June 2010

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

Paper Reference(s)

**6680/01**

# Edexcel GCE

## Mechanics M4

## Advanced/Advanced Subsidiary

Tuesday 22 June 2010 – 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, differentiation and 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.** [*In this question* **i** *and* **j** *are unit vectors due east and due north respectively*]

A man cycles at a constant speed $u$ m s$^{-1}$ on level ground and finds that when his velocity is $u\mathbf{j}$ m s$^{-1}$ the velocity of the wind appears to be $v(3\mathbf{i} - 4\mathbf{j})$ m s$^{-1}$, where $v$ is a positive constant.

When the man cycles with velocity $\frac{1}{5}u(-3\mathbf{i}+4\mathbf{j})$ m s$^{-1}$, the velocity of the wind appears to be $w\mathbf{i}$ m s$^{-1}$, where $w$ is a positive constant.

Find, in terms of $u$, the true velocity of the wind.

**(7)**

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**2.** Two smooth uniform spheres $S$ and $T$ have equal radii. The mass of $S$ is 0.3 kg and the mass of $T$ is 0.6 kg. The spheres are moving on a smooth horizontal plane and collide obliquely. Immediately before the collision the velocity of $S$ is $\mathbf{u}_1$ m s$^{-1}$ and the velocity of $T$ is $\mathbf{u}_2$ m s$^{-1}$. The coefficient of restitution between the spheres is 0.5. Immediately after the collision the velocity of $S$ is $(-\mathbf{i} + 2\mathbf{j})$ m s$^{-1}$ and the velocity of $T$ is $(\mathbf{i} + \mathbf{j})$ m s$^{-1}$. Given that when the spheres collide the line joining their centres is parallel to $\mathbf{i}$,

(a) find

(i) $\mathbf{u}_1$,

(ii) $\mathbf{u}_2$.

**(6)**

After the collision, $T$ goes on to collide with a smooth vertical wall which is parallel to $\mathbf{j}$. Given that the coefficient of restitution between $T$ and the wall is also 0.5, find

(b) the angle through which the direction of motion of $T$ is deflected as a result of the collision with the wall,

**(5)**

(c) the loss in kinetic energy of $T$ caused by the collision with the wall.

**(3)**

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**Question 2 continued**

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**3.** At 12 noon, ship $A$ is 8 km due west of ship $B$. Ship $A$ is moving due north at a constant speed of 10 km h$^{-1}$. Ship $B$ is moving at a constant speed of 6 km h$^{-1}$ on a bearing so that it passes as close to $A$ as possible.

(a) Find the bearing on which ship $B$ moves.

**(4)**

(b) Find the shortest distance between the two ships.

**(3)**

(c) Find the time when the two ships are closest.

**(3)**

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**Question 3 continued**



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**4.** A particle of mass $m$ is projected vertically upwards, at time $t = 0$, with speed $U$. The particle is subject to air resistance of magnitude $\frac{mgv^2}{k^2}$, where $v$ is the speed of the particle at time $t$ and $k$ is a positive constant.

(a) Show that the particle reaches its greatest height above the point of projection at time $\frac{k}{g}\tan^{-1}\left(\frac{U}{k}\right)$.

**(6)**

(b) Find the greatest height above the point of projection attained by the particle.

**(6)**

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**Question 4 continued**



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**5.**

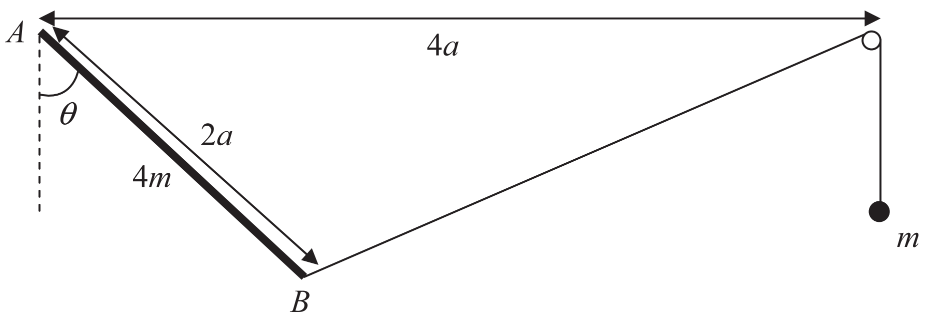


**Figure 1**

The end $A$ of a uniform rod $AB$, of length $2a$ and mass $4m$, is smoothly hinged to a fixed point. The end $B$ is attached to one end of a light inextensible string which passes over a small smooth pulley, fixed at the same level as $A$. The distance from $A$ to the pulley is $4a$. The other end of the string carries a particle of mass $m$ which hangs freely, vertically below the pulley, with the string taut. The angle between the rod and the downward vertical is $\theta$, where $0 < \theta < \frac{\pi}{2}$, as shown in Figure 1.

(a) Show that the potential energy of the system is

$$2mga(\sqrt{(5 - 4\sin\theta)} - 2\cos\theta) + \text{constant}.$$

**(5)**

(b) Hence, or otherwise, show that any value of $\theta$ which corresponds to a position of equilibrium of the system satisfies the equation

$$4\sin^3\theta - 6\sin^2\theta + 1 = 0.$$

**(5)**

(c) Given that $\theta = \frac{\pi}{6}$ corresponds to a position of equilibrium, determine its stability.

**(5)**

Leave blank

**Question 5 continued**

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**6.** Two points $A$ and $B$ lie on a smooth horizontal table with $AB = 4a$. One end of a light elastic spring, of natural length $a$ and modulus of elasticity $2mg$, is attached to $A$. The other end of the spring is attached to a particle $P$ of mass $m$. Another light elastic spring, of natural length $a$ and modulus of elasticity $mg$, has one end attached to $B$ and the other end attached to $P$. The particle $P$ is on the table at rest and in equilibrium.

(a) Show that $AP = \dfrac{5a}{3}$.

**(4)**

The particle $P$ is now moved along the table from its equilibrium position through a distance $0.5a$ towards $B$ and released from rest at time $t = 0$. At time $t$, $P$ is moving with speed $v$ and has displacement $x$ from its equilibrium position. There is a resistance to motion of magnitude $4m\omega v$ where $\omega = \sqrt{\left(\dfrac{g}{a}\right)}$.

(b) Show that $\dfrac{d^2x}{dt^2} + 4\omega\dfrac{dx}{dt} + 3\omega^2 x = 0$.

**(5)**

(c) Find the velocity, $\dfrac{dx}{dt}$, of $P$ in terms of $a, \omega$ and $t$.

**(8)**



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**Question 6 continued**



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