, where $\tan\theta = \frac{5}{12}$

A particle of mass 6 kg is projected with speed 5 $\text{m s}^{-1}$ from a point $A$ on the plane, up a line of greatest slope of the plane.

The coefficient of friction between the particle and the plane is $\frac{1}{4}$

(a) Find the magnitude of the frictional force acting on the particle as it moves up the plane.

**(3)**

The particle comes to instantaneous rest at the point $B$.

(b) Find the distance $AB$.

**(5)**

The particle now slides down the plane from $B$. At the instant when the particle passes through the point $C$ on the plane, the speed of the particle is again 5 $\text{m s}^{-1}$

(c) Find the distance $BC$.

**(5)**

(a) $\tan\theta = \frac{5}{12} \Rightarrow \sin\theta = \frac{5}{13}, \cos\theta = \frac{12}{13}$

Resolve perpendicular to the plane:

$R = 6g\cos\theta = 6g \times \frac{12}{13} = \frac{72g}{13}$

$F = \frac{1}{4}R = \frac{18g}{13} = 13.569...$

Frictional force = 13.6 N

(b) Equation of motion parallel to the plane (up the plane +ve):

$-F - 6g\sin\theta = 6a$

$-\frac{18g}{13} - \frac{30g}{13} = 6a \Rightarrow a = -\frac{8g}{13} = -6.0307...$

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

$0 = 5^2 - 2 \times \frac{8g}{13} s$

$s = \frac{25 \times 13}{16g} = \frac{325}{156.8} = 2.0727...$

AB = 2.07 m

(c) Equation of motion parallel to the plane (down the plane +ve):





DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 6 continued**

$6g \sin\theta - F = 6a'$

$\frac{30g}{13} - \frac{18g}{13} = 6a' \Rightarrow a' = \frac{2g}{13} = 1.5076...$

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

$s^2 = 0 + 2 \times \frac{2g}{13} \times s$

$s = \frac{25 \times 13}{4g} = \frac{325}{39.2} = 8.2908...$

$BC = 8.29\ m$

Leave blank

**Question 6 continued**

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 6 continued**

**(Total 13 marks)**

**Q6**

Leave blank

**7.**

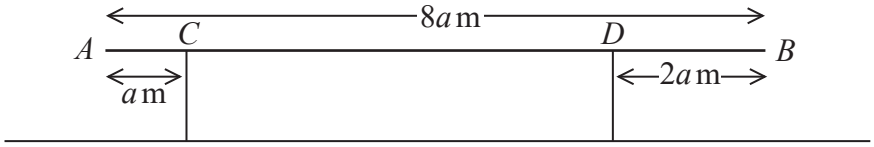



**Figure 2**

A non-uniform beam $AB$, of mass 60 kg and length $8a$ metres, rests in equilibrium in a horizontal position on two vertical supports. One support is at $C$, where $AC = a$ metres and the other support is at $D$, where $DB = 2a$ metres, as shown in Figure 2.

The magnitude of the normal reaction between the beam and the support at $D$ is three times the magnitude of the normal reaction between the beam and the support at $C$.

By modelling the beam as a non-uniform rod whose centre of mass is at a distance $x$ metres from $A$,

(a) find an expression for $x$ in terms of $a$.

**(5)**

A box of mass $M$ kg is placed on the beam at $E$, where $AE = 2a$ metres.

The beam remains in equilibrium in a horizontal position.

The magnitude of the normal reaction between the beam and the support at $C$ is now equal to the magnitude of the normal reaction between the beam and the support at $D$.

By modelling the box as a particle,

(b) find the value of $M$.

**(5)**

(a) Let the reaction at C be R, so the reaction at D is 3R.

Resolve (↑): $R + 3R = 60g \Rightarrow R = 15g$

M(A): $60g \times x = R \times a + 3R \times 6a$

$60g\,x = 15g\,a + 45g \times 6a$

$60x = 15a + 270a = 285a$

$x = \frac{285a}{60} = \frac{19a}{4} \quad (= 4.75a)$

(b) Let each reaction now be S.

Resolve (↑): $S + S = 60g + Mg \Rightarrow 2S = (60 + M)g$

M(A): $S \times a + S \times 6a = 60g \times x + Mg \times 2a$

$7S = 60g \times \frac{19a}{4} + 2Mga \Rightarrow 7S = 285g + 2Mg$

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 7 continued**

$7 \times \frac{(60 + M)g}{2} = 285g + 2Mg$

$420 + 7M = 570 + 4M$

$3M = 150$

$M = 50$

Leave blank

**Question 7 continued**

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 7 continued**

**(Total 10 marks)**

**Q7**

Leave blank

**8.** Two trams, tram $A$ and tram $B$, run on parallel straight horizontal tracks. Initially the two trams are at rest in the depot and level with each other.

At time $t = 0$, tram $A$ starts to move. Tram $A$ moves with constant acceleration $2\,\text{m s}^{-2}$ for 5 seconds and then continues to move along the track at constant speed.

At time $t = 20$ seconds, tram $B$ starts from rest and moves in the same direction as tram $A$. Tram $B$ moves with constant acceleration $3\,\text{m s}^{-2}$ for 4 seconds and then continues to move along the track at constant speed.

The trams are modelled as particles.

(a) Sketch, on the same axes, a speed-time graph for the motion of tram $A$ and a speed-time graph for the motion of tram $B$, from $t = 0$ to the instant when tram $B$ overtakes tram $A$.

**(3)**

At the instant when the two trams are moving with the same speed, tram $A$ is $d$ metres in front of tram $B$.

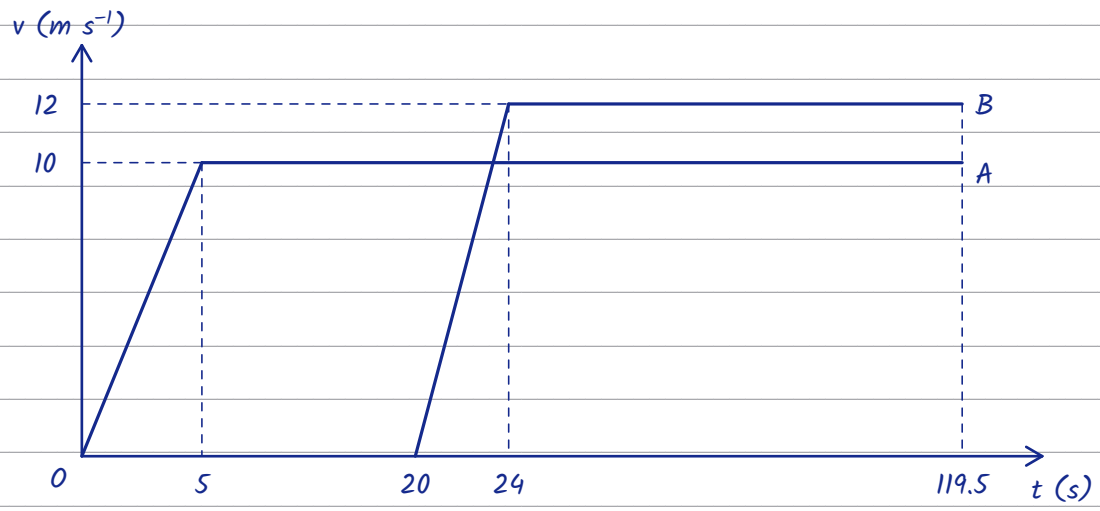
(b) Find the value of $d$.

**(5)**

(c) Find the distance of the trams from the depot at the instant when tram $B$ overtakes tram $A$.

**(5)**

(a)




(b) Same speed ($10\ \text{m s}^{-1}$) when B has accelerated for $\frac{10}{3}$ s:

$t = 20 + \frac{10}{3} = \frac{70}{3}$ s

Distance of A $= \frac{1}{2} \times 5 \times 10 + 10 \times \left(\frac{70}{3} - 5\right) = 25 + \frac{550}{3} = \frac{625}{3}$

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 8 continued**

Distance of B $= \frac{1}{2} \times \frac{10}{3} \times 10 = \frac{50}{3}$

$d = \frac{625}{3} - \frac{50}{3} = \frac{575}{3} = 191.66...$

$d = 192$

(c) At time $t$ s ($t > 24$), distances from the depot are equal:

A: $\frac{1}{2} \times 5 \times 10 + 10(t - 5) = 10t - 25$

B: $\frac{1}{2} \times 4 \times 12 + 12(t - 24) = 12t - 264$

$10t - 25 = 12t - 264$

$2t = 239 \Rightarrow t = 119.5$

Distance $= 10 \times 119.5 - 25 = 1170$

Distance from the depot = 1170 m

Leave blank

**Question 8 continued**

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Leave blank

**Question 8 continued**

Leave blank

**Question 8 continued**

**Q8**

**(Total 13 marks)**

**TOTAL FOR PAPER: 75 MARKS**

**END**

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA