Essential Pre-Uni Physics F2.6

GCSE A Level

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In a strange form of billiards, the cue ball is one third the mass of the other balls, which are stripey. There is no spin, and I hit a stripey ball centrally with the cue ball (travelling at $1.4\,\mathrm{m\,s^{-1}}$) such that the cue ball rebounds in the opposite direction with half of its initial speed. What is the speed of the stripey ball?

Home Gameboard Physics Mechanics Dynamics Essential Pre-Uni Physics F2.7

Essential Pre-Uni Physics F2.7

GCSE A Level

I am stranded, stationary, in space, but near to my spacecraft. I detach my $30\,\mathrm{kg}$ oxygen cylinder, and fling it away from the spacecraft with a speed of $3.0\,\mathrm{m\,s^{-1}}$. If my mass (without the cylinder) is $80\,\mathrm{kg}$, how fast will I travel in the other direction towards my spacecraft?

Gameboard:

STEM SMART Double Maths 43 - Momentum, Impulse and Collisions

Two Particles on a String

GCSE A Level

Two particles P and Q, of masses $2m$ and m respectively, are joined by a light inextensible string (actually a string with a very high spring constant, so it can provide a large force for a very small extension). They rest on a smooth horizontal plane, with the string slack. The particle P is projected in a horizontal direction, directly away from Q, with speed u.

Part A Kinetic Energy Loss

Find the loss in kinetic energy when the string becomes taut (and remains taut as the particles move together) in terms of m and u.

The following symbols may be useful: `m, u`

Part B Impulse

Calculate the impulse (which is equal to the change in momentum) that acts on the particle Q in terms of m and u when the string becomes taut.

The following symbols may be useful: `m, u`

Used with permission from UCLES, A Level Mathematics, Syllabus C, June 1986, Paper 2, Question 1.

Gameboard:

STEM SMART Double Maths 43 - Momentum, Impulse and Collisions

Home Gameboard Physics Mechanics Dynamics Restitution and a Wall

Restitution and a Wall

Further A

P P P

A particle, of mass $0.8\,\mathrm{kg}$, moves along a smooth horizontal surface. It hits a vertical wall, which is at right angles to the direction of motion of the particles, and rebounds. The speed of the particle as it hits the wall is $4\,\mathrm{m\,s^{-1}}$ and the coefficient of restitution between the particule and the wall is 0.3.

Part A Impulse

Find the magnitude of the impulse that the wall exerts on the particle, giving your answer to 3 s.f.

Part B Loss of kinetic energy

Find the kinetic energy lost in the impact, giving your answer to 3 s.f.

Used with permission from UCLES, A Level, June 2012, Paper 4729, Question 1

Gameboard:

STEM SMART Double Maths 43 - Momentum, Impulse and Collisions

Three Collisions

A Level

Three particles A, B, and C lie at rest in that order in a straight line on a smooth horizontal table. The particle A is then projected directly towards B with velocity u. Particle A collides with B which then collides with C. Each of the particles has mass m, and the collisions are elastic.

Part A Velocity of A after collision with B

What is the velocity v_1 of particle A immediately after the collision with particle B? Give your answer in terms of u and m.

The following symbols may be useful: `m, u, v_1`

Part B Velocity of B after collision with C

What is the velocity w_2 of the particle B immediately after the collision with particle C? Give your answer in terms of u and m.

The following symbols may be useful: `m, u, w_2`

Part C Velocity of C after collision with B

What is the velocity w_3 of the particle C immediately after the collision with particle B? Give your answer in terms of u and m.

The following symbols may be useful: `m, u, w_3`

Part D New masses - velocity of A

Now consider the same scenario but this time the masses of A, B, and C are m, $2m$ and $3m$ respectively.

Find the velocity $\underline{\boldsymbol{v}}_1$ of A immediately after the collision with B, in terms of $\underline{\boldsymbol{u}}$ and m.

The following symbols may be useful: `m, u, v_1`

Part E New masses - velocity of B

Find the velocity $\underline{\boldsymbol{w}}_2$ of B immediately after the collision with C, in terms of $\underline{\boldsymbol{u}}$ and m.

The following symbols may be useful: `m, u, w_2`

Part F New masses - velocity of C

Find the velocity $\underline{\boldsymbol{w}}_3$ of C immediately after the collision with B, in terms of $\underline{\boldsymbol{u}}$ and m.

The following symbols may be useful: `m, u, w_3`

Part G Velocity after inelastic collision

What is the speed v_{f} of the composite particle after the second impact, if the balls, of mass m, $2m$ and $3m$, collided completely inelastically instead?

The following symbols may be useful: `m, u, v_f`

Gameboard:

STEM SMART Double Maths 43 - Momentum, Impulse and Collisions

Restitution and a Bouncing Ball

Further A

A small ball of mass $0.5\,\mathrm{kg}$ is held at a height of $3.136\,\mathrm{m}$ above a horizontal floor. The ball is released from rest and rebounds from the floor (see **Figure 1**). The coefficient of restitution between the ball and floor is e. Throughout this question treat the acceleration due to gravity as $9.8\,\mathrm{m\,s^{-2}}$.

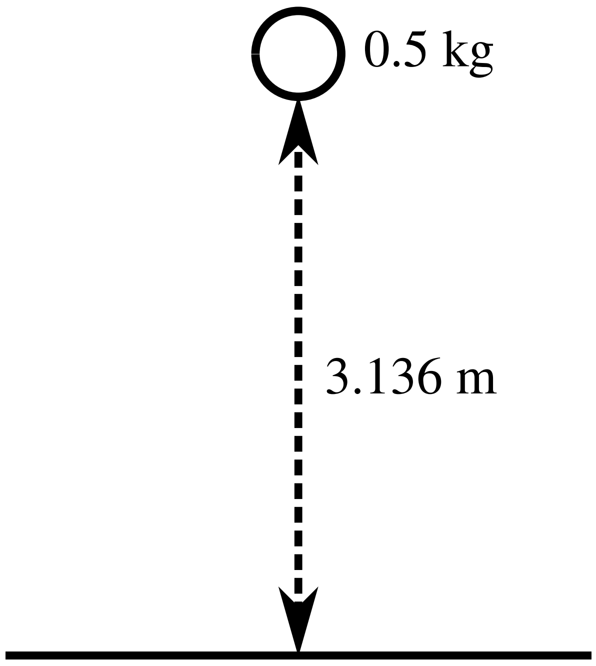

Figure 1: A ball above a horizontal floor.

Part A Speed of ball

Find in terms of e the speed of the ball immediately after the impact with the floor.

The following symbols may be useful: e

Part B Magnitude of impulse

Find the magnitude of the impulse that the floor exerts on the ball.

The following symbols may be useful: e

Part C First and second bounce

Find the time between the first and second bounce in terms of e.

The following symbols may be useful: e

Part D Second and third bounce

Find, in terms of e, the time between the second and third bounce.

The following symbols may be useful: e

Part E Third and fourth bounce

Write down, in terms of e, the time between the third and fourth bounce.

The following symbols may be useful: e

Part F Value of e

Given that the time from the ball being released until it comes to rest is $5\,\mathrm{s}$, find the exact value of e.

The following symbols may be useful: e

Used with permission from UCLES, A Level Maths, January 2012, OCR M2, Question 6

Gameboard:

STEM SMART Double Maths 43 - Momentum, Impulse and Collisions

Perpendicular Impulse

Further A

A particle P of mass $0.05\,\mathrm{kg}$ is moving on a smooth horizontal surface with speed $2\,\mathrm{m\,s^{-1}}$, when it is struck by a horizontal blow in a direction perpendicular to its direction of motion. The magnitude of the impulse of the blow is I. The speed of P after the blow is $2.5\,\mathrm{m\,s^{-1}}$.

Part A Impulse

Find the exact value of I.

Part B Coefficient of restitution

Immediately before the blow P is moving parallel to a smooth vertical wall. After the blow P hits the wall and rebounds from the wall with speed $\sqrt{5}\,\mathrm{m\,s^{-1}}$.

Find the exact value of the coefficient of restitution between P and the wall.

The following symbols may be useful: e

Used with permission from UCLES, A Level, January 2012, Paper 4730, Question 1

Gameboard:

STEM SMART Double Maths 43 - Momentum, Impulse and Collisions

Impulse and an Inclined Plane

Further A

B is a point on a smooth plane surface inclined at an angle of 15° to the horizontal. A particle P of mass $0.45\,\mathrm{kg}$ is released from rest at the point A which is $2.5\,\mathrm{m}$ vertically above B. The particle P rebounds from the surface at an angle of 60° to the line of greatest slope through B, with a speed of u. The impulse exerted on P by the surface is $\underline{\boldsymbol{I}}$ and is in a direction making an angle of θ with the upward vertical through B, as shown in **Figure 1**.

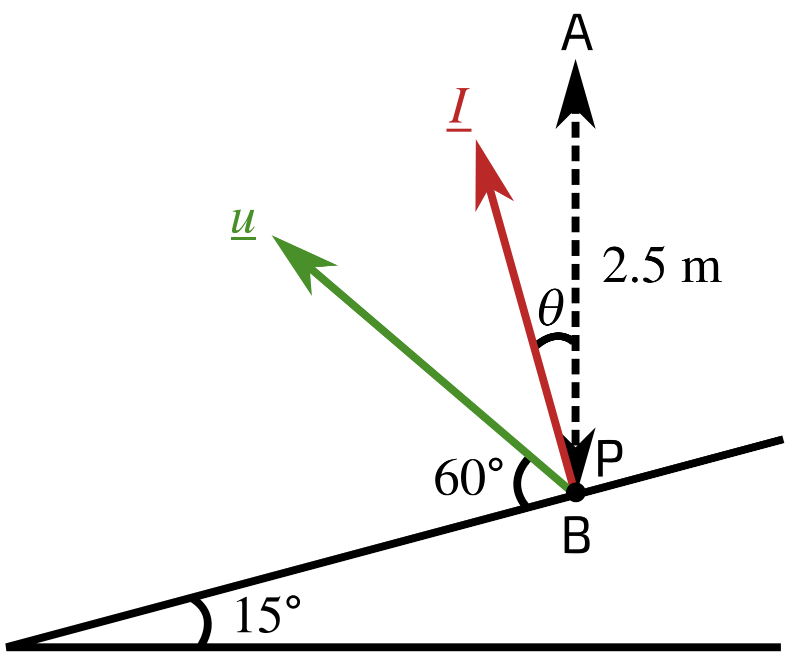

Figure 1: The inclined plane onto which P falls, with the impulse $\underline{\boldsymbol{I}}$ and the rebound velocity $\underline{\boldsymbol{u}}$ shown.

Part A Modelling assumptions

Which modelling assumption allows us to find that $\theta = 15^\circ$?

- The plane is smooth.
- The collision is elastic.
- Ignore air resistance.
- The plane is rough.

Part B Find u

Find the magnitude of $\underline{\boldsymbol{u}}$.

Part C Find I

Find the magnitude of $\underline{\boldsymbol{I}}$.

Used with permission from UCLES, A Level, June 2012, Paper 4730, Question 2

Gameboard:
STEM SMART Double Maths 43 - Momentum, Impulse and Collisions

Restitution: Sphere Collision

Further A

Two small uniform smooth spheres A and B, of equal radius, have masses $5m\,\mathrm{kg}$ and $2m\,\mathrm{kg}$ respectively. The spheres are moving on a smooth horizontal surface when they collide.

Before the collision A is moving with speed $1.3\,\mathrm{m\,s^{-1}}$ in a direction making an angle α with the line of centres, where $\tan\alpha = \frac{5}{12}$, and B is moving towards A in a direction making an angle of 60° with the line of centres. After the collision A moves in a direction at right angles to its original direction of motion (see **Figure 1**).

The coefficient of restitution between A and B is $\frac{5}{6}$.

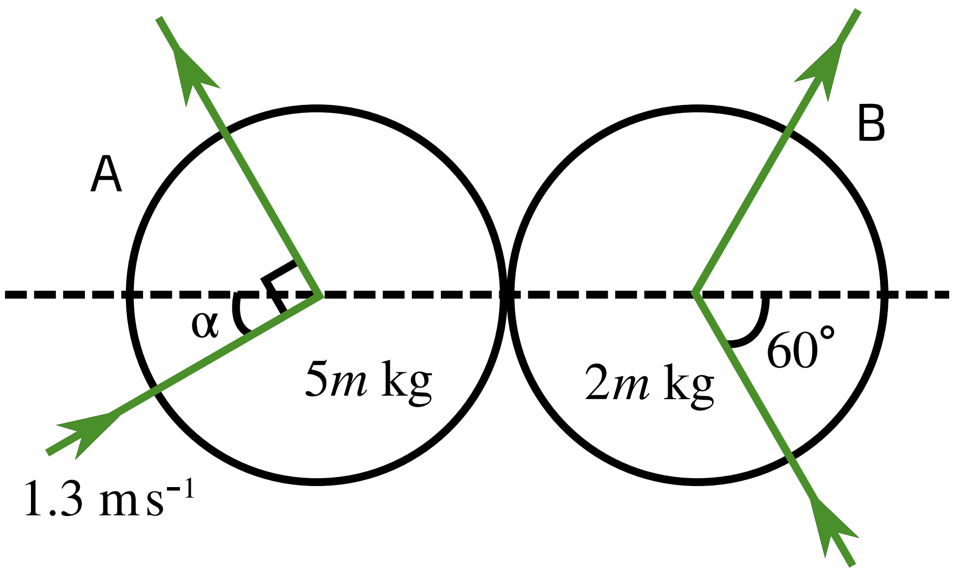

Figure 1: A diagram of the situation described in the question.

Part A Speed after collision

Find the speed of A after the collision.

Part B Component of velocity

Find the component of the velocity of B parallel to the line of centres after the collision.

Gameboard:

STEM SMART Double Maths 43 - Momentum, Impulse and Collisions

Oblique Collisions and Walls

Further A

Two uniform smooth spheres A and B, of equal radius, have masses $2m\,\mathrm{kg}$ and $3m\,\mathrm{kg}$ respectively. The spheres are approaching each other on a horizontal surface when they collide.

Before the collision A is moving with speed $5\,\mathrm{m\,s^{-1}}$ in a direction making an angle α with the line of centres, where $\cos\alpha = \frac{4}{5}$, and B is moving with speed $3.25\,\mathrm{m\,s^{-1}}$ in a direction making an angle β with the line of centres, where $\cos\beta = \frac{5}{13}$.

A straight vertical wall is situated to the right of B, perpendicular to the line of centres, as shown in **Figure 1**. The coefficient of restitution between A and B is $\frac{2}{3}$.

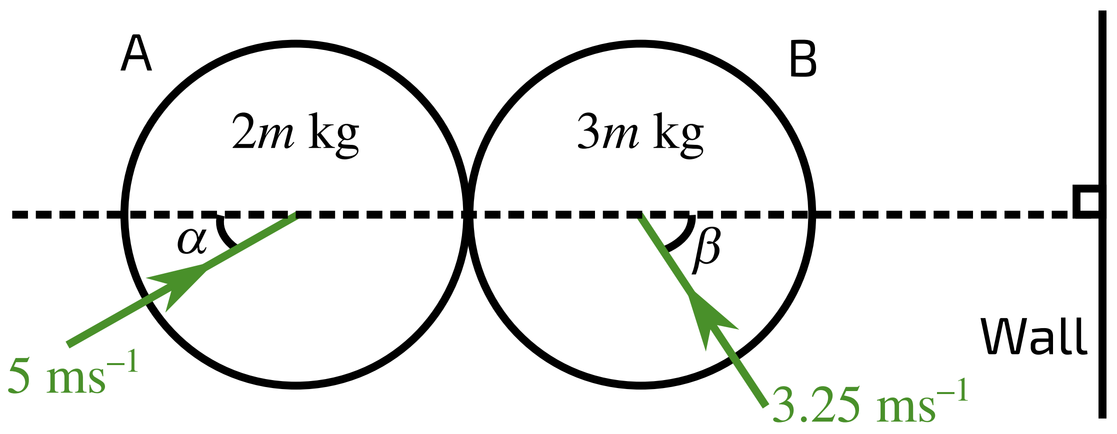

Figure 1: A and B collide with each other, with the line of centres shown. A wall is to right of B and is perpendicular to the line of centres.

Part A Speed of A

Find the exact value of the speed of A after the collision.

Part B Velocity of B

Find the exact value of the component of the velocity of B along the line of centres after the collision.

Part C Coefficient of restitution

B subsequently hits the wall.

Explain why A and B will have a second collision if the coefficient of restitution, e, between B and the wall is sufficiently large and find the set of values of e for which this second collision will occur.

Perpendicular to the line of centres, the velocity of A is ______ $\mathrm{m\,s^{-1}}$ and the velocity of B is ______ $\mathrm{m\,s^{-1}}$. Since these are ______, a second collision between A and B will occur provided that, parallel to the line of centres, B is ______ A. For this to occur, we find that e ______ ______.

Items:

2.25 | 3 | $<$ | $\frac{1}{2}$ | $>$ | **faster than** | 3.75 | $\frac{4}{9}$ | **different** | 1.25 | $\frac{5}{9}$ | **the same** | **slower than** | $\frac{13}{15}$ | 5 | 3.25 | $=$ | $\frac{9}{5}$