Kinetic energy lost in a collision

92 marks

Hints online, answers free with an account: mathswariz.uk/worksheets/ocr-further-maths-mech-collision-energy/

Date

A Do Now

Quick questions to start.

A1 Needed today [2 marks]

A sphere of mass $0.5\ \text{kg}$ moves at $6\ \text{m s}^{-1}$. Find its kinetic energy. Does the answer depend on its direction?

Answer .....

A2 Last lesson [3 marks]

Spheres A and B each have mass $2\ \text{kg}$. A moves at $4\ \text{m s}^{-1}$ and hits B, which is at rest. The coefficient of restitution is 0.5. Find the velocities after the collision.

Answer .....

A3 From chapter 2 [2 marks]

A particle of mass $2\ \text{kg}$ slows from $7\ \text{m s}^{-1}$ to $3\ \text{m s}^{-1}$. Find the kinetic energy it loses.

Answer .....

A4 Needed today [2 marks]

Solve $1 - e^2 = 0.36$, given that $0 \leqslant e \leqslant 1$.

Answer .....

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Your teacher works each example with you (I do). You try the one beside it together (We do). Then practise that part on your own (You do).

PART 1 Kinetic energy lost when the velocities are given

EXAMPLE 1 · I DO

Sphere A of mass $3\ \text{kg}$ moves at $4\ \text{m s}^{-1}$. Sphere B, of equal radius and mass $1\ \text{kg}$, moves at $2\ \text{m s}^{-1}$ in the same direction. After A catches B, they move in the same direction at $3.2\ \text{m s}^{-1}$ and $4.4\ \text{m s}^{-1}$. Find the kinetic energy lost in the collision.

Hint Add the kinetic energies of both spheres before, then both after. The loss is before minus after. Square each speed on its own.

YOUR TURN · WE DO

B1 Sphere A of mass $2\ \text{kg}$ moves at $3\ \text{m s}^{-1}$. Sphere B, of equal radius and mass $1\ \text{kg}$, moves at $4\ \text{m s}^{-1}$ towards A. After the collision A moves at $1\ \text{m s}^{-1}$ with its direction reversed, and B moves at $4\ \text{m s}^{-1}$ with its direction reversed. Find the kinetic energy lost. [4 marks]

Answer .....

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C1 Sphere A of mass $4\ \text{kg}$ moves at $5\ \text{m s}^{-1}$ and hits sphere B, of equal radius and mass $1\ \text{kg}$, which is at rest. Afterwards A moves at $3\ \text{m s}^{-1}$ and B at $8\ \text{m s}^{-1}$, both in A's original direction. Sam writes: [4 marks]

$$\text{loss} = \tfrac{1}{2}(4)(5^2) - \tfrac{1}{2}(4)(3^2) = 32\ \text{J}.$$

Explain Sam's mistake, find the true loss, and name this type of collision.

Answer .....

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C2 Sphere A of mass $0.5\ \text{kg}$ moves at $4\ \text{m s}^{-1}$. Sphere B, of equal radius and mass $0.3\ \text{kg}$, moves at $2\ \text{m s}^{-1}$ towards A. After the collision A moves at $0.2\ \text{m s}^{-1}$ with its direction reversed. Find the velocity of B after the collision and the kinetic energy lost. [5 marks]

Answer .....

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PART 2 Finding the velocities first, then the loss

EXAMPLE 2 · I DO

Particle A of mass $4\ \text{kg}$ moves at $5\ \text{m s}^{-1}$ and collides with particle B of mass $1\ \text{kg}$, which is at rest. They coalesce. Find the kinetic energy lost.

Hint Find the common velocity from momentum first. After the collision there is one particle of mass $4 + 1$.

YOUR TURN · WE DO

B2 Particle A of mass $3\ \text{kg}$ moves at $6\ \text{m s}^{-1}$. Particle B of mass $2\ \text{kg}$ moves at $4\ \text{m s}^{-1}$ towards A. They collide and coalesce. Find the velocity of the combined particle and the kinetic energy lost. [4 marks]

Answer .....

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EXAMPLE 3 · I DO

Sphere A of mass $2\ \text{kg}$ moves at $6\ \text{m s}^{-1}$ and hits sphere B, of equal radius and mass $4\ \text{kg}$, which is at rest. The coefficient of restitution is 0.5. Find the kinetic energy lost.

Hint You need the velocities after before you can find the kinetic energy after. Use momentum and restitution first.

YOUR TURN · WE DO

B3 Sphere A of mass $3\ \text{kg}$ moves at $5\ \text{m s}^{-1}$ and hits sphere B, of equal radius and mass $2\ \text{kg}$, which is at rest. The coefficient of restitution is 0.2. Find the velocities after the collision and the kinetic energy lost. [6 marks]

Answer .....

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C3 Spheres A and B each have mass $1\ \text{kg}$. A moves at $6\ \text{m s}^{-1}$ and hits B, which is at rest. Find the kinetic energy lost when (i) $e = 0$, (ii) $e = 1$. Which value of e gives the greatest loss? Where does the lost kinetic energy go? [4 marks]

Answer .....

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C4 Sphere A of mass $4\ \mathrm{kg}$ moves at $5\ \mathrm{m\,s^{-1}}$. Sphere B, of equal radius and mass $2\ \mathrm{kg}$, moves at $2\ \mathrm{m\,s^{-1}}$ in the same direction. A catches B and the coefficient of restitution is 0.5. Find the velocities after the collision and the kinetic energy lost. [6 marks]

Answer .....

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PART 3 Percentage loss

EXAMPLE 4 · I DO

Sphere A of mass $2\ \text{kg}$ moves at $5\ \text{m s}^{-1}$. Sphere B, of equal radius and mass $2\ \text{kg}$, moves at $1\ \text{m s}^{-1}$ in the same direction. After A catches B, they move in the same direction at $2\ \text{m s}^{-1}$ and $4\ \text{m s}^{-1}$. Find the kinetic energy lost as a percentage of the kinetic energy before the collision.

Hint The percentage is out of the kinetic energy BEFORE the collision.

YOUR TURN · WE DO

B4 Sphere A of mass $3\ \text{kg}$ moves at $4\ \text{m s}^{-1}$. Sphere B, of equal radius and mass $1\ \text{kg}$, moves at $4\ \text{m s}^{-1}$ towards A. The coefficient of restitution is 0.5. Find the velocities after the collision, and the kinetic energy lost as a percentage of the kinetic energy before. [6 marks]

Answer .....

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EXAMPLE 5 · I DO

Sphere A of mass $2\ \text{kg}$ moves at $6\ \text{m s}^{-1}$ and hits sphere B, of equal radius and mass $1\ \text{kg}$, which is at rest. The kinetic energy lost is $9\ \text{J}$. Find the coefficient of restitution.

Hint Find v_A and v_B in terms of e, then write the loss in terms of e. Keep only the root with $0 \leqslant e \leqslant 1$.

YOUR TURN · WE DO

B5 Spheres A and B of equal radius each have mass $2\ \text{kg}$. A moves at $4\ \text{m s}^{-1}$ and hits B, which is at rest. The kinetic energy lost is $5.12\ \text{J}$. Find the coefficient of restitution. [6 marks]

Answer .....

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C5 Particle A of mass $2\ \text{kg}$ moves at $u\ \text{m s}^{-1}$ and collides with particle B of mass $3\ \text{kg}$, which is at rest. They coalesce, and $15\ \text{J}$ of kinetic energy is lost. Find u. [4 marks]

Answer .....

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C6 Sphere A of mass $1\ \mathrm{kg}$ moves at $6\ \mathrm{m\,s^{-1}}$ and hits sphere B, of equal radius and mass $3\ \mathrm{kg}$, which is at rest. In the collision 48% of the kinetic energy is lost. Find the coefficient of restitution, and the velocities of A and B after the collision. [7 marks]

Answer .....

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D1

> Alex says: “In an inelastic collision all of the kinetic energy is lost.”

Particle A of mass $3\ \text{kg}$ moves at $6\ \text{m s}^{-1}$. Particle B of mass $1\ \text{kg}$ moves at $2\ \text{m s}^{-1}$ in the same direction. A catches B and they coalesce.

(a) Find the velocity of the combined particle. [2 marks]

Answer .....

(b) Find the kinetic energy lost. [3 marks]

Answer .....

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(c) Explain why Alex is wrong. State what happens to the kinetic energy that is lost. [3 marks]

Total for D1: 8 marks

D2 Sphere A of mass $2m$ moves with speed u and hits sphere B, of equal radius and mass m, which is at rest. The coefficient of restitution is e.

(a) Find the velocities of A and B after the collision, in terms of e and u. [4 marks]

Answer .....

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(b) Show that the kinetic energy lost is $\frac{1}{3}mu^2(1-e^2)$. [4 marks]

(c) State the fraction of the kinetic energy that is lost when $e = 0$, and the fraction when $e = 1$. Explain why no value of e can give a larger fraction than the first. [3 marks]

Total for D2: 11 marks

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E Extension

Stretch

No route is given. The hints are at the end of the sheet. Use one at a time.

E1 Particle A of mass m moves with speed $2u$. Particle B of mass km moves with speed u towards A. The particles collide and coalesce, and nine tenths of the total kinetic energy is lost. Find the possible values of k. For each value, find the velocity of the combined particle. [8 marks]

Answer .....

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Extension hints

Cover these with paper. Uncover one at a time.

E1

Hint 1 Find the velocity of the combined particle in terms of k and u, with B's velocity before as $-u$.

Hint 2 Write the kinetic energy before and after. Nine tenths lost means the energy after is one tenth of the energy before.

Hint 3 Clear the fractions to get a quadratic in k. Keep both roots, and check the direction of motion for each.

How did it go?

Colour one circle on each line: not yet, nearly, yes.

I can find the kinetic energy lost in a collision, using both particles before and after.	○ ○ ○
I can find the loss as a percentage of the kinetic energy before the collision.	○ ○ ○
I can use a given loss of kinetic energy to find e, a speed or a mass.	○ ○ ○
I can explain what $e = 1$ and $e = 0$ mean for the kinetic energy.	○ ○ ○

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