On momentum

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Warm-up problems

1. Give the definition of *momentum* in physics. What formula can be used to work it out and what is the unit used to measure it?

2. Energy and momentum are both special quantities in physics, because they are both *conserved*. Explain what this means and how it can be useful.

3. What happens to the momentum of an object if a force is applied? Can you write this relationship down in a word equation which relates momentum to force?

Regular problems

4. In each situation, calculate the momentum of the object.

   (a) A child of mass 40 kg riding on a skateboard at a speed of 2 m/s.

   (b) A pebble of mass 100 g flying from a catapult at 15 m/s.

   (c) A car of mass 1250 kg travelling at 10 m/s.

5. A body of mass 4 kg moves with a velocity of 2 m/s and collides head on with another body of mass 4 kg which is stationary to begin with. The two stick together.

   (a) Draw a diagram of the situation before the collision.

   (b) What is the momentum of each body before the collision?

   (c) Draw a second diagram to show the situation after the bodies have stuck together.

   (d) What is the speed of the composite object formed by the two bodies after the collision?

6. Two skateboarders are standing on their skateboards at a skatepark. Alice weighs 80 kg and Bob weighs 60 kg. They push away from each other, and Alice starts to move at 3 m/s.

   (a) Draw a diagram of the situation, showing which way each of the skaters will move, their masses and Alice's velocity.

   (b) What is the total momentum of Alice and Bob before they push off?

   (c) What is Alice's momentum afterwards?

   (d) What is Bob's momentum afterwards?

(e) What speed does Bob move off with?

(f) What is the total momentum afterwards?

7. A bullet of mass 6 g is fired from a gun of mass 0.5 kg. The velocity of the bullet is 300 m/s. What is the recoil velocity of the gun?

8. A bullet of mass 45 g is travelling horizontally at 400 m/s when it strikes a wooden block of mass 16 kg that is suspended from a piece of string. The bullet becomes embedded in the block.

   (a) Using conservation of momentum, calculate the velocity at which the block begins to move,

   (b) The block swings upwards. Calculate the height to which it swings

   (c) Calculate the amount of the bullet's kinetic energy that is converted to sound and heat.

Extension problems

9. A large drop of rain is falling vertically. It strikes a stationary caterpillar[1], of mass 1 g, on the edge of a leaf. The drop is in contact with the caterpillar for 0.1 ms (1 ms is 1/1000 s) and the caterpillar moves off as a result of the impact, with a velocity of 2 m/s downwards.

   (a) Draw a diagram of this situation, showing all the relevant information.

   (b) What is the momentum change, **in kg m/s**, of the caterpillar?

   (c) What kinetic energy does the caterpillar leave the leaf with?

   (d) If the leaf is in a tree, 10 m above the ground, how much energy (from gravitational potential) does the caterpillar gain during its fall?

10. A particle of mass $5m$ moving with a speed of v explodes and splits into two pieces, with masses $2m$ and $3m$. The lighter piece continues to move in the same direction with a velocity $5v$ relative to the heavier piece. What is the actual velocity of the lighter piece?

[1]Small caterpillars crawl under leaves when heavy rain falls. It isn't that they just want to keep dry, they also need to avoid the devastating blow of a direct hit from a raindrop, which could prove fatal.