Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number

Candidate Number

Pearson Edexcel Level 3 GCE

Paper reference **9MA0/32**

Mathematics

Advanced
PAPER 32: Mechanics

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

Total Marks

Candidates may use any calculator allowed 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.
- Unless otherwise indicated, whenever a 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.
- The total mark for this part of the examination is 50. There are 5 questions.
- 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

1. [*In this question, position vectors are given relative to a fixed origin.*]

At time t seconds, where $t > 0$, a particle P has velocity $\mathbf{v}\,\mathrm{m\,s^{-1}}$ where

$$\mathbf{v} = 3t^2\mathbf{i} - 6t^{\frac{1}{2}}\mathbf{j}$$

(a) Find the speed of P at time $t = 2$ seconds.

(2)

(b) Find an expression, in terms of t, $\mathbf{i}$ and $\mathbf{j}$, for the acceleration of P at time t seconds, where $t > 0$

(2)

At time $t = 4$ seconds, the position vector of P is $(\mathbf{i} - 4\mathbf{j})$ m.

(c) Find the position vector of P at time $t = 1$ second.

(4)

a) sub $t=2$ into $\underline{v}$: $\underline{v} = 3(2)^2\underline{i} - 6(2)^{1/2}\underline{j}$

$\underline{v} = 12\underline{i} - 6\sqrt{2}\underline{j}$

1 1

speed $= \sqrt{12^2 + (-6\sqrt{2})^2} = 6\sqrt{6} = 15\ \mathrm{ms^{-1}}$ (2sf)

1 1

b) $\underline{a} = \dfrac{d\underline{v}}{dt} = 6t\underline{i} - 3t^{-1/2}\underline{j}$

1

c) $\underline{r} = \int \underline{v}\,dt = t^3\underline{i} - 4t^{3/2}\underline{j} + \underline{c}$ 1

sub in $t=4$, $\underline{r} = \underline{i} - 4\underline{j}$

$\underline{i} - 4\underline{j} = (4)^3\underline{i} - 4(4)^{3/2}\underline{j} + \underline{c}$ 1

$\underline{i} - 4\underline{j} = 64\underline{i} - 32\underline{j} + \underline{c}$

$\underline{c} = -63\underline{i} + 28\underline{j}$

$\therefore\ \underline{r} = (t^3 - 63)\underline{i} + (-4t^{3/2} + 28)\underline{j}$

sub in $t=1$

$\underline{r} = -62\underline{i} + 24\underline{j}$ 1

Question 1 continued

(Total for Question 1 is 8 marks)

2.

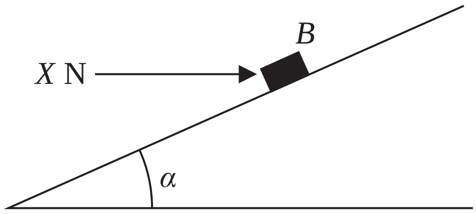


Figure 1

A rough plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$

A small block B of mass 5 kg is held in equilibrium on the plane by a horizontal force of magnitude X newtons, as shown in Figure 1.

The force acts in a vertical plane which contains a line of greatest slope of the inclined plane.

The block B is modelled as a particle.

The magnitude of the normal reaction of the plane on B is 68.6 N.

Using the model,

(a) (i) find the magnitude of the frictional force acting on B,

(3)

(ii) state the direction of the frictional force acting on B.

(1)

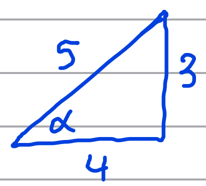
The horizontal force of magnitude X newtons is now removed and B moves down the plane.

Given that the coefficient of friction between B and the plane is 0.5

(b) find the acceleration of B down the plane.

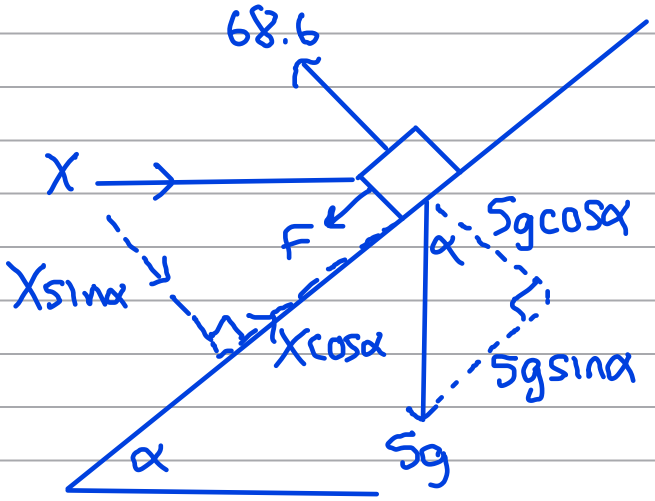
(6)

$\tan\alpha = 3/4$

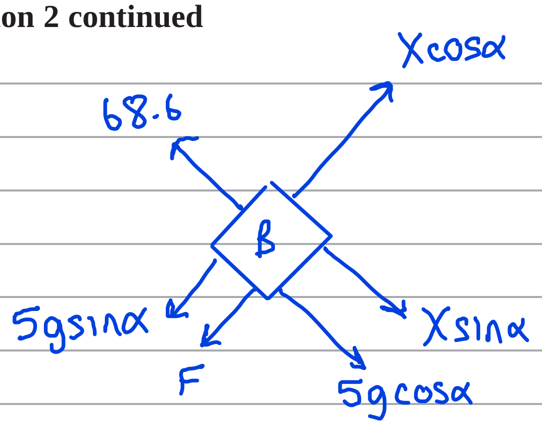


$\sin\alpha = 3/5$

$\cos\alpha = 4/5$



Question 2 continued



"R( )" means resolve

a)

(i) $R(\nwarrow)$: $68.6 = X\sin\alpha + 5g\cos\alpha$ (1)

$$\Rightarrow X = \frac{68.6 - 5g\cos\alpha}{\sin\alpha} = 49\text{ N}$$ (1)

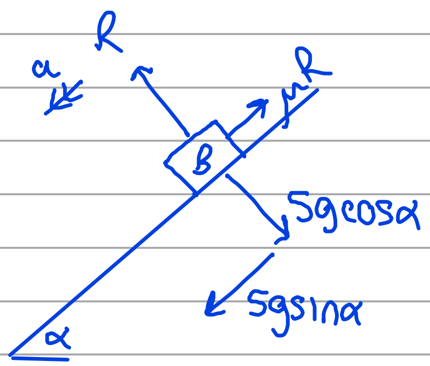
$R(\nearrow)$: $X\cos\alpha = 5g\sin\alpha + F$

$\Rightarrow F = X\cos\alpha - 5g\sin\alpha = 9.8\text{ N}$ (1)

(ii) Down the plane (1)
Friction opposes motion; without friction the box would slide up the plane, so friction must act down to counteract this.

b) $\mu = 0.5$

$F = \mu R$
$= 0.5R$ (1)



- R changes as X is removed
- friction now acts up the plane

$R(\nwarrow)$: $R = 5g\cos\alpha = 39.2$ (1) (1)

$R(\swarrow)$: $5g\sin\alpha - \mu R = 5a$ (1) (1)

$$\therefore a = \frac{5g\sin\alpha - \mu R}{5}$$

$a = 1.96\text{ ms}^{-2}$ (3sf) (1)

Question 2 continued

Question 2 continued

(Total for Question 2 is 10 marks)

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

A particle P of mass 4 kg is at rest at the point A on a smooth horizontal plane.

At time $t = 0$, two forces, $\mathbf{F}_1 = (4\mathbf{i} - \mathbf{j})\,\text{N}$ and $\mathbf{F}_2 = (\lambda\mathbf{i} + \mu\mathbf{j})\,\text{N}$, where λ and μ are constants, are applied to P

Given that P moves in the direction of the vector $(3\mathbf{i} + \mathbf{j})$

(a) show that

$$\lambda - 3\mu + 7 = 0$$

(4)

At time $t = 4$ seconds, P passes through the point B.

Given that $\lambda = 2$

(b) find the length of AB.

(5)

a) $F_1 + F_2 = k\begin{pmatrix}3\\1\end{pmatrix}$

$\begin{pmatrix}4\\-1\end{pmatrix} + \begin{pmatrix}\lambda\\\mu\end{pmatrix} = \begin{pmatrix}3k\\k\end{pmatrix}$ 1

$4 + \lambda = 3k$ ①
$-1 + \mu = k$ ②

sub ② into ①: $4 + \lambda = 3(-1 + \mu)$ 1
$4 + \lambda = -3 + 3\mu$ 1
$\Rightarrow \lambda - 3\mu + 7 = 0$ 1

b) given $\lambda = 2$, so find μ:

$2 - 3\mu + 7 = 0$
$\mu = 3$

$\therefore$ resultant force is

$\begin{pmatrix}4\\-1\end{pmatrix} + \begin{pmatrix}2\\3\end{pmatrix} = \begin{pmatrix}6\\2\end{pmatrix}$ 1

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Question 3 continued

$\underline{F} = m\underline{a}$

$\begin{pmatrix} 6 \\ 2 \end{pmatrix} = 4\underline{a}$ ①

$\underline{a} = \begin{pmatrix} 1.5 \\ 0.5 \end{pmatrix}$

motion AB:

$\underline{s} = \underline{s}$

$\underline{u} = 0$

$\underline{v} =$

$\underline{a} = 1.5\underline{i} + 0.5\underline{j}$

$\underline{t} = 4$

$\underline{s} = \underline{u}t + \frac{1}{2}\underline{a}t^2$

$= 0 + \frac{4^2}{2}\begin{pmatrix} 1.5 \\ 0.5 \end{pmatrix}$ ①

$\underline{s} = \begin{pmatrix} 12 \\ 4 \end{pmatrix}$

u=0 as starts from rest

distance $= |\underline{s}| = \sqrt{12^2+4^2}$ ① $= 4\sqrt{10}$ ①

Question 3 continued

Question 3 continued

(Total for Question 3 is 9 marks)

4.

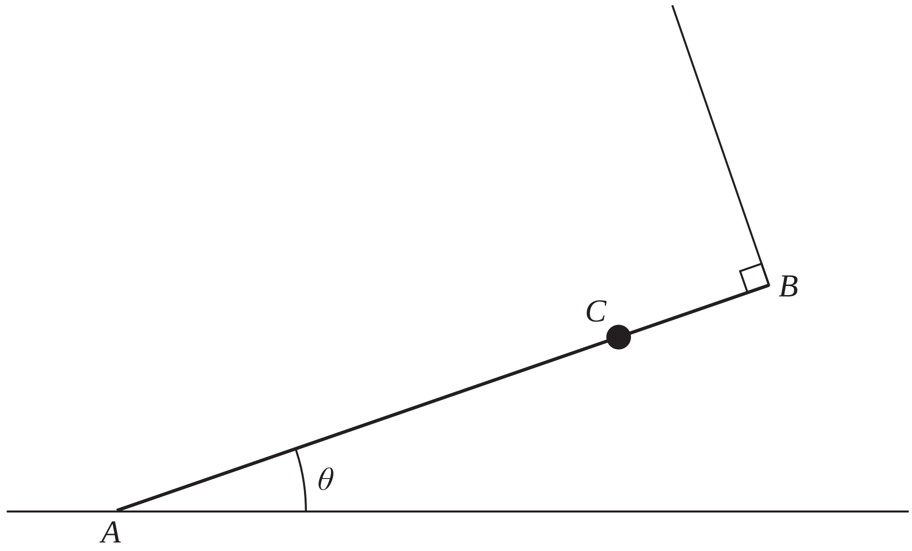

Figure 2

A uniform rod AB has mass M and length $2a$

A particle of mass $2M$ is attached to the rod at the point C, where $AC = 1.5a$

The rod rests with its end A on rough horizontal ground.

The rod is held in equilibrium at an angle θ to the ground by a light string that is attached to the end B of the rod.

The string is perpendicular to the rod, as shown in Figure 2.

(a) Explain why the frictional force acting on the rod at A acts horizontally to the right on the diagram.

(1)

The tension in the string is T

(b) Show that $T = 2Mg\cos\theta$

(3)

Given that $\cos\theta = \dfrac{3}{5}$

(c) show that the magnitude of the vertical force exerted by the ground on the rod at A is $\dfrac{57Mg}{25}$

(3)

The coefficient of friction between the rod and the ground is μ

Given that the rod is in limiting equilibrium,

(d) show that $\mu = \dfrac{8}{19}$

(4)

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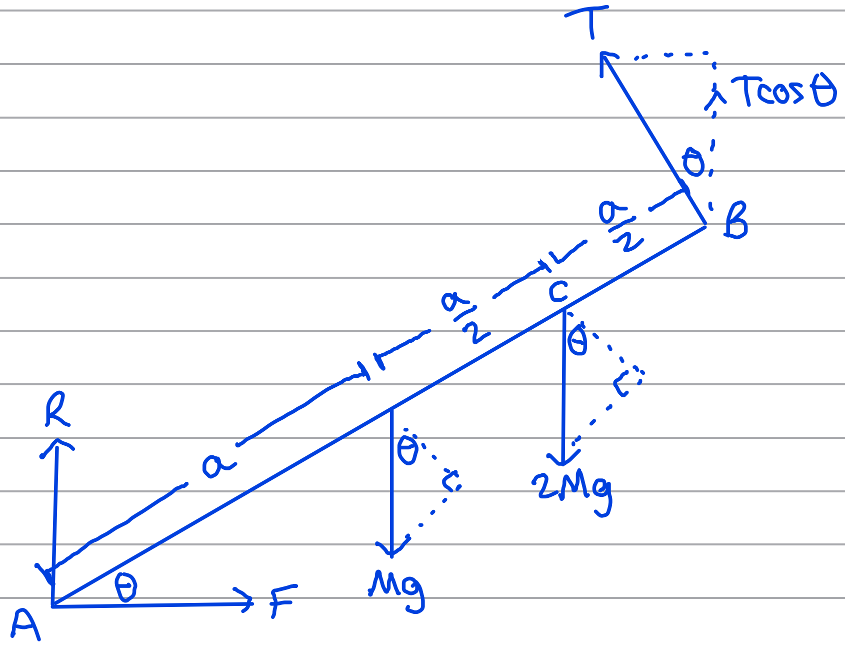
Question 4 continued



a) The only other force that has a horizontal component is T, which acts to the left. For the rod to be in equilibrium, friction must act to the right. ①

b) $M(A): Mg \times a\cos\theta + 2Mg \times \frac{3a}{2}\cos\theta = T \times 2a$ ① ①

$4aMg\cos\theta = 2aT$

$T = \frac{4aMg\cos\theta}{2a} = 2Mg\cos\theta$ ①

c) $\cos\theta = \frac{3}{5}$ $\therefore T = 2Mg\left(\frac{3}{5}\right) = \frac{6Mg}{5}$

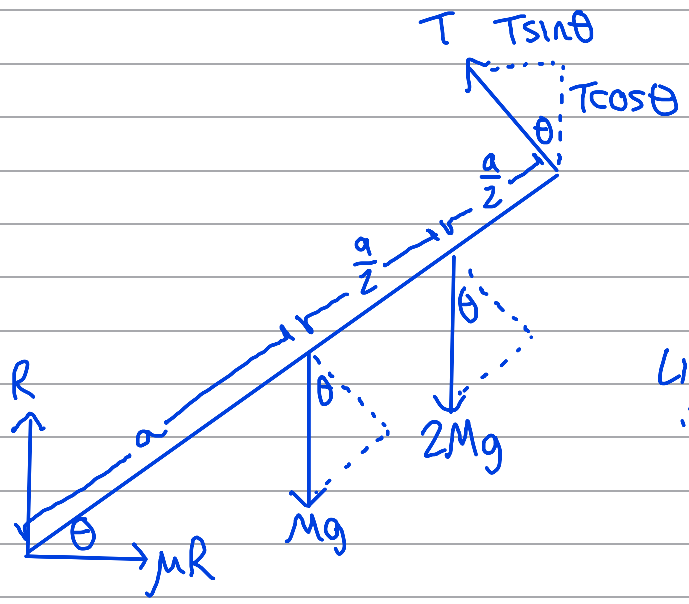
① $R(\uparrow): R + T\cos\theta = Mg + 2Mg$ ①

$R = 3Mg - \frac{6}{5}Mg\left(\frac{3}{5}\right)$

$R = \frac{57Mg}{25}$ ①

Question 4 continued

d)



Limiting equilibrium
$\therefore F = \mu R$ ①

①
$R(\rightarrow)$: $\mu R = T\sin\theta$ ①

sub in $R = \frac{57Mg}{25}$, $T = \frac{6Mg}{5}$, $\sin\theta = \frac{4}{5}$

$$\mu = \frac{T\sin\theta}{R} = \frac{\frac{6}{5}Mg \times \frac{4}{5}}{\frac{57Mg}{25}} = \frac{8}{19}$$ ①

P 7 2 1 3 1 A 0 1 4 2 0

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Question 4 continued

(Total for Question 4 is 11 marks)

5.

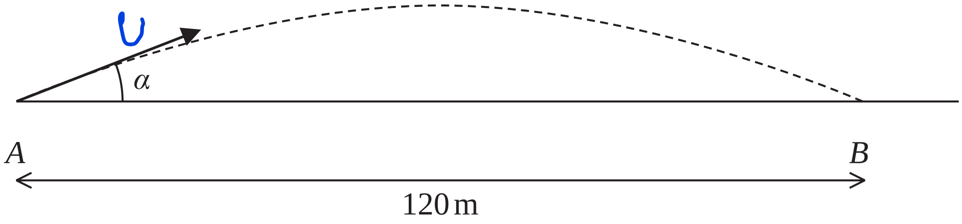


Figure 3

A golf ball is at rest at the point A on horizontal ground.

The ball is hit and initially moves at an angle α to the ground.

The ball first hits the ground at the point B, where $AB = 120\,\text{m}$, as shown in Figure 3.

The motion of the ball is modelled as that of a particle, moving freely under gravity, whose initial speed is $U\,\text{m}\,\text{s}^{-1}$

Using this model,

(a) show that $U^2 \sin\alpha \cos\alpha = 588$

(6)

The ball reaches a maximum height of $10\,\text{m}$ above the ground.

(b) Show that $U^2 = 1960$

(4)

In a refinement to the model, the effect of air resistance is included.

The motion of the ball, from A to B, is now modelled as that of a particle whose initial speed is $V\,\text{m}\,\text{s}^{-1}$

This refined model is used to calculate a value for V

(c) State which is greater, U or V, giving a reason for your answer.

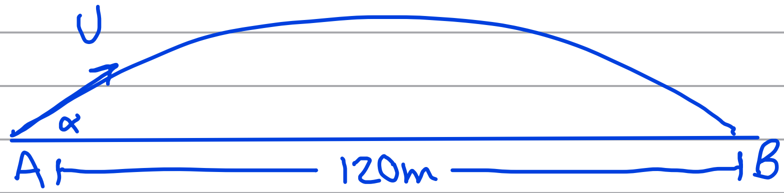
(1)

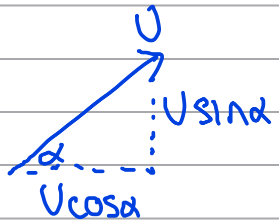
(d) State one further refinement to the model that would make the model more realistic.

(1)

Question 5 continued

a)





Motion AB:

Method: eliminate t to form an equation in terms of only U and α.

Horizontal $(\rightarrow +)$

$s = 120$ (1)

$u = U\cos\alpha$

$v =$

$a = 0$

$t = t$

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

$120 = Ut\cos\alpha$ (1)

$\Rightarrow t = \dfrac{120}{U\cos\alpha}$

Vertical $(\uparrow +)$

$s = 0$ (1)

$u = U\sin\alpha$

$v =$

$a = -9$

$t = \dfrac{120}{U\cos\alpha}$ (1)

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

$$0 = \frac{120U\sin\alpha}{U\cos\alpha} - \frac{9}{2}\left(\frac{120}{U\cos\alpha}\right)^2 \quad (1)$$

$$0 = \frac{120\sin\alpha}{\cos\alpha} - 4.9\left(\frac{14{,}400}{U^2\cos^2\alpha}\right)$$

$$0 = 120U^2\sin\alpha\cos\alpha - 70560$$

$$120U^2\sin\alpha\cos\alpha = 70560$$

$$U^2\sin\alpha\cos\alpha = 588 \quad (1)$$

Question 5 continued

b)

Motion AC:

Vertical: $(\uparrow +)$ 1

$s = 10$ $\qquad v^2 = u^2 + 2as$

$u = U\sin\alpha$

$v = 0$ $\qquad 0 = U^2\sin^2\alpha - 20g$ 1

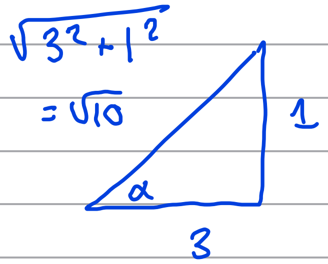
$a = -g$

$t =$ $\qquad U^2\sin^2\alpha = 196$ (1)

from (a), $U^2\sin\alpha\cos\alpha = 588$ (2)

(1) ÷ (2): $\dfrac{U^2\sin^2\alpha}{U^2\sin\alpha\cos\alpha} = \dfrac{196}{588}$ 1

$\tan\alpha = \dfrac{1}{3}$



$\therefore \sin\alpha = \dfrac{1}{\sqrt{10}} \Rightarrow \sin^2\alpha = \dfrac{1}{10}$

we dont need to worry about the sign of $\sin\alpha$; α is acute so $\sin\alpha$, $\cos\alpha$, and $\tan\alpha$ are all positive.

(1): $U^2 = \dfrac{196}{1/10} = 1960$ 1

c) V must be greater as air resistance has to be overcome 1

d) consider the dimensions of the ball. 1

P 7 2 1 3 1 A 0 1 8 2 0

Question 5 continued

Question 5 continued

(Total for Question 5 is 12 marks)

TOTAL FOR MECHANICS IS 50 MARKS