Essential Pre-Uni Physics F2.6

GCSE A Level

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?

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 45 - 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 45 - Momentum, Impulse and Collisions

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 particle, 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 45 - Momentum, Impulse and Collisions

Three Collisions

A Level

P P P

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`

Used with permission from UCLES, A Level Applied Mathematics, June 1969, Paper 2, Question 8.

Gameboard:
STEM SMART Double Maths 45 - 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 $9.8\,\mathrm{m\,s^{-2}}$.

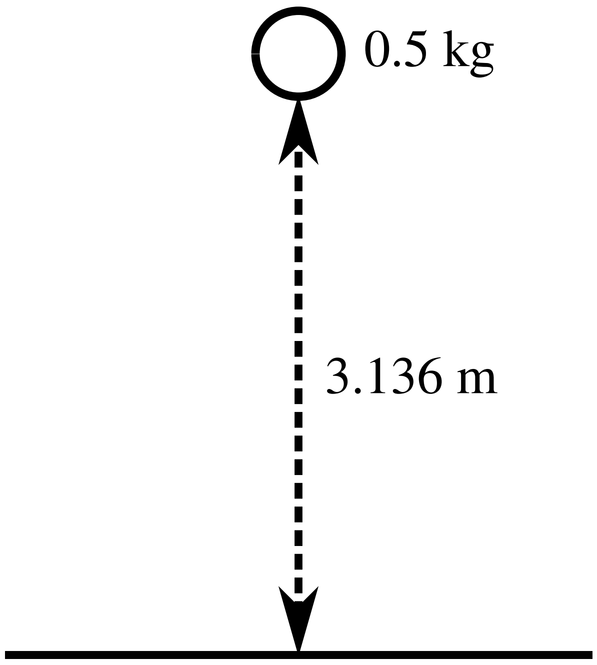

Figure 1: A ball above a horizontal floor.

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 45 - Momentum, Impulse and Collisions

Perpendicular Impulse

Further A

P P P

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 45 - 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**.

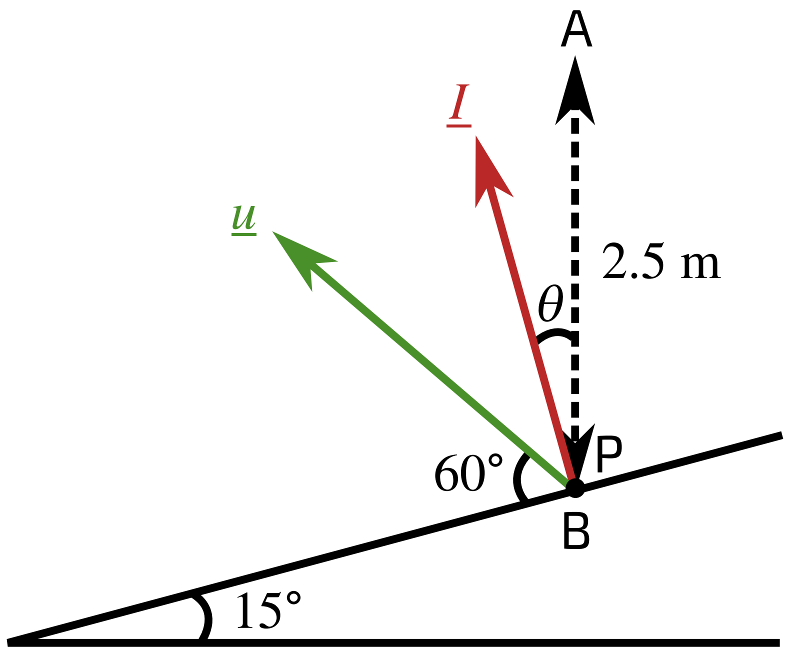

Figure 1: The inclined plane onto which P falls, with the impulse $\underline{\boldsymbol{I}}$ and the rebound velocity $\underline{\boldsymbol{u}}$ shown.

Part A Modelling assumptions

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

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

Part B Find u

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

Part C Find I

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

Gameboard:

STEM SMART Double Maths 45 - Momentum, Impulse and Collisions

Restitution: Sphere Collision

Further A

Two small uniform smooth spheres A and B, of equal radius, have masses $5m$ and $2m$ 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, as shown in **Figure 1**.

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

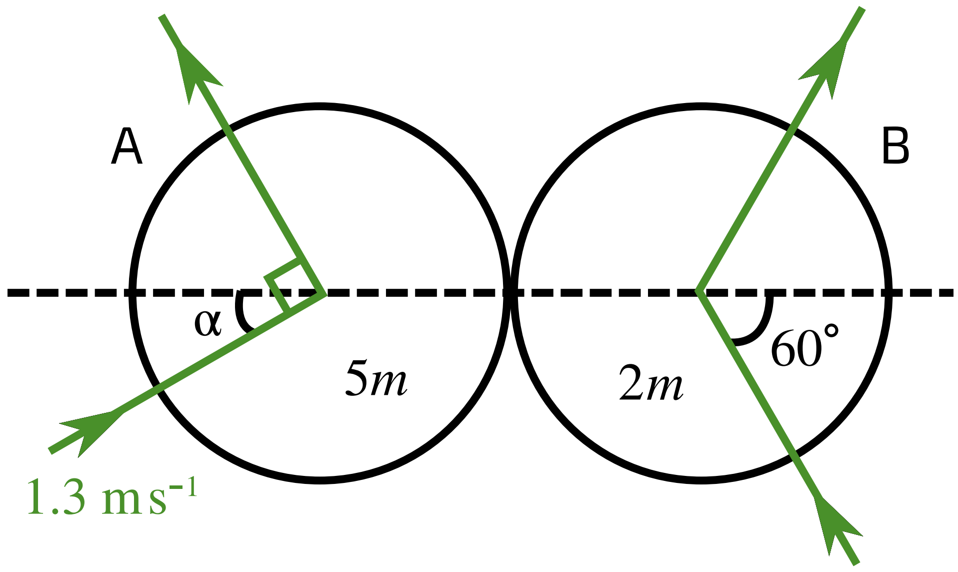

Figure 1: A diagram of the situation described in the question.

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.

Used with permission from UCLES, A Level, June 2018, Paper 4730, Question 5.

Gameboard:

STEM SMART Double Maths 45 - Momentum, Impulse and Collisions

Physics. You work it out.

Home Gameboard Physics Mechanics Dynamics Oblique Collisions and Walls

Oblique Collisions and Walls

Further A

Two uniform smooth spheres A and B, of equal radius, have masses $2m$ and $3m$ 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 $\frac{2}{3}$.

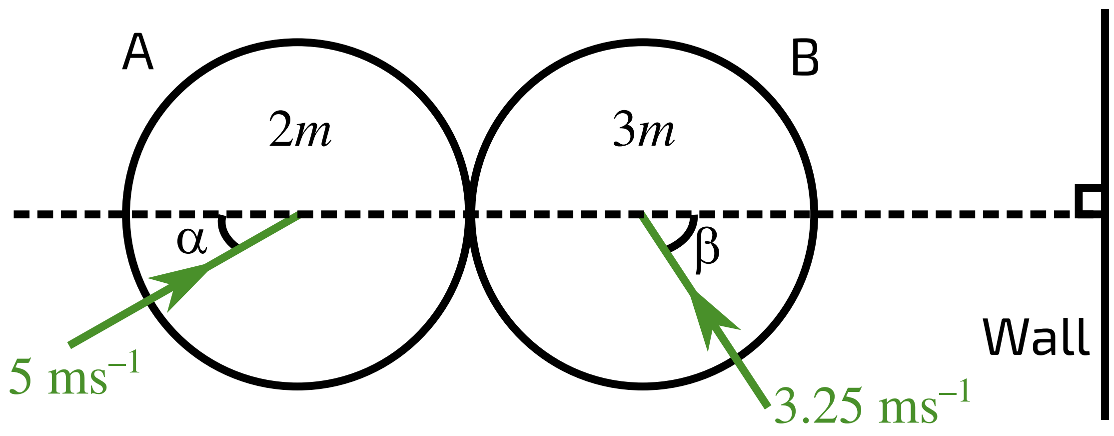

Figure 1: A and B collide with each other, with the line of centres shown. A wall is to right of B and is perpendicular to the line of centres.

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:

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

Used with permission from UCLES, A Level, June 2016, Paper 4730, Question 3