Centre No.						Paper Reference	Surname	Initial(s)
Candidate No.						6 6 8 1 / 0 1 R	Signature	

Paper Reference(s)

6681/01R

Edexcel GCE

Mechanics M5

Advanced/Advanced Subsidiary

Monday 24 June 2013 – Afternoon

Time: 1 hour 30 minutes

Examiner's use only

Team Leader's use only

Question Number	Leave Blank
1	
2	
3	
4	
5	
6	
Total	

Materials required for examination	**Items included with question papers**
Mathematical Formulae (Pink)	Nil

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 or symbolic differentiation/integration, or have retrievable mathematical formulae stored in them.

Instructions to Candidates

In the boxes above, write your centre number, candidate number, your surname, initials and signature.
Check that you have the correct question paper.
Answer ALL the questions.
You must write your answer to each question in the space following the question.
Whenever a numerical value of g is required, take $g = 9.8$ m s^{-2}.
When a calculator is used, the answer should be given to an appropriate degree of accuracy.

Information for Candidates

A booklet 'Mathematical Formulae and Statistical Tables' is provided.
Full marks may be obtained for answers to ALL questions.
The marks for individual questions and the parts of questions are shown in round brackets: e.g. **(2)**.
There are 6 questions in this question paper. The total mark for this paper is 75.
There are 24 pages in this question paper. Any blank pages are indicated.

Advice to Candidates

You must ensure that your answers to parts of questions are clearly labelled.
You should show sufficient working to make your methods clear to the Examiner.
Answers without working may not gain full credit.

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1. A particle moves in a plane in such a way that its position vector $\mathbf{r}$ metres at time t seconds satisfies the differential equation

$$\frac{d^2\mathbf{r}}{dt^2} - 2\frac{d\mathbf{r}}{dt} = \mathbf{0}$$

When $t = 0$, the particle is at the origin and is moving with velocity $(4\mathbf{i} + 2\mathbf{j})$ m s^{-1}.

Find $\mathbf{r}$ in terms of t.

(7)

Leave blank

2. Three forces $\mathbf{F}_1 = (3\mathbf{i} - \mathbf{j} + \mathbf{k})$ N, $\mathbf{F}_2 = (2\mathbf{i} - \mathbf{k})$ N, and $\mathbf{F}_3$ act on a rigid body.

The force $\mathbf{F}_1$ acts through the point with position vector $(\mathbf{i} + 2\mathbf{j} + \mathbf{k})$ m, the force $\mathbf{F}_2$ acts through the point with position vector $(\mathbf{i} - 2\mathbf{j})$ m and the force $\mathbf{F}_3$ acts through the point with position vector $(\mathbf{i} + \mathbf{j} + \mathbf{k})$ m.

Given that the system $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ reduces to a couple $\mathbf{G}$,

(a) find $\mathbf{G}$.

(6)

The line of action of $\mathbf{F}_3$ is changed so that the system $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ now reduces to a couple $(6\mathbf{i} + 8\mathbf{j} + 2\mathbf{k})$ N m.

(b) Find an equation of the new line of action of $\mathbf{F}_3$, giving your answer in the form $\mathbf{r} = \mathbf{a} + t\mathbf{b}$, where $\mathbf{a}$ and $\mathbf{b}$ are constant vectors.

(5)

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Question 2 continued

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3. A spacecraft is moving in a straight line in deep space. The spacecraft moves by ejecting burnt fuel backwards at a constant speed of 2000 m s^{-1} relative to the spacecraft. The burnt fuel is ejected at a constant rate of c kg s^{-1}. At time t seconds the total mass of the spacecraft, including fuel, is m kg and the speed of the spacecraft is v m s^{-1}.

(a) Show that, while the spacecraft is ejecting burnt fuel,

$$m\frac{\mathrm{d}v}{\mathrm{d}t} = 2000c$$

(7)

At time $t = 0$, the mass of the spacecraft is M_0 kg and the speed of the spacecraft is 2000 m s^{-1}. When $t = 50$, the spacecraft is still ejecting burnt fuel and its speed is 6000 m s^{-1}.

(b) Find c in terms of M_0.

(7)

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Question 3 continued

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4. Show, using integration, that the moment of inertia of a uniform solid right circular cone of mass M, height h and base radius a, about an axis through the vertex, parallel to the base, is

$$\frac{3M}{20}(a^2 + 4h^2)$$

[*You may assume without proof that the moment of inertia of a uniform circular disc, of radius r and mass m, about a diameter is* $\frac{1}{4}mr^2$.]

(13)

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Question 4 continued

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5.

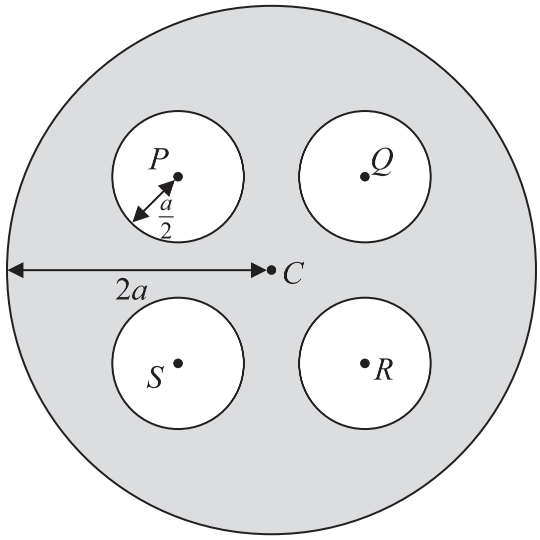

Figure 1

A uniform circular lamina has radius $2a$ and centre C. The points P, Q, R and S on the lamina are the vertices of a square with centre C and $CP = a$. Four circular discs, each of radius $\frac{a}{2}$, with centres P, Q, R and S, are removed from the lamina. The remaining lamina forms a template T, as shown in Figure 1.

The radius of gyration of T about an axis through C, perpendicular to T, is k.

(a) Show that $k^2 = \dfrac{55a^2}{24}$

(7)

The template T is free to rotate in a vertical plane about a fixed smooth horizontal axis which is perpendicular to T and passes through a point on its outer rim.

(b) Write down an equation of rotational motion for T and deduce that the period of small oscillations of T about its stable equilibrium position is

$$2\pi\sqrt{\left(\frac{151a}{48g}\right)}$$

(8)

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Question 5 continued

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6. A uniform circular disc, of radius r and mass m, is free to rotate in a vertical plane about a fixed smooth horizontal axis L which is perpendicular to the plane of the disc and passes through a point which is $\frac{1}{4}r$ from the centre of the disc. The disc is held at rest with its centre vertically above the axis. The disc is then slightly disturbed from its rest position. You may assume without proof that the moment of inertia of the disc about L is $\frac{9mr^2}{16}$.

(a) Show that the angular speed of the disc when it has turned through $\frac{\pi}{2}$ is $\sqrt{\left(\frac{8g}{9r}\right)}$.

(4)

(b) Find the magnitude of the force exerted on the disc by the axis when the disc has turned through $\frac{\pi}{2}$.

(11)

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Question 6 continued