A Level · Edexcel · Further Maths

2 hours 10 questions

Elastic Collisions in 2D

Oblique Collisions with a Surface / Oblique Collisions of Two Spheres / Problem Solving with Oblique Collisions

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Total Marks **/108**

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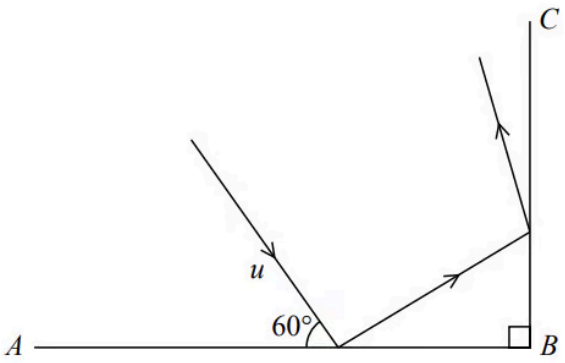

Figure 1

1 (a)

Figure 1 represents the plan view of part of a horizontal floor, where AB and BC are perpendicular vertical walls.

The floor and the walls are modelled as smooth.

A ball is projected along the floor towards AB with speed u ms^{-1} on a path at an angle of 60° to AB. The ball hits AB and then hits BC.

The ball is modelled as a particle.

The coefficient of restitution between the ball and wall AB is $\frac{1}{\sqrt{3}}$.

The coefficient of restitution between the ball and wall BC is $\sqrt{\frac{2}{5}}$.

Show that, using this model, the final kinetic energy of the ball is 35% of the initial kinetic energy of the ball.

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(8 marks)

(b) In reality the floor and the walls may not be smooth. What effect will the model have had on the calculation of the percentage of kinetic energy remaining?

(1 mark)

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2 (a) [In this question $\mathbf{i}$ and $\mathbf{j}$ are perpendicular unit vectors in a horizontal plane.]

A smooth uniform sphere A has mass $2m$ kg and another smooth uniform sphere B, with the same radius as A, has mass $3m$ kg.

The spheres are moving on a smooth horizontal plane when they collide obliquely.

Immediately before the collision the velocity of A is $(3\mathbf{i}+3\mathbf{j})\ \text{ms}^{-1}$ and the velocity of B is $(-5\mathbf{i}+2\mathbf{j})\ \text{ms}^{-1}$.

At the instant of collision, the line joining the centres of the spheres is parallel to $\mathbf{i}$.

The coefficient of restitution between the spheres is $\frac{1}{4}$.

Find the velocity of B immediately after the collision.

(7 marks)

(b) Find, to the nearest degree, the size of the angle through which the direction of motion of B is deflected as a result of the collision.

(2 marks)

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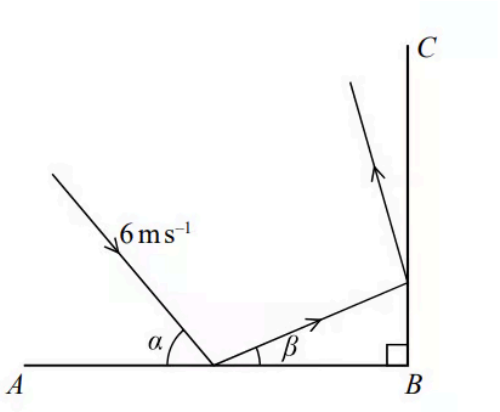

Figure 2

3 (a)

Figure 2 represents the plan view of part of a horizontal floor, where AB and BC are fixed vertical walls with AB perpendicular to BC.

A small ball is projected along the floor towards AB with speed 6 ms^{-1} on a path that makes an angle α with AB, where $\tan \alpha = \frac{4}{3}$. The ball hits AB and then hits BC.

Immediately after hitting AB, the ball is moving at an angle β to AB, where $\tan \beta = \frac{1}{3}$.

The coefficient of restitution between the ball and AB is e.

The coefficient of restitution between the ball and BC is $\frac{1}{2}$.

By modelling the ball as a particle and the floor and walls as being smooth,

show that the value $e = \frac{1}{4}$.

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(5 marks)

(b) Find the speed of the ball immediately after it hits BC.

(4 marks)

(c) Suggest two ways in which the model could be refined to make it more realistic.

(2 marks)

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4 (a) [*In this question* $\mathbf{i}$ *and* $\mathbf{j}$ *are perpendicular unit vectors in a horizontal plane.*]

A smooth uniform sphere A has mass 0.2 kg and another smooth uniform sphere B, with the same radius as A, has mass 0.4 kg.

The spheres are moving on a smooth horizontal surface when they collide obliquely. Immediately before the collision, the velocity of A is $(3\mathbf{i}+2\mathbf{j})\ \text{ms}^{-1}$ and the velocity of B is $(-4\mathbf{i}-\mathbf{j})\ \text{ms}^{-1}$.

At the instant of collision, the line joining the centres of the spheres is parallel to $\mathbf{i}$.

The coefficient of restitution between the spheres is $\frac{3}{7}$.

Find the velocity of A immediately after the collision.

(7 marks)

(b) Find the magnitude of the impulse received by A in the collision.

(2 marks)

(c) Find, to the nearest degree, the size of the angle through which the direction of motion of A is deflected as a result of the collision.

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(3 marks)

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5 (a) *[In this question, $\mathbf{i}$ and $\mathbf{j}$ are perpendicular unit vectors in a horizontal plane.]*

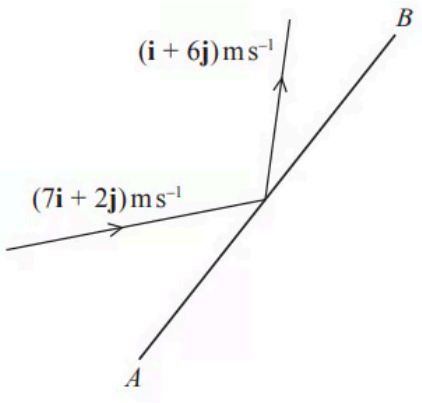

Figure 1

Figure 1 represents the plan view of part of a smooth horizontal floor, where AB represents a fixed smooth vertical wall.

A small ball of mass 0.5 kg is moving on the floor when it strikes the wall.

Immediately before the impact the velocity of the ball is $(7\mathbf{i} + 2\mathbf{j})\ \text{ms}^{-1}$.

Immediately after the impact the velocity of the ball is $(\mathbf{i} + 6\mathbf{j})\ \text{ms}^{-1}$.

The coefficient of restitution between the ball and the wall is e.

Show that AB is parallel to $(2\mathbf{i} + 3\mathbf{j})$.

(4 marks)

(b) Find the value of e.

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(5 marks)

6 (a) A smooth uniform sphere P has mass 0.3 kg. Another smooth uniform sphere Q, with the same radius as P, has mass 0.2 kg.

The spheres are moving on a smooth horizontal surface when they collide obliquely. Immediately before the collision the velocity of P is $(4\mathbf{i} + 2\mathbf{j})\ \text{ms}^{-1}$ and the velocity of Q is $(-3\mathbf{i} + \mathbf{j})\ \text{ms}^{-1}$.

At the instant of collision, the line joining the centres of the spheres is parallel to $\mathbf{i}$.

The kinetic energy of Q immediately after the collision is half the kinetic energy of Q immediately before the collision.

Find

i) the velocity of P immediately after the collision,
ii) the velocity of Q immediately after the collision,
iii) the coefficient of restitution between P and Q,
carefully justifying your answers.

(11 marks)

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(b) Find the size of the angle through which the direction of motion of P is deflected by the collision.

(3 marks)

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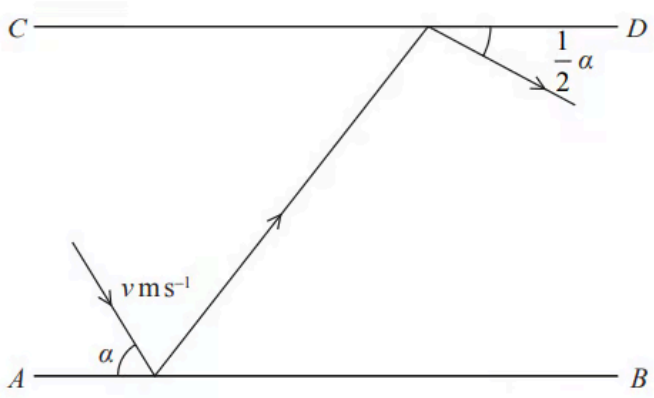

Figure 2

7 (a)

Figure 2 represents the plan view of part of a horizontal floor, where AB and CD represent fixed vertical walls, with AB parallel to CD.

A small ball is projected along the floor towards wall AB. Immediately before hitting wall AB, the ball is moving with speed v ms^{-1} at an angle α to AB , where $0 < \alpha < \frac{\pi}{2}$.

The ball hits wall AB and then hits wall CD.

After the impact with wall CD, the ball is moving at angle $\frac{1}{2}\alpha$ to CD.

The coefficient of restitution between the ball and wall AB is $\frac{2}{3}$.

The coefficient of restitution between the ball and wall CD is also $\frac{2}{3}$.

The floor and the walls are modelled as being smooth. The ball is modelled as a particle.

Show that $\tan\left(\frac{1}{2}\alpha\right) = \frac{1}{3}$.

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(7 marks)

(b) Find the percentage of the initial kinetic energy of the ball that is lost as a result of the two impacts.

(4 marks)

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8 (a) [*In this question,* $\mathbf{i}$ *and* $\mathbf{j}$ *are perpendicular unit vectors in a horizontal plane.*]

A smooth uniform sphere P has mass 0.3 kg. Another smooth uniform sphere Q, with the same radius as P, has mass 0.5 kg.

The spheres are moving on a smooth horizontal surface when they collide obliquely. Immediately before the collision the velocity of P is $(u\mathbf{i} + 2\mathbf{j})\ \text{ms}^{-1}$, where u is a positive constant, and the velocity of Q is $(-4\mathbf{i} + 3\mathbf{j})\ \text{ms}^{-1}$.

At the instant when the spheres collide, the line joining their centres is parallel to $\mathbf{i}$.

The coefficient of restitution between P and Q is $\frac{3}{5}$.

As a result of the collision, the direction of motion of P is deflected through an angle of 90° and the direction of motion of Q is deflected through an angle of $\alpha°$

Find the value of u.

(8 marks)

(b) Find the value of α.

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(5 marks)

(c) State how you have used the fact that P and Q have equal radii.

(1 mark)

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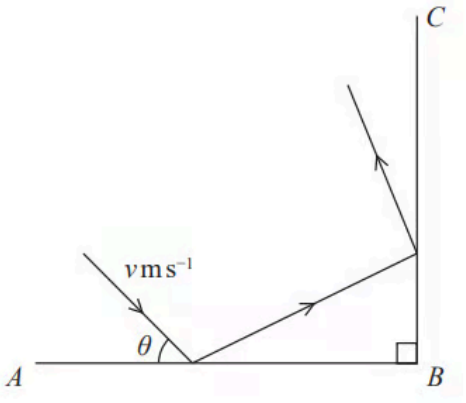

Figure 1

9 (a)

Figure 1 represents the plan view of part of a horizontal floor, where AB and BC represent fixed vertical walls, with AB perpendicular to BC.

A small ball is projected along the floor towards the wall AB. Immediately before hitting the wall AB the ball is moving with speed $v\ \text{ms}^{-1}$ at an angle θ to AB.

The ball hits the wall AB and then hits the wall BC.

The coefficient of restitution between the ball and the wall AB is $\frac{1}{3}$.

The coefficient of restitution between the ball and the wall BC is e.

The floor and the walls are modelled as being smooth.

The ball is modelled as a particle.

The ball loses half of its kinetic energy in the impact with the wall AB.

Find the exact value of $\cos\theta$.

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(5 marks)

(b) The ball loses half of its remaining kinetic energy in the impact with the wall BC.

Find the exact value of e.

(5 marks)

10 (a) *[In this question, $\mathbf{i}$ and $\mathbf{j}$ are perpendicular unit vectors in a horizontal plane.]*

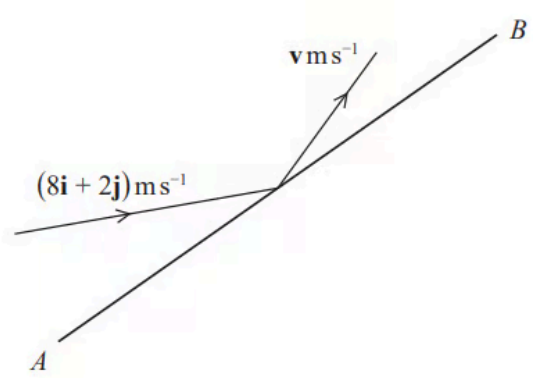

Figure 3

Figure 3 represents the plan view of part of a smooth horizontal floor, where AB is a fixed smooth vertical wall.

The direction of $\overrightarrow{AB}$ is in the direction of the vector $(\mathbf{i} + \mathbf{j})$.

A small ball of mass 0.25 kg is moving on the floor when it strikes the wall AB.

Immediately before its impact with the wall AB, the velocity of the ball is $(8\mathbf{i} + 2\mathbf{j})\ \text{ms}^{-1}$.

Immediately after its impact with the wall AB, the velocity of the ball is $\mathbf{v}\ \text{ms}^{-1}$.

The coefficient of restitution between the ball and the wall is $\frac{1}{3}$.

By modelling the ball as a particle,

show that $\mathbf{v} = (4\mathbf{i} + 6\mathbf{j})$.

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(6 marks)

(b) Find the magnitude of the impulse received by the ball in the impact.

(3 marks)

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