Write your name here

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Centre Number | | | | | |

Candidate Number | | | | |

Mechanics M5

Advanced/Advanced Subsidiary

Tuesday 21 June 2016 – Morning
Time: 1 hour 30 minutes

Paper Reference
6681/01

You must have:
Mathematical Formulae and Statistical Tables (Pink)

Total Marks

Candidates may use any calculator allowed by the regulations of the Joint Council for Qualifications. 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). Coloured pencils and highlighter pens must not be used.
- **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 $g = 9.8$ m s^{-2}, and give your answer to either two significant figures or three significant figures.
- When a calculator is used, the answer should be given to an appropriate degree of accuracy.

Information

- 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.

Turn over ▶

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1. [*In this question*, **i** *and* **j** *are perpendicular unit vectors in a horizontal plane.*]

A bead P of mass 0.4 kg is threaded on a smooth straight horizontal wire. The wire lies along the line with vector equation $\mathbf{r} = (\mathbf{i} + 2\mathbf{j}) + \lambda(-2\mathbf{i} + 3\mathbf{j})$. The bead is initially at rest at the point A with position vector $(-\mathbf{i} + 5\mathbf{j})$ m. A constant horizontal force $(0.5\mathbf{i} + \mathbf{j})$ N acts on P and moves it along the wire to the point B. At B the speed of P is 5 m s^{-1}.

Find the position vector of B.

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Question 1 continued

Q1

(Total 7 marks)

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2. A particle P is moving in a plane. At time t seconds the position vector of P is $\mathbf{r}$ metres and the velocity of P is $\mathbf{v}$ m s^{-1}. When $t = \frac{\pi}{2}$, P is instantaneously at rest at the point with position vector $(\mathbf{i} - \mathbf{j})$ m.

Given that $\mathbf{r}$ satisfies the differential equation

$$\frac{\mathrm{d}^2\mathbf{r}}{\mathrm{d}t^2} + 4\mathbf{r} = (3\sin t)\,\mathbf{i}$$

find $\mathbf{v}$ in terms of t.

(13)

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Question 2 continued

Q2

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3. Three forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ act on a rigid body at the points with position vectors $\mathbf{r}_1$, $\mathbf{r}_2$ and $\mathbf{r}_3$ respectively, where

$\mathbf{F}_1 = (2\mathbf{j} - \mathbf{k})$ N $\quad \mathbf{F}_2 = (\mathbf{i} + \mathbf{k})$ N $\quad \mathbf{F}_3 = (\mathbf{i} + \mathbf{j})$ N

$\mathbf{r}_1 = (4\mathbf{j} - \mathbf{k})$ m $\quad \mathbf{r}_2 = (2\mathbf{i} + \mathbf{k})$ m $\quad \mathbf{r}_3 = (3\mathbf{i} + \mathbf{j} + \mathbf{k})$ m

The system of the three forces is equivalent to a single force **R** acting through the point with position vector $(\mathbf{i} - \mathbf{j} + \mathbf{k})$ m, together with a couple of moment **G**.

(a) Find **R**.

(2)

(b) Find **G**.

(9)

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Question 3 continued

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Q3

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4. Find, using integration, the moment of inertia of a uniform cylindrical shell of radius r, height h and mass M, about a diameter of one end.

(10)

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Question 4 continued

Q4

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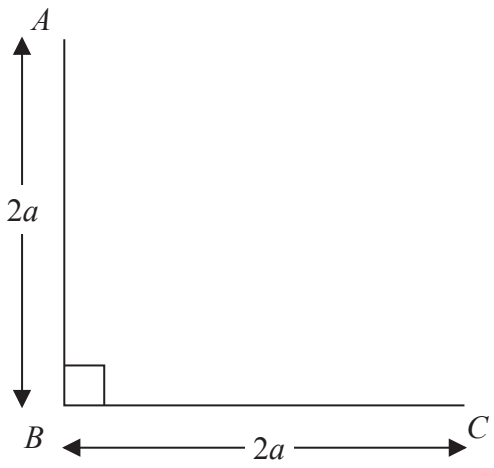


Figure 1

A uniform piece of wire ABC, of mass $2m$ and length $4a$, is bent into two straight equal portions, AB and BC, which are at right angles to each other, as shown in Figure 1. The wire rotates freely in a vertical plane about a fixed smooth horizontal axis L which passes through A and is perpendicular to the plane of the wire.

(a) Show that the moment of inertia of the wire about L is $\frac{20ma^2}{3}$

(3)

(b) By writing down an equation of rotational motion for the wire as it rotates about L, find the period of small oscillations of the wire about its position of stable equilibrium.

(8)

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Question 5 continued

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6. A firework rocket, excluding its fuel, has mass m_0 kg. The rocket moves vertically upwards by ejecting burnt fuel vertically downwards with constant speed u m s^{-1}, $u > 24.5$, relative to the rocket. The rocket starts from rest on the ground at time $t = 0$. At time t seconds, $t \leqslant 2$, the speed of the rocket is v m s^{-1} and the mass of the rocket including its fuel is $m_0(5 - 2t)$ kg. It is assumed that air resistance is negligible and the acceleration due to gravity is constant.

(a) Show that, for $t \leqslant 2$

$$\frac{dv}{dt} = \frac{2u}{5 - 2t} - 9.8$$

(6)

(b) Find the speed of the rocket at the instant when all of its fuel has been burnt.

(6)

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Question 6 continued

Q6

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7. A uniform square lamina $PQRS$, of mass m and side $2a$, is free to rotate about a fixed smooth horizontal axis which passes through P and Q. The lamina hangs at rest in a vertical plane with SR below PQ and is given a horizontal impulse of magnitude J at the midpoint of SR. The impulse is perpendicular to SR.

(a) Find the initial angular speed of the lamina.

(3)

(b) Find the magnitude of the angular deceleration of the lamina at the instant when the lamina has turned through $\frac{\pi}{6}$ radians.

(3)

(c) Find the magnitude of the component of the force exerted on the lamina by the axis, in a direction perpendicular to the lamina, at the instant when the lamina has turned through $\frac{\pi}{6}$ radians.

(5)

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TOTAL FOR PAPER: 75 MARKS

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