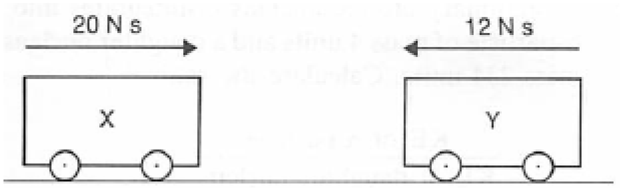
Collisions Supplementary Questions

Study Guide 19

Part 1 - Conservation of Momentum

1.



The figure shows two trolleys X and Y just before they collide, with their associated momenta. If the trolleys travel in opposite directions after the collision, and the momentum of X is 3 N s, what is the magnitude of the corresponding momentum of Y?

2. A cannon of mass 1.5 tonnes fires a cannon-ball of mass 5 kg. The speed with which the ball leaves the cannon is 70 m/s relative to the Earth. What is the initial speed of recoil of the cannon?

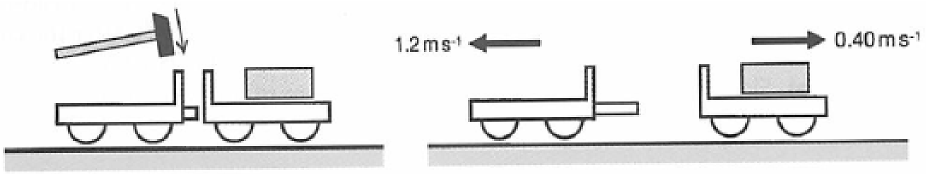
3. A block of wood of mass 1.4 kg, initially at rest, is free to slide on a horizontal surface. A bullet of mass 0.12 kg travelling at a speed of 780 m/s is fired horizontally at the block and becomes embedded in it. Immediately after the collision, what speed do the bullet and block move off with?

4. Two railway trucks, A and B, of masses 500 kg and 800 kg travelling on the same line in opposite directions with speeds of 5.0 m/s and 8.0 m/s respectively, collide so that truck A, after impact, has reversed its direction and has a speed of 4.0 m/s. Find the velocity of B after impact.

5. Two air-track trucks are at rest with a compressed spring between them. A rope tied to both trucks prevents them from moving apart. When the rope is burned through, one truck moves away with a speed of 0.32 m/s, and the other moves in the opposite direction with a speed of 0.45 m/s. If the first truck has a mass of 0.40 kg, determine the mass of the other truck.

6. Six identical trucks are at rest and coupled to each other on a horizontal track. A seventh similar truck moving at 1 m/s collides and couples with the others. Ignoring friction and other resistive forces, determine the speed at which the seven trucks will move off at.

7. The diagram shows two trucks that are at rest which are then catapulted apart by the release of a spring-loaded piston located on one of the trucks. Each truck has a mass of 1.0 kg, but one of the trucks carries a block of mass m. Using the supplied data, determine the mass of the block.



8. An astronaut of mass 70 kg becomes detached from his space shuttle whilst carrying out repairs, floating at a distance of 15 m away from it. Determine the velocity with which he must throw away his tool box, which has a mass of 20 kg, if he is to get back to the shuttle in 30 seconds.

9*. A body of mass m travelling with speed 6u collides and coalesces with a body of mass 4m travelling in the same direction with speed 2u. Compute the speed with which the two bodies travel together.

10*. Three identical railway trucks, each of mass m, are coupled together and are at rest on a smooth horizontal section of track. A fourth truck of mass 3m moving at 6 m/s collides and couples with the stationary trucks. After impact the speed of the trucks is v. Determine the value of v.

11. A girl and a boy sit at opposite ends of a stationary rowing-boat and throw a heavy ball back and forth between them. The boat is not anchored.

    i) Describe and explain its motion while they are playing catch. Ignore the effects of air and water resistance.

    ii) The girl transfers to a second, similar boat, also stationary and unanchored. They re-start their game of catch. Describe and explain the motion of the two boats.

12*. In the event of the entire world's population arriving on the Isle of Wight for a rock festival it would be crowded. Consider what happens to the Earth's motion, when at this imaginary event everyone is instructed to jump upwards on a given signal - perhaps a guitar chord sufficiently amplified. Assume the average mass of a person is 60 kg, the average jump height is 0.5 m, and the mass of the earth is 6.0×10^{24} kg and that there are 7.0×10^{9} people.

Part 2 - Energy and Momentum - Elastic and Inelastic Collisions

1. A railway wagon of mass 15 tonnes which has a speed of 5 m/s collides head on with a wagon of mass 10 tonnes travelling at 2 m/s. They couple together on impact. Find:
   i) the speed of the coupled wagons after the collision;
   ii) the kinetic energy transformed to other forms in the collision.

2. A sphere of mass 3 kg moving with velocity 4 m/s collides head-on with a stationary sphere of mass 2 kg and imparts to it a velocity of 4.5 m/s. Determine:
   i) the velocity of the 3 kg sphere after the collision;
   ii) the amount of energy lost by the moving bodies in the collision;
   iii) if the collision is elastic or inelastic.

3. In an elastic head-on collision, a ball of mass 1 kg moving at 4 m/s collides with a stationary ball of mass 2 kg. Calculate the velocities of the balls after the collision, indicating the direction in which they are travelling.

4. A particle A of mass m moving with an initial velocity u makes a head on collision with another particle B of mass 2m, B being initially at rest. In terms of u, calculate the final velocity of A if the collision is:
   i) perfectly elastic;
   ii) perfectly inelastic.

5. A carbon atom of mass 12 u travelling to the right with a speed of 1.200×10^6 m/s is involved in a head-on collision with a neutron of mass 1.000 u travelling to the left with a speed of 3.200×10^7 m/s.
   a) If the subsequent motion of the neutron is to the right with a speed of 2.929×10^7 m/s,
      i) find the velocity of the carbon atom;
      ii) show that the collision is elastic.
   b) If the neutron is absorbed by the carbon atom to form another isotope, find the velocity of this isotope.

N.B.

The u is a non-S.I. unit which is defined in terms of ^{12}C and most often used in nuclear physics calculations. In this question you can use it for the unit of mass but this would not have been the case if you had to calculate kinetic energies, where the kg would be essential.

6. An unstable but stationary Uranium-238 nucleus fissions into an alpha-particle of mass 4 u and the daughter nucleus Thorium-234. Determine the ratio of the kinetic energy of the alpha-particle to that of the Thorium-234 nucleus.

7*. A 1050 kg car is stopped on an icy road at the bottom of a hill which rises 1 m for every 12.5 m along the road. The car is hit from behind by a truck of mass 6700 kg which is moving at 50 km/h. The collision is perfectly inelastic. Calculate the distance up the hill which the combined wreckage slides.

8*. A bullet of mass 1.3×10^{-2} kg is fired horizontally. The bullet strikes and becomes embedded in a stationary block of mass 0.9 kg, which is suspended by a massless cord so that it can swing freely. The block and bullet together swing to a vertical height of 1.12 m.
Determine the initial speed of the bullet.

9*. A mass of 5 kg initially at rest disintegrates explosively into two fragments of mass 2 kg and 3 kg respectively. Calculate the ratio of the kinetic energy of the 2 kg fragment to that of the 3 kg fragment immediately after the explosion.

10*. A body, initially at rest, explodes into two fragments of mass M and 3M, whose combined total kinetic energy is E. Determine the kinetic energy of the fragment of mass M in terms of E.

11**. A moving particle of mass m collides with a particle of mass M ($M > m$) which is initially stationary. As a result of the collision, the particle of mass m is brought to rest. Determine the fraction of the original kinetic energy that remains after the collision in terms of m and M.

12**. A particle travelling along a straight line with velocity v explodes into two equal parts. The explosion causes the kinetic energy of the system to be doubled. Assuming that the forces of the explosion act along the initial line of travel, determine the velocities of the two parts of the body after the explosion.

Answers - Collisions Supplementary Questions

Part 1

1. 11 N s
2. 0.233 m/s
3. 61.6 m/s
4. 2.38 m/s
5. 0.284 kg
6. 0.143 m/s
7. 2 kg
8. 1.75 m/s

9*. 2.8 u

10*. 3 m/s

12*. Earth moves at 2.2×10^{-13} m/s

Part 2

1. i) 2.2 m/s ii) 147,000 J
2. i) 1 m/s ii) 2.25 J iii) Inelastic
3. 2.67 m/s, 1.33 m/s
4. i) 2u/3, -u/3 ii) u/3
5. a) i) 3.91×10^6 m/s b) 1.35×10^6 m/s (to the left)
6. 58.5

7*. 91.9 m

8*. 329 m/s

9*. 1.5

10*. 3E/4

11**. m/M

12**. One particle is stationary whilst the other travels at 2v in the initial direction of travel.