Please check the examination details below before entering your candidate information

Candidate surname StemUp Model Solution | Other names

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Friday 16 May 2025

Afternoon

Paper reference **8FM0/26**

Further Mathematics

Advanced Subsidiary
Further Mathematics options
26: Further Mechanics 2
(Part of option J)

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 $g = 9.8$ 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.
- The total mark for this part of the examination is 40. There are 4 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 ▶

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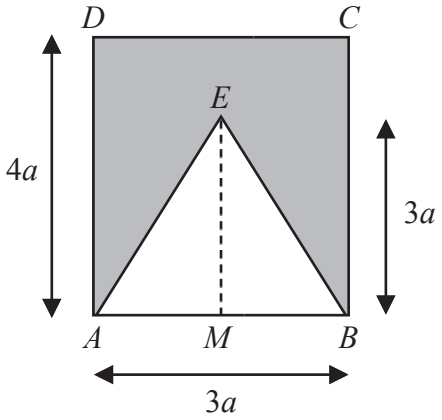


Figure 1

A uniform plane lamina, shown shaded in Figure 1, is formed by removing an isosceles triangle ABE from a rectangle $ABCD$.

- The midpoint of AB is M
- $AB = 3a$
- $AD = 4a$
- $EM = 3a$
- $AE = EB$

(a) Show that the distance of the centre of mass of the lamina from AB is $\frac{13a}{5}$

(5)

The lamina is suspended by a string attached to the lamina at D.

The lamina hangs freely in equilibrium.

(b) Find, to the nearest degree, the angle between AD and the vertical.

(3)

(a) Shape: ABCD ABE lamina

Area: $12a^2$ $\frac{9a^2}{2}$ $\frac{15a^2}{2}$

Distance from AB: $2a$ a $\bar{x}$

Moments about AB:

$12a^2 \times 2a - \frac{9a^2}{2} \times a = \frac{15a^2}{2} \bar{x}$

$24a^3 - \frac{9a^3}{2} = \frac{39a^3}{2} = \frac{15a^2}{2} \bar{x}$

$\bar{x} = \frac{39a}{15} = \frac{13a}{5}$ as required

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Question 1 continued

(b) By symmetry, the centre of mass G is 1.5a from AD.

Distance of G from DC = $4a - \frac{13a}{5} = \frac{7a}{5}$

When hanging from D, DG is vertical, so the angle α between AD and the vertical is the angle between DA and DG:

$\tan \alpha = \frac{1.5a}{4a - 13a/5} = \frac{3a/2}{7a/5} = \frac{15}{14}$

$\alpha = 46.97...°$

Angle between AD and the vertical = 47° (nearest degree)

Question 1 continued

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Question 1 continued

(Total for Question 1 is 8 marks)

2. A particle P moves on the x-axis. At time t seconds the velocity of P is v m s^{-1} in the positive x-direction, where

$$v = 3 - \sqrt{2t+1} \qquad t \geqslant 0$$

(a) Find the value of t when P is at instantaneous rest.

(2)

The acceleration of P at time t seconds is a m s^{-2} in the positive x-direction.

(b) Show that $a = \dfrac{1}{v-3}$

(3)

(c) Find the speed of P when it is decelerating at $\dfrac{4}{3}$ m s^{-2}

(2)

(d) Find the total distance travelled by P between $t = 0$ and $t = \dfrac{15}{2}$

[*Solutions relying on calculator technology are not acceptable.*]

(4)

(a) At rest: $0 = 3 - \sqrt{(2t+1)}$

$\sqrt{(2t+1)} = 3 \Rightarrow 2t + 1 = 9$

$t = 4$

(b) $a = \dfrac{dv}{dt} = -\dfrac{1}{2}(2t+1)^{-1/2} \times 2$

$a = -\dfrac{1}{\sqrt{(2t+1)}}$

From $v = 3 - \sqrt{(2t+1)}$: $\sqrt{(2t+1)} = 3 - v$

$a = -\dfrac{1}{3-v} \Rightarrow a = \dfrac{1}{v-3}$ as required

(c) Decelerating at $\frac{4}{3}$ m s^{-2}, so $a = -\frac{4}{3}$

$-\dfrac{4}{3} = \dfrac{1}{v-3} \Rightarrow v - 3 = -\dfrac{3}{4}$

$v = 2.25$, so the speed is 2.25 m s^{-1}

(d) $x = \int (3 - (2t+1)^{1/2})\, dt = 3t - \dfrac{1}{3}(2t+1)^{3/2} + C$

P changes direction at $t = 4$ ($v > 0$ for $t < 4$, $v < 0$ for $t > 4$)

Let $f(t) = 3t - \dfrac{1}{3}(2t+1)^{3/2}$

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Question 2 continued

$f(0) = -\frac{1}{3}$, $f(4) = 12 - \frac{27}{3} = 3$, $f(7.5) = 22.5 - \frac{64}{3} = \frac{7}{6}$

Distance $= (f(4) - f(0)) - (f(7.5) - f(4)) = \left(3 + \frac{1}{3}\right) - \left(\frac{7}{6} - 3\right)$

$= \frac{10}{3} + \frac{11}{6} = \frac{31}{6}$

Total distance $= 5\frac{1}{6}$ m

(Total for Question 2 is 11 marks)

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3. [*In this question you may quote, without proof, the formula for the distance of the centre of mass of a circular arc from its centre.*]

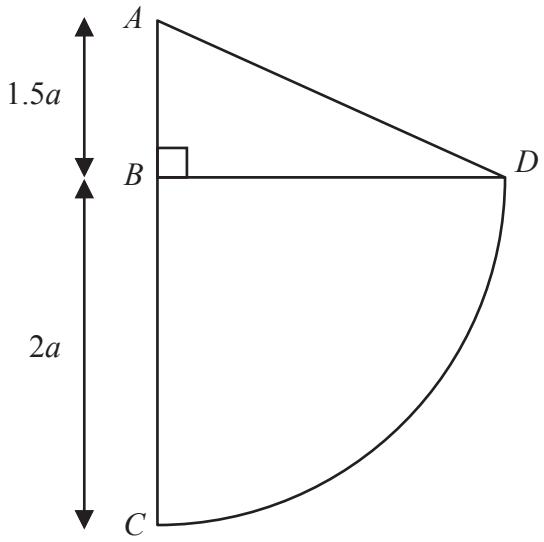


Figure 2

Uniform wire is used to form the rigid framework shown in Figure 2.

The framework consists of four straight pieces of wire, AB, BC, BD and AD and one piece in the shape of an arc of a circle, CD.

In the framework

- $AB = 1.5a$ and $BC = BD = 2a$
- CD is an arc of a circle of radius $2a$ and centre B
- ABC is a straight line and ABD is a right angle
- A, B, C and D all lie in the same plane

(a) Show that the distance of the centre of mass of arc CD from AC is $\dfrac{4a}{\pi}$

(2)

(b) Show that the distance of the centre of mass of the framework from AC is $\dfrac{17a}{2(8+\pi)}$

(4)

The framework is freely pivoted at A.

The framework is held in equilibrium, with BD horizontal, by an upward vertical force that is applied to the framework at D.

The mass of the framework is M.

The magnitude of the force exerted on the framework by the pivot at A is kMg.

(c) Find the value of k giving your answer in terms of π in its simplest form.

(3)

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Question 3 continued

(a) Arc CD: radius $2a$, angle at B $= \frac{\pi}{2}$, so $\alpha = \frac{\pi}{4}$

Distance of centre of mass from B (along the bisector) $= \frac{r \sin \alpha}{\alpha} = \frac{2a \sin(\pi/4)}{\pi/4} = \frac{4\sqrt{2}\, a}{\pi}$

The bisector makes an angle of $\pi/4$ with AC, so

distance from AC $= \frac{2a \sin(\pi/4)}{\pi/4} \times \cos\frac{\pi}{4} = \frac{4\sqrt{2}\, a}{\pi} \times \frac{\sqrt{2}}{2} = \frac{4a}{\pi}$ as required

(b) $AD = \sqrt{((1.5a)^2 + (2a)^2)} = 2.5a$; arc CD $= \frac{1}{4} \times 2\pi(2a) = \pi a$

Piece:	AB	BC	BD	AD	arc CD	framework
Length:	$1.5a$	$2a$	$2a$	$2.5a$	πa	$8a + \pi a$
Dist. from AC:	0	0	a	a	$\frac{4a}{\pi}$	$\bar{x}$

Moments about AC:

$1.5a \times 0 + 2a \times 0 + 2a \times a + 2.5a \times a + \pi a \times \frac{4a}{\pi} = (8a + \pi a)\,\bar{x}$

$2a^2 + 2.5a^2 + 4a^2 = 8.5a^2 = (8 + \pi)a\,\bar{x}$

$\bar{x} = \frac{8.5a}{8 + \pi} = \frac{17a}{2(8 + \pi)}$ as required

(c) With BD horizontal, AC is vertical. All forces are vertical, so the force at the pivot A is vertical, of magnitude kMg. D is $2a$ horizontally from AC.

Moments about D:

$kMg \times 2a = Mg\left(2a - \frac{17a}{2(8 + \pi)}\right)$

$2k = 2 - \frac{17}{2(8 + \pi)} \Rightarrow k = 1 - \frac{17}{4(8 + \pi)} = \frac{32 + 4\pi - 17}{4(8 + \pi)}$

$k = \frac{15 + 4\pi}{4(8 + \pi)}$

Question 3 continued

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Question 3 continued

(Total for Question 3 is 9 marks)

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4. A car is travelling round a circular track. The car moves with constant speed in a horizontal circle of radius r.

In an initial model,

- the car and driver are modelled as a single particle
- the track is modelled as being rough, so that there is sideways friction between the tyres of the car and the track with coefficient of friction μ
- the track is modelled as being **horizontal**

Using this model, the maximum speed at which the car can move round the circle of radius r without slipping sideways is $\frac{1}{2}\sqrt{gr}$.

(a) Show that $\mu = \frac{1}{4}$

(5)

In a refined model,

- the car and driver are modelled as a single particle
- the track is modelled as being rough, so that there is sideways friction between the tyres of the car and the track with coefficient of friction $\frac{1}{4}$
- the track is modelled as being **banked** at an angle θ to the horizontal

Using this model, the **minimum** speed at which the car can move round the circle of radius r without slipping sideways is $\sqrt{\frac{4rg}{35}}$

(b) Find the value of $\tan\theta$

(7)

(a) Resolve vertically: $R = mg$

N2L horizontally (towards centre): $F = \frac{mv^2}{r} = m \times \frac{gr/4}{r} = \frac{1}{4}mg$

About to slip at maximum speed, so $F = \mu R$ (limiting friction)

$\frac{1}{4}mg = \mu \times mg$

$\mu = \frac{1}{4}$ as required

(b) At the minimum speed the car is about to slip down the slope, so friction F acts up the slope, with $F = \frac{1}{4}R$.

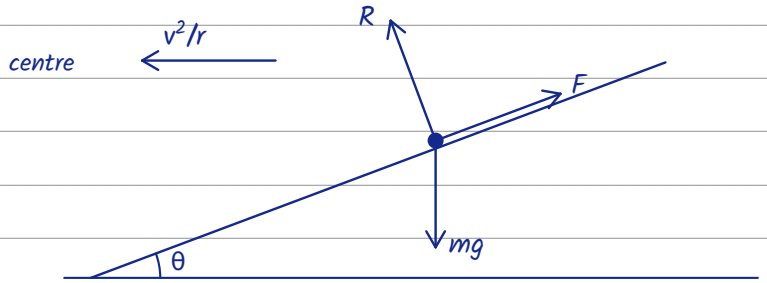
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Question 4 continued



Resolve vertically:

$R\cos\theta + F\sin\theta = mg$

N2L horizontally (towards the centre):

$$R\sin\theta - F\cos\theta = \frac{mv^2}{r} = m \times \frac{4rg/35}{r} = \frac{4mg}{35}$$

Using $F = \frac{1}{4}R$:

$$R\left(\cos\theta + \frac{1}{4}\sin\theta\right) = mg, \qquad R\left(\sin\theta - \frac{1}{4}\cos\theta\right) = \frac{4mg}{35}$$

Dividing, then dividing top and bottom by $\cos\theta$:

$$\frac{\tan\theta - 1/4}{1 + (1/4)\tan\theta} = \frac{4}{35}$$

$$35\tan\theta - \frac{35}{4} = 4 + \tan\theta$$

$$34\tan\theta = \frac{51}{4} \quad \Rightarrow \quad \tan\theta = \frac{51}{136}$$

$$\tan\theta = \frac{3}{8} \quad (= 0.375)$$

Question 4 continued

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Question 4 continued

Question 4 continued

(Total for Question 4 is 12 marks)

TOTAL FOR FURTHER MECHANICS 2 IS 40 MARKS

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