Please check the examination details below before entering your candidate information

Candidate surname StemUp Model Solution | Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Tuesday 6 May 2025

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 ▶

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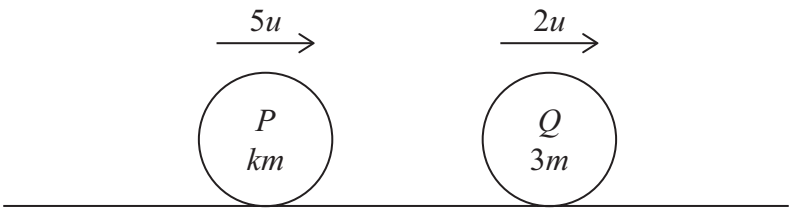


Figure 1

Figure 1 shows two particles, P and Q, moving in the same direction along the same straight line on a smooth horizontal surface.
Particle P has mass km and particle Q has mass $3m$
The particles collide directly.

Immediately before the collision, the speed of P is $5u$ and the speed of Q is $2u$

Immediately after the collision, the speed of P is $2u$ and its direction of motion is unchanged.

Immediately after the collision, the speed of Q is v

The impulse exerted on Q by P in the collision has magnitude $4.5mu$

(a) Find v in terms of u only.

(3)

(b) Find the value of k

(3)

(a) Impulse on Q = change in momentum of Q (direction of motion positive)

$4.5mu = 3mv - 3m \times 2u$

$4.5u = 3v - 6u \Rightarrow 3v = 10.5u$

$v = 3.5u$

(b) Impulse on P = $-4.5mu$ (equal and opposite to the impulse on Q)

$-4.5mu = km \times 2u - km \times 5u$

$-4.5mu = -3kmu$

$k = \frac{4.5}{3} = 1.5$

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Question 1 continued

(Total for Question 1 is 6 marks)

2. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively. Position vectors are given relative to a fixed origin.*]

Two particles, A and B, are moving on a smooth horizontal surface.
Each particle is moving with constant velocity.

At time t seconds, the position vector of A is given by $\mathbf{r}$ metres.

- When $t = 2$, $\mathbf{r} = (-5\mathbf{i} + 16\mathbf{j})$
- When $t = 5$, $\mathbf{r} = (10\mathbf{i} + 4\mathbf{j})$

(a) Find, in terms of **i** and **j**, the velocity of A.

(2)

(b) Find an expression for $\mathbf{r}$ at time t seconds.
Give your answer in the form $p\mathbf{i} + q\mathbf{j}$, where p and q are functions of t

(2)

At time t seconds, the position vector of B is given by $\mathbf{s}$ metres where

$$\mathbf{s} = -5\mathbf{i} + 7\mathbf{j} + t(2\mathbf{i} - 3\mathbf{j})$$

(c) Find, to the nearest degree, the bearing of B from A when $t = 5$

(3)

(a) From $t = 2$ to $t = 5$ is 3 seconds, constant velocity:

$$v = \frac{(10i + 4j) - (-5i + 16j)}{3} = \frac{15i - 12j}{3}$$

Velocity of A $= (5i - 4j)$ m s^{-1}

(b) $r = (-5i + 16j) + (t - 2)(5i - 4j)$

$r = -5i + 16j - 10i + 8j + t(5i - 4j)$

$r = (5t - 15)i + (24 - 4t)j$

(c) At $t = 5$: $r = 10i + 4j$

$s = -5i + 7j + 5(2i - 3j) = 5i - 8j$

$AB = s - r = (5i - 8j) - (10i + 4j) = -5i - 12j$

B is 5 west and 12 south of A.

$\tan\theta = \frac{5}{12} \Rightarrow \theta = 22.619...°$ (west of south)

Bearing $= 180° + 22.619...° = 202.619...°$

Bearing of B from A $= 203°$

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Question 2 continued

Question 2 continued

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Question 2 continued

(Total for Question 2 is 7 marks)

3. A particle is projected vertically upwards with speed $U\,\text{m s}^{-1}$ from a point A.

The point A is 12 m vertically above the point B.

Point B is on horizontal ground.

The particle moves freely under gravity until it hits the ground at B.

The time taken for the particle to travel from A to B is 4 seconds.

(a) Find the value of U.

(3)

(b) Find the speed of the particle as it hits the ground at B.

(3)

(c) Sketch a speed-time graph for the motion of the particle from the instant it leaves A to the instant it reaches B. (No further calculations are required.)

(2)

(a) Take upwards as positive. A to B: $s = -12$, $t = 4$, $a = -9.8$

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

$-12 = 4U - \frac{1}{2} \times 9.8 \times 4^2$

$-12 = 4U - 78.4 \Rightarrow 4U = 66.4$

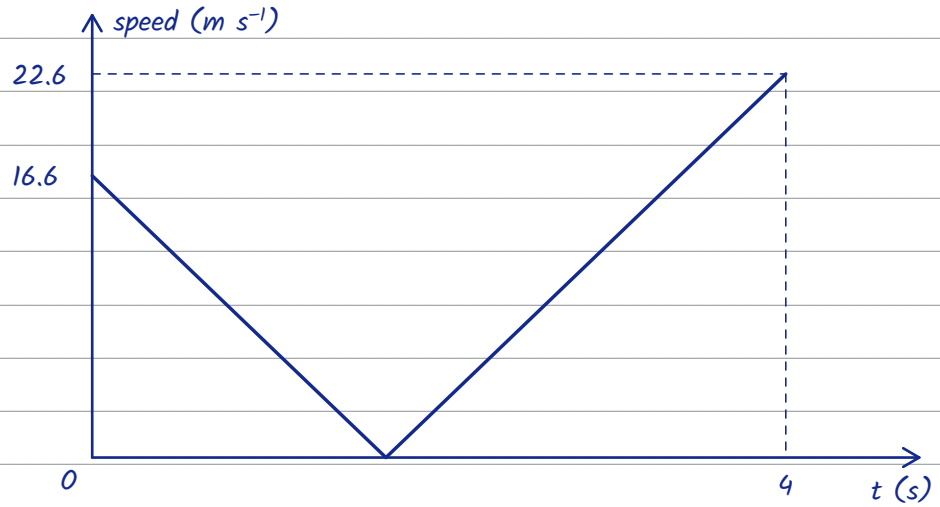
$U = 16.6$

(b) $v = u + at$

$v = 16.6 - 9.8 \times 4 = 16.6 - 39.2 = -22.6$

Speed as it hits the ground = 22.6 m s^{-1}

(c)



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Question 3 continued

Question 3 continued

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Question 3 continued

(Total for Question 3 is 8 marks)

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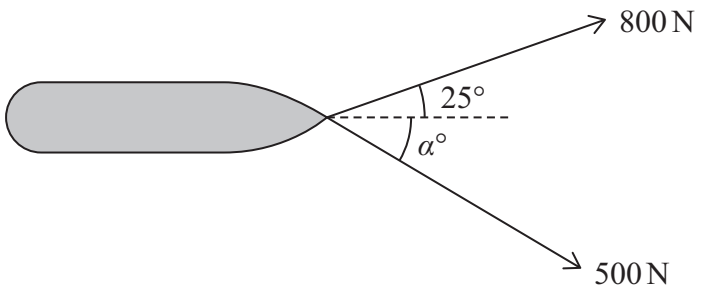


Figure 2

Two ropes are attached to a point on the front of a barge.
The barge is being pulled horizontally in a straight line along the centre of a long straight canal.

One rope makes an angle of 25° with the direction of motion of the barge and has a tension of 800 N.
The other rope makes an angle of $\alpha°$ with the direction of motion of the barge and has a tension of 500 N, as shown in Figure 2.

Both ropes are horizontal.

(a) Find the value of α

(3)

The mass of the barge is 15 tonnes and the resistance to the motion of the barge is a constant force of magnitude 750 N.

(b) Find the acceleration of the barge.

(4)

(a) The barge moves along the canal, so there is no resultant force perpendicular to the direction of motion. Resolve perpendicular:

$800 \sin 25° = 500 \sin \alpha°$

$\sin \alpha° = \frac{800 \sin 25°}{500} = 0.67618...$

$\alpha = 42.546... \Rightarrow \alpha = 42.5$

(b) N2L parallel to the direction of motion, $m = 15\,000$ kg:

$800 \cos 25° + 500 \cos 42.546...° - 750 = 15\,000a$

$725.046... + 368.364... - 750 = 15\,000a$

$343.410... = 15\,000a$

$a = 0.022894...$

Acceleration = 0.0229 m s^{-2}

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Question 4 continued

Question 4 continued

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Question 4 continued

(Total for Question 4 is 7 marks)

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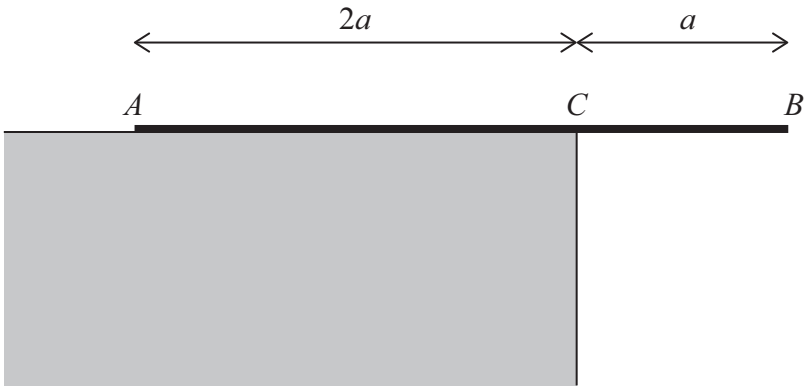


Figure 3

A non-uniform rod AB of length $3a$ rests in equilibrium on a horizontal ledge and overhangs the edge of the ledge at C.
The point C is such that $AC = 2a$ and $CB = a$, as shown in Figure 3.

The rod has weight W.

The distance of the centre of mass of the rod from A is d.

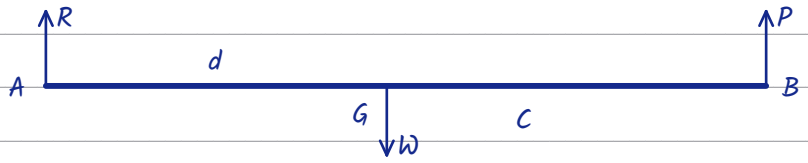
The rod is perpendicular to the edge of the ledge.

When a force of magnitude P, **acting vertically upwards**, is applied to the rod at B, the rod is on the point of tilting about A.

When the force applied at B is replaced by a force of magnitude $1.25P$, **acting vertically downwards** at B, the rod is on the point of tilting about C.

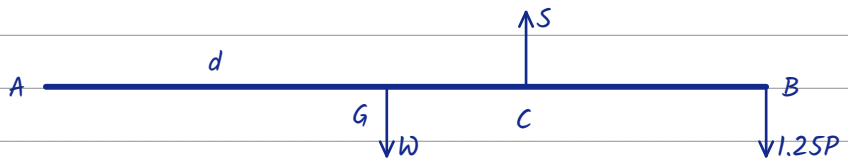
Find d in terms of a.

(6)



Tilting about A: the reaction is at A only. Taking moments about A:

$W \times d = P \times 3a \quad \Rightarrow \quad 3aP = dW$



Tilting about C: the reaction is at C only. Taking moments about C:

$W(2a - d) = 1.25P \times a \quad \Rightarrow \quad 1.25Pa = W(2a - d)$

From the first equation: $P = \frac{dW}{3a}$

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Question 5 continued

$1.25a \times \frac{dW}{3a} = W(2a - d)$

$\frac{1.25d}{3} = 2a - d \Rightarrow \frac{4.25d}{3} = 2a$

$d = \frac{6a}{4.25} = \frac{24a}{17}$

$d = \frac{24a}{17}$

Question 5 continued

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Question 5 continued

(Total for Question 5 is 6 marks)

6.

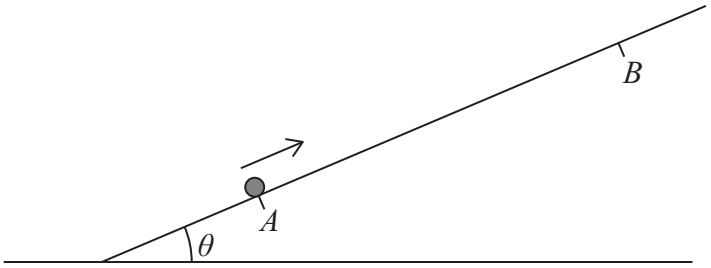


Figure 4

Figure 4 shows a rough plane inclined at an angle θ to the horizontal, where $\tan\theta = \frac{3}{4}$

The points A and B lie on a line of greatest slope of the plane, with B above A.

A package P of mass m is projected up the plane from A towards B.

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

The package P is modelled as a particle.

(a) Show that the **deceleration** of P, as it moves from A to B, is $\frac{4}{5}g$

(6)

The package P comes to rest at B.

Given that P is projected from A with speed $U\,\text{m s}^{-1}$ and that $AB = 1.5\,\text{m}$,

(b) find the value of U.

(2)

On reaching B, P is held at rest there by a force of magnitude X newtons acting up the plane in the direction AB.

Given that the mass of P is 2 kg,

(c) find the smallest possible value of X.

(3)

(a) $\tan\theta = \frac{3}{4} \Rightarrow \sin\theta = \frac{3}{5}, \cos\theta = \frac{4}{5}$

Resolve perpendicular to the plane: $R = mg\cos\theta = \frac{4}{5}mg$

Friction (limiting, P is sliding): $F = \frac{1}{4}R = \frac{1}{4} \times \frac{4}{5}mg = \frac{1}{5}mg$

Moving up the plane, friction acts down the plane. N2L down the plane:

$F + mg\sin\theta = ma$

$\frac{1}{5}mg + \frac{3}{5}mg = ma$

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Question 6 continued

$a = \frac{4}{5}g$

So the deceleration of P is $\frac{4}{5}g$ as required.

(b) $v^2 = u^2 + 2as$ with $v = 0$, $a = -\frac{4}{5}g$, $s = 1.5$

$0 = U^2 - 2 \times \frac{4}{5} \times 9.8 \times 1.5$

$U^2 = 23.52 \Rightarrow U = 4.8497...$

$U = 4.85$

(c) Smallest X: P is on the point of slipping down the plane,
so friction acts up the plane and $F = \mu R$. $m = 2$
Resolve parallel to the plane: $X + F = 2g \sin\theta$

$X + \frac{1}{4} \times 2g \cos\theta = 2g \sin\theta$

$X + \frac{1}{4} \times 2 \times 9.8 \times \frac{4}{5} = 2 \times 9.8 \times \frac{3}{5}$

$X + 3.92 = 11.76$

$X = 7.84$

Question 6 continued

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Question 6 continued

(Total for Question 6 is 11 marks)

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

Two boats, A and B, are each moving with constant acceleration.

At time t hours after noon, boat A has velocity $\mathbf{v}_A$ km h^{-1}, where

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

(a) Find the magnitude of the acceleration of A.

(2)

When $t = 2$, the velocity of B is $(4\mathbf{i} + \mathbf{j})$ km h^{-1}

When $t = 5$, the velocity of B is $(\mathbf{i} - 5\mathbf{j})$ km h^{-1}

(b) Find the acceleration of B, giving your answer in terms of **i** and **j**.

(2)

(c) Find the velocity of B at time $t = 0$, giving your answer in terms of **i** and **j**.

(2)

At time T_1 hours after noon, both boats are moving with the same speed.

(d) Find the exact value of T_1

(4)

At time T_2 hours after noon, both boats are moving in the same direction.

(e) Show that $3T_2^2 + pT_2 + q = 0$, where p and q are integers to be found.

(3)

(a) $v_A = 2i + 3j + (i - 4j)t$, so $a_A = (i - 4j)$ km h^{-2}

$|a_A| = \sqrt{(1^2 + (-4)^2)} = \sqrt{17} = 4.1231...$

Magnitude of acceleration $= \sqrt{17}$ km h^{-2} $(= 4.12)$

(b) $a_B = \dfrac{(i - 5j) - (4i + j)}{5 - 2} = \dfrac{-3i - 6j}{3}$

$a_B = (-i - 2j)$ km h^{-2}

(c) $v = u + at$ from $t = 0$ to $t = 2$:

$4i + j = u + 2(-i - 2j)$

$u = 4i + j + 2i + 4j$

Velocity of B at $t = 0$: $(6i + 5j)$ km h^{-1}

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Question 7 continued

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

$\mathbf{v}_B = (6\mathbf{i} + 5\mathbf{j}) + t(-\mathbf{i} - 2\mathbf{j}) = (6 - t)\mathbf{i} + (5 - 2t)\mathbf{j}$

Same speed at $t = T_1$:

$(6 - T_1)^2 + (5 - 2T_1)^2 = (2 + T_1)^2 + (3 - 4T_1)^2$

$36 - 12T_1 + T_1^2 + 25 - 20T_1 + 4T_1^2 = 4 + 4T_1 + T_1^2 + 9 - 24T_1 + 16T_1^2$

$61 - 32T_1 + 5T_1^2 = 13 - 20T_1 + 17T_1^2$

$12T_1^2 + 12T_1 - 48 = 0 \quad \Rightarrow \quad T_1^2 + T_1 - 4 = 0$

$$T_1 = \frac{-1 \pm \sqrt{(1 + 16)}}{2} = \frac{-1 \pm \sqrt{17}}{2}$$

$T_1 > 0$, so $T_1 = \dfrac{-1 + \sqrt{17}}{2}$

(e) Same direction at $t = T_2$: the velocities are parallel, so

$$\frac{5 - 2T_2}{6 - T_2} = \frac{3 - 4T_2}{2 + T_2}$$

$(5 - 2T_2)(2 + T_2) = (3 - 4T_2)(6 - T_2)$

$10 + 5T_2 - 4T_2 - 2T_2^2 = 18 - 3T_2 - 24T_2 + 4T_2^2$

$10 + T_2 - 2T_2^2 = 18 - 27T_2 + 4T_2^2$

$0 = 6T_2^2 - 28T_2 + 8$

$3T_2^2 - 14T_2 + 4 = 0$, so $p = -14$, $q = 4$

Question 7 continued

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Question 7 continued

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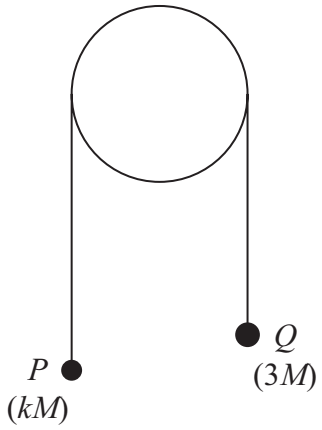


Figure 5

Two small balls, P and Q, have masses kM and $3M$ respectively, where $k < 3$

The balls are attached to the ends of a light inextensible string that passes over a fixed light smooth pulley.

The system is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 5.

The system is released from rest and, in the subsequent motion, P moves with an acceleration of magnitude $\frac{1}{5}g$

The balls are modelled as particles.

(a) Write down an equation of motion for P.

(2)

(b) Find the value of k.

(3)

Given that $M = 0.5\,\text{kg}$,

(c) find the magnitude of the force exerted on the pulley by the string while Q is moving downwards.

(3)

At the instant when the system is released, P is more than 2.5 m from the pulley and Q is 2.5 m above horizontal ground.
After hitting the ground, Q rebounds with a speed of $0.4\,\text{m s}^{-1}$

(d) Find the magnitude of the impulse received by Q when it hits the ground.

(5)

In the subsequent motion, P does not hit the pulley.

(e) Find the total time from when the balls are released until P first comes to rest.

(4)

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Question 8 continued

(a) P moves upwards with acceleration $g/5$ (P is lighter as $k < 3$).

N2L for P (↑): $T - kMg = kM \times \frac{1}{5} g$

(b) N2L for Q (↓): $3Mg - T = 3M \times \frac{1}{5} g \Rightarrow T = \frac{12}{5} Mg$

Add the two equations: $3Mg - kMg = \frac{1}{5}(kM + 3M)g$

$15 - 5k = k + 3 \Rightarrow 6k = 12$

$k = 2$

(c) $M = 0.5$: $T = \frac{12}{5} \times 0.5 \times 9.8 = 11.76$ N

The two vertical parts of the string both pull down on the pulley:

Force on pulley $= 2T = 2 \times 11.76 = 23.52$

Magnitude of force = 23.5 N

(d) Speed of Q as it hits the ground: $u = 0$, $a = \frac{1}{5} g$, $s = 2.5$

$v^2 = 0 + 2 \times \frac{1}{5} \times 9.8 \times 2.5 = 9.8$

$v = \sqrt{9.8} = 3.13049...$ m s^{-1} (downwards)

Impulse = change in momentum of Q (mass $3M = 1.5$ kg)

$I = 1.5(0.4 - (-3.13049...)) = 1.5 \times 3.53049...$

$I = 5.2957...$

Magnitude of impulse = 5.30 N s

(e) Before Q hits the ground: $v = u + at \Rightarrow 3.13049... = 0 + \frac{1}{5} \times 9.8 \times t_1$

$t_1 = 1.5971...$ s

After Q hits the ground the string goes slack, so P moves

freely under gravity with initial speed 3.13049... m s^{-1} upwards:

$0 = 3.13049... - 9.8t_2 \Rightarrow t_2 = 0.31943...$ s

Total time $= t_1 + t_2 = 1.5971... + 0.31943... = 1.9166...$

Total time = 1.92 s

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Question 8 continued

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Question 8 continued

Question 8 continued

(Total for Question 8 is 17 marks)

TOTAL FOR PAPER IS 75 MARKS

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