AS Level Physics

Chapter 6 – Newton's Law of Motion and Momentum

6.2.2 Collisions

Worked Examples

Collisions

Exam Style Question 1

a) State, in words, Newton's second law of motion.

b) Fig. 1.1 shows the masses and velocities of two objects A and B moving directly towards each other. A and B stick together on impact and move with a common velocity, v.

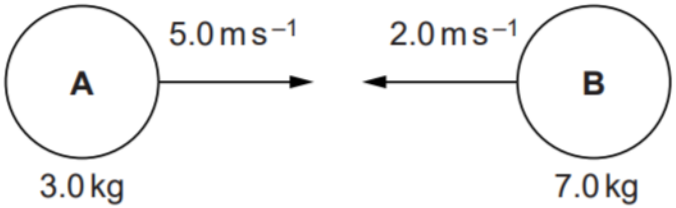

Fig. 1.1

i) Determine the velocity v.

ii) Determine the impulse of the force experienced by the object A and state its direction.

iii) Explain, using Newton's third law of motion, the relationship between the impulse experienced by A and the impulse experienced by B during the impact.

Collisions

Exam Style Question 1

Answer:

a) State, in words, Newton's second law of motion

Rate of change of momentum of a body is proportional to the net force acting on it and takes place in the direction of that force.

bi) Determine the velocity v.

Total momentum before = Total momentum after

$$m_1v_1 + m_2v_2 = m_3v_3$$

$$(3\ kg \times 5.0\ m\ s^{-1}) + (7.0\ kg \times -2.0\ m\ s^{-1}) = (10\ kg)v_3$$

$$15kg\ m\ s^{-1} - 14\ kg\ m\ s^{-1} = 10v_3$$

$$\therefore v_3 = \frac{15 - 14}{10}$$

$$v_3 = 0.1\ m\ s^{-1}$$

Therefore the velocity is $0.1\ m\ s^{-1}$ to the right.

Collisions

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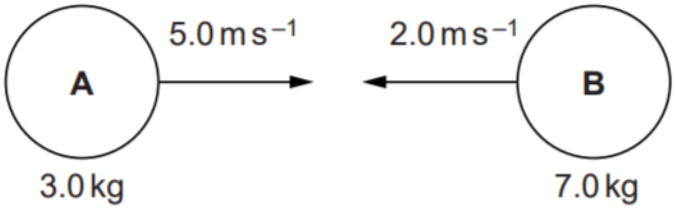

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Collisions

Exam Style Question 1

Answer:

bii) Determine the impulse of the force experienced by the object A and state its direction.

Use: $impulse = F\Delta t = m(v-u)$

$$impulse = m(v-u)$$

$$impulse = 3\ kg(0.1\ m\ s^{-1} - 5\ m\ s^{-1})$$

$$impulse = -14.7\ N\ s$$

Negative sign indicates the direction, in this case the negative sign means the object is moving to the left.

Therefore the impulse of the force experienced by the object A is 14.7 $N\ s$ to the left.

biii) Explain, using Newton's third law of motion, the relationship between the impulse experienced by A and the impulse experienced by B during the impact.

Newtons 3rd law says that if an object A exerts a force on object B, then object B exerts an equal and opposite force on object A.
We also know $impulse = Ft$ and time of contact is the same for both objects. Therefore impulse on A is equal and opposite to impulse on B.

Collisions

Exam Style Question 2

ai) State the principle of conservation of linear momentum.

aii) Explain what is meant by an inelastic collision.

aiii) Fig. 1.1 shows the head-on-collision of two blocks on a frictionless surface.

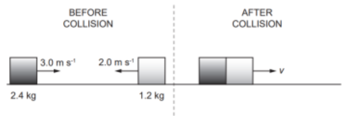

Fig. 1.1

Before the collision, the $2.4\ kg$ block is moving to the right with a speed of $3.0\ m\ s^{-1}$ and the $1.2\ kg$ block is moving to the left at a speed of $2.0\ m\ s^{-1}$. During the collision the blocks stick together. Immediately after the collision the blocks have a common speed v.

Calculate the speed v.

Show that this collision is inelastic.

b) Fig 1.2 shows a helicopter viewed from above.

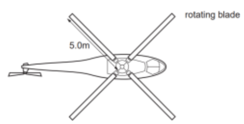

Fig. 1.2

The blades of the helicopter rotate in a circle of radius $5.0\ m$. When the helicopter is hovering, the blades propel air vertically downwards with a constant speed of $12\ m\ s^{-1}$. Assume that the descending air occupies a uniform cylinder of radius $5.0\ m$.

The density of air is $1.3\ kg\ m^{-3}$.

i) Show that the mass of air propelled downwards in a time of 5.0 seconds is about $6000\ kg$.

ii) Calculate

1) The momentum of this mass of descending air.

2) The force provided by the rotating helicopter blades to propel this air downwards.

3) The mass of the hovering helicopter.

Collisions

Exam Style Question 2

Answer:

ai) State the principle of conservation of linear momentum.

Total momentum is constant/conserved.

aii) Explain what is meant by an inelastic collision.

An Inelastic collision is where kinetic energy (KE) is NOT conserved however momentum is conserved.

aiii) Calculate the speed v.

Total momentum before = Total momentum after

$$m_1v_1 + m_2v_2 = (m_1 + m_2)v_3$$

$$(2.4kg \times 3ms^{-1}) + (1.2kg \times -2ms^{-1}) = (2.4kg + 1.2kg)(v_3)$$

$$7.2\ kg\ ms^{-1} - 2.4\ kg\ ms^{-1} = 3.6v_3$$

$$3.6v_3 = 4.8$$

$$\boldsymbol{v_3 = 1.3\ ms^{-1}\ to\ the\ right}$$

Show that the collision is inelastic.

For a collision to be inelastic momentum is conserved and KE is not conserved.
We already know that the momentum is conserved because that's what we assumed for the previous question so we just have to find out the kinetic energy before and after the collision to see if they are equal.

Kinetic energy before does not equal to the KE after the collision therefore this collision is inelastic.

Before:

$$E_K\ total = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

$$\left(\frac{1}{2} \times 2.4kg \times (3ms^{-1})^2\right) + \left(\frac{1}{2} \times 1.2kg \times (2ms^{-1})^2\right)$$

$$E_K\ total\ Before = 13.2J$$

After:

$$E_K\ total = \frac{1}{2}(m_1 + m_2)v_3^2$$

$$\left(\frac{1}{2} \times (2.4kg + 1.2kg) \times (1.3ms^{-1})^2\right)$$

$$E_K\ total\ After = 3.042\ J$$

EXPLOSIONS

Exam Style Question 2

ai) State the principle of conservation of linear momentum.

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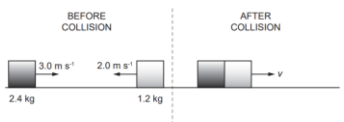
aiii) Fig. 1.1 shows the head-on-collision of two blocks on a frictionless surface.



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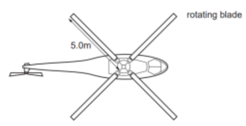
Calculate the speed v.

b) Fig 1.2 shows a helicopter viewed from above.



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The density of air is $1.3\ kg\ m^{-3}$.

i) Show that the mass of air propelled downwards in a time of 5.0 seconds is about $6000\ kg$.

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1) The momentum of this mass of descending air.

2) The force provided by the rotating helicopter blades to propel this air downwards.

3) The mass of the hovering helicopter.

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Collisions

Exam Style Question 2

Answer:

bi) Show that the mass of air propelled downwards in a time of $\mathbf{5.0}$ seconds is about $\mathbf{6000\ kg}$.

Use $density = \frac{mass}{volume}$ and rearrange for $mass$.

$$\therefore mass = density \times volume$$

We have density and we have been told to assume the descending air occupies a uniform cylinder of radius $5.0\ m$:

$$\therefore volume = volume\ of\ a\ cylinder = \pi r^2 h$$
$$volume = \pi(5.0^2)(12\ m\ s^{-1})(5.0\ seconds)$$
$$volume = 1500\pi\ m^3$$

Because the helicopter is hovering, and the blades are propelling air vertically downwards at $12\ ms^{-1}$ for 5 seconds we can calculate the height of the cylinder by doing $12 m\ s^{-1} \times 5\ s = 60\ m$. Therefore, the height of the cylinder is 60m.

Now calculate the mass:

$$mass = (1.3\ kg\ m^{-3})(1500\pi\ m^3)$$
$$mass = 6126.105675\ kg$$

Therefore mass of air propelled downwards is about $6000\ kg$.

bii1) Calculate The momentum of this mass of descending air.

$$momentum = mass \times velocity$$
$$momentum = 6126.105675\ kg \times 12\ m\ s^{-1}$$
$$momentum = 73513.26809\ kg\ ms^{-1}$$
$$\therefore momentum = 7.4 \times 10^4\ kg\ ms^{-1}$$

bii2) Calculate The force provided by the rotating helicopter blades to propel this air downwards.

$$Force = \frac{\Delta momentum}{\Delta time}$$
$$Force = \frac{73513.26809\ kg\ ms^{-1}}{5\ seconds}$$
$$Force = 14702.65362\ N$$
$$Force = 14700\ N$$

biii3) calculate The mass of the hovering helicopter.

We know that the force provided by the rotating helicopter blades is 14700 N. This provides the upwards force. As the helicopter is hovering, it is in equilibrium and so the upwards force is equal to the downwards force. Therefore the weight of the helicopter is 14700 N. Using this weight we can calculate the mass:

$$W = mg$$
$$\therefore m = \frac{W}{g} = \frac{14702.65362\ N}{9.81\ ms^{-2}} = 1498.741449\ kg$$

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Please see **'6.2.1 Collisions notes'** pack for revision notes.

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