Home   Gameboard   Physics   Mechanics   Dynamics   Conservation of Momentum 6

Conservation of Momentum 6

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?

isaac Physics. *You work it out.*
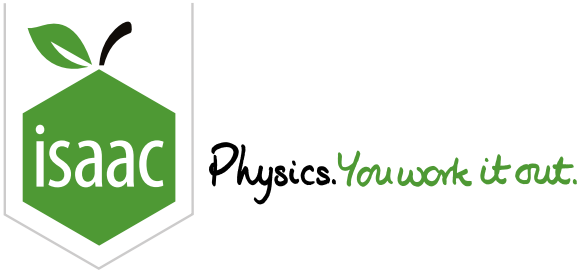
Two Particles on a String

GCSE   A Level
C C C   C C C

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`
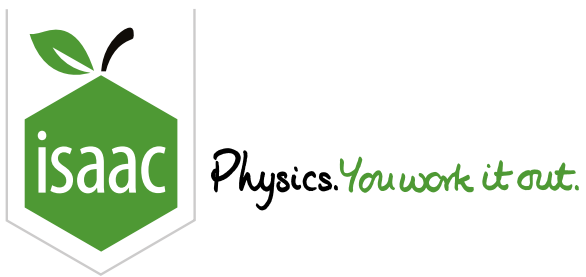
Part B   Impulse

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

A particle, of mass $0.8\,\text{kg}$, 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 $4\,\text{m s}^{-1}$ and the coefficient of restitution between the particle 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.
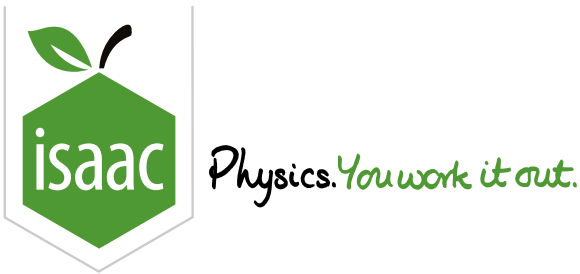
Part B   Loss of kinetic energy

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

Physics. *You work it out.*

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

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

Part E   New masses - velocity of B

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

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

Part F   New masses - velocity of C

Find the velocity $\underline{w}_3$ of C immediately after the collision with B, in terms of $\underline{u}$ 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?
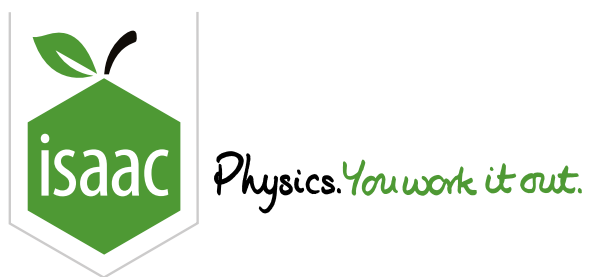
The following symbols may be useful: `m, u, v_f`

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 $9.8\,\mathrm{m\,s^{-2}}$.
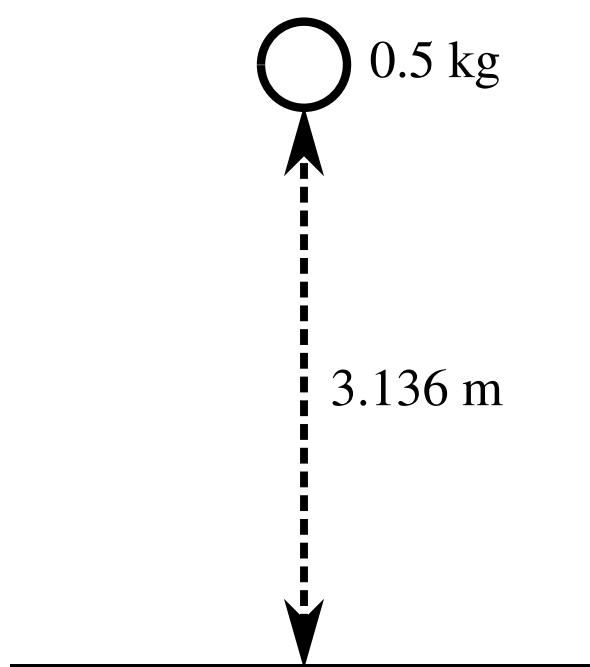

Figure 1: A ball above a horizontal floor.

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 $5\,\text{s}$, find the exact value of e.
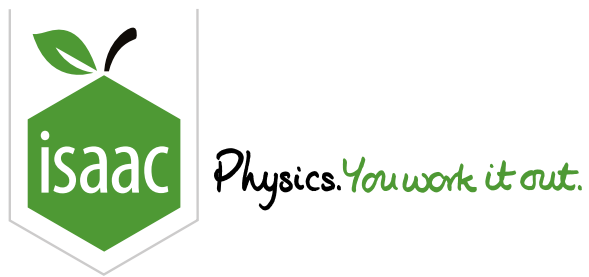
The following symbols may be useful: e

Gameboard:

STEM SMART Double Maths 45 - Momentum, Impulse and Collisions

Perpendicular Impulse

Further A

A particle P of mass $0.05\,\text{kg}$ is moving on a smooth horizontal surface with speed $2\,\text{m}\,\text{s}^{-1}$, 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 $2.5\,\text{m}\,\text{s}^{-1}$.

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 $\sqrt{5}\,\text{m}\,\text{s}^{-1}$.

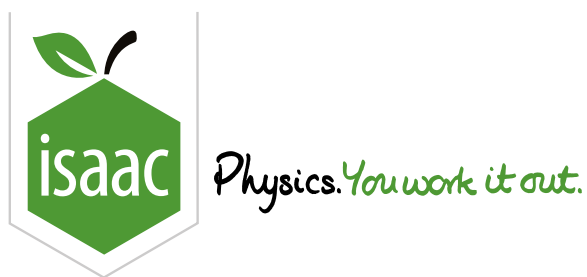Find the exact value of the coefficient of restitution between P and the wall.

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 $\underline{I}$ and is in a direction making an angle of θ with the upward vertical through B, as shown in **Figure 1**.
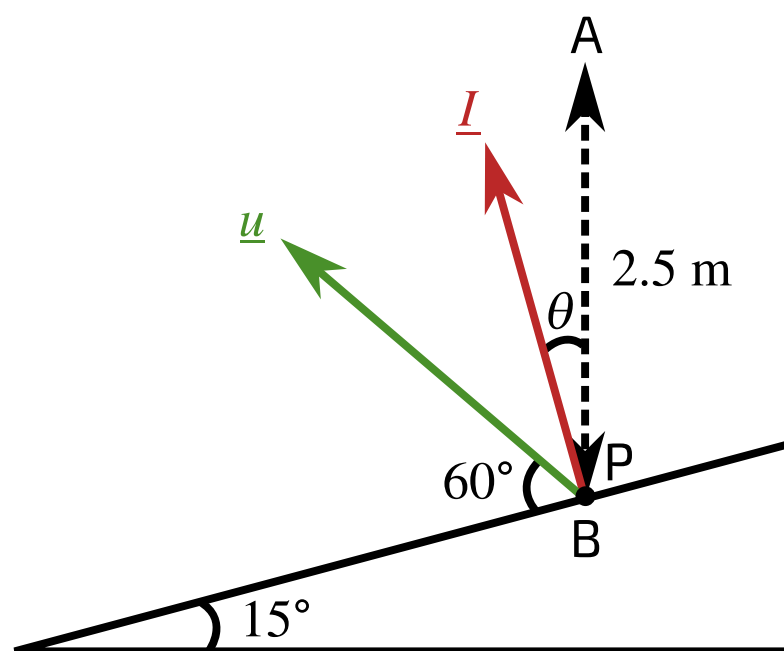

Figure 1: The inclined plane onto which P falls, with the impulse $\underline{I}$ and the rebound velocity $\underline{u}$ shown.

Part A   Modelling assumptions

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

○   The collision is elastic.

○   The plane is rough.

○   The plane is smooth.

○   Ignore air resistance.

Part B   Find u

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

Part C   Find I

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

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

Gameboard:

STEM SMART Double Maths 45 - Momentum, Impulse and Collisions

isaac **Physics.** *You work it out.*

Restitution: Sphere Collision

Further A

c   c   c

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**.

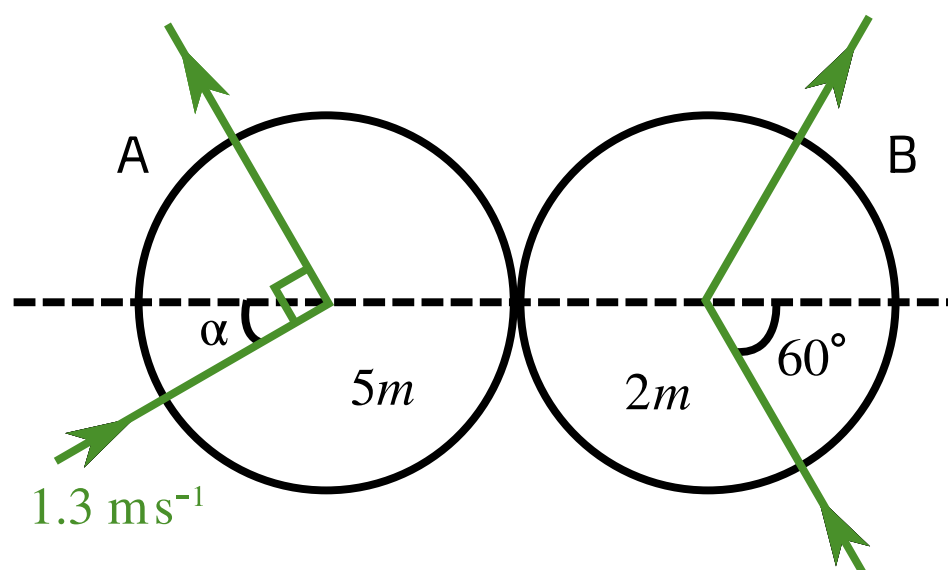The coefficient of restitution between A and B is $\frac{5}{6}$.

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

Part A   Speed after collision

Find the speed of A after the collision.
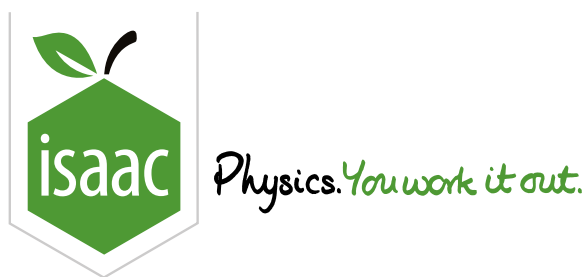
Part B   Component of velocity

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

Gameboard:

STEM SMART Double Maths 45 - Momentum, Impulse and Collisions

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 $\frac{2}{3}$.
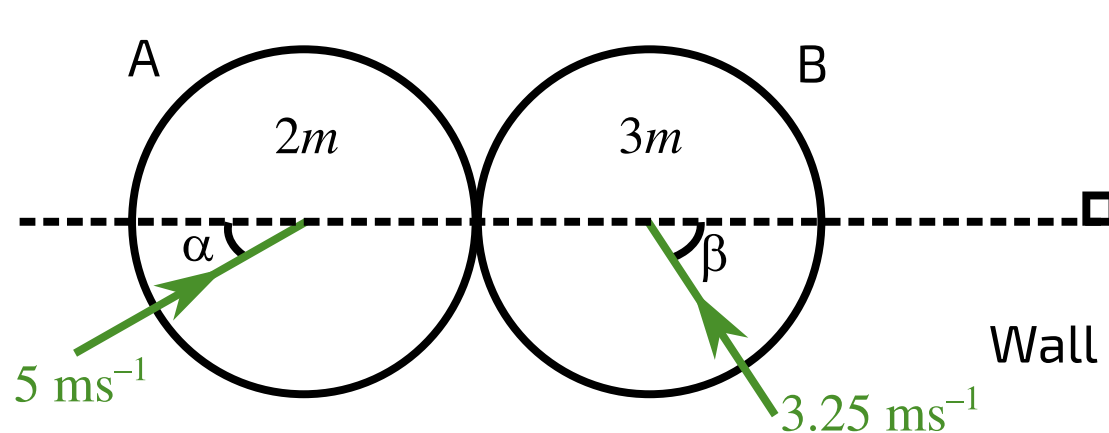

Figure 1: A and B collide with each other, with the line of centres shown. A wall is to right of B and is perpendicular to the line of centres.

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:

$\boxed{\textbf{faster than}}$ $\boxed{\frac{1}{2}}$ $\boxed{2.25}$ $\boxed{5}$ $\boxed{\textbf{the same}}$ $\boxed{\textbf{slower than}}$ $\boxed{<}$ $\boxed{3.75}$ $\boxed{\frac{4}{9}}$ $\boxed{\frac{9}{5}}$ $\boxed{=}$ $\boxed{\textbf{different}}$ $\boxed{1.25}$ $\boxed{3.25}$ $\boxed{>}$ $\boxed{\frac{5}{9}}$

$\boxed{3}$ $\boxed{\frac{13}{15}}$

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