Mixed questions

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$$\text{Force} = \frac{\text{change in momentum}}{\text{time}}$$

$$\text{momentum} = \text{mass} \times \text{velocity}$$

$$\text{work done by a force} = \text{Force} \times \text{distance moved in the direction of the force}$$

$$\text{kinetic energy} = \frac{1}{2} \times \text{mass} \times \text{velocity}^2$$

$$\text{gravitational potential energy} = \text{weight} \times \text{height}$$

1. A cannon of mass 200 kg stands on the deck of a ship of mass 50 000 kg. This cannon fires a cannonball of mass 5 kg north at 250 m/s. The cannon recoils, but is restrained by its gun crew.
   (a) Will the boat move? If so, which way?
   (b) What was the total momentum of the cannon, cannonball and boat before the shot is fired?
   (c) What is the momentum of the cannonball as it is fired?
   (d) What is the momentum of the boat and cannon after the cannon is restrained?
   (e) How fast will the boat move?

2. Two skateboarders are standing on their skateboards at a skatepark. Alice weighs 80 kg and Bob weighs 60 kg. They puch 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?

3. A car of mass 1000 kg is moving at 20 m/s. The driver applies the brakes, and the car comes to a standstill in a distance of 50 m, which takes 5 s.
   (a) What is the momentum of the car to start with?

(b) What is the kinetic energy of the car to start with?

(c) What is the momentum of the car at the end?

(d) What force has been applied by the brakes on the car?

(e) How much energy has been absorbed by the brakes (hint: think about how much work the car has done on the brakes)?

4. A car of mass 1000 kg is attached to pulls a caravan of mass 800 kg. The car and carvan accelerate from rest to a speed of 15 m/s in a time of 5 s. During this time, the car covers 37.5 m.

(a) What is the change in momentum?

(b) What is the total force exerted by the car's wheels on the road (the driving force)?

(c) What is the work done by the engine in driving?

(d) What is the force of the car on the caravan?

(e) What is the force of the caravan on the car?

(f) Show that the total impulse (Force $\times$ time) is equal to the car's change in momentum.

5. 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 is the force exerted on the caterpillar?

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

(e) 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?

[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.