Momentum Notes

Momentum – as with energy, momentum is a useful property of an object in motion as it is always conserved in collisions. Conservation of momentum is used to understand events in many areas of Physics.

Equation: $\vec{p} = m\vec{v}$ units: $m\,(kg)$ $\vec{v}\,(\frac{m}{s}) \rightarrow \frac{kg \cdot m}{s}$ [ ]

Linear Momentum is a vector that is in the same direction as the velocity vector.

Eg. What is the momentum of a 5.0 kg groundhog traveling at 1.3 m/s [S]?

$m = 5.0\,kg$
$\vec{v} = 1.3\,\frac{m}{s}[S]$

So: $\vec{p} = (5.0\,kg)(1.3\,\frac{m}{s}[S])$
$= 6.5\,\frac{kg \cdot m}{s}[S]$

Impulse is the change of momentum over time by an unbalanced net Force.

Remember: F = ma

$\vec{a} = \frac{v_f - v_i}{t}$ (uniform $\vec{a}$) → sub

$F = m\left(\frac{v_f - v_i}{t}\right)$

$Ft = m(v_f - v_i)$

$= mv_f - mv_i$

since $\vec{p} = m\vec{v}$

$\vec{F}t = \Delta\vec{p}$

impulse = change of momentum.

Eg. A 0.16 kg hockey puck traveling at 5.0 m/s [N] is hit for 0.0020 s and changes velocity to 40.0 m/s [S].

a) What is the impulse imparted by the hockey stick?

$J = Ft = \Delta\vec{p} = m(v_f - v_i) = (0.16\,kg)(40.0\,m/s\,[S] + 5.0\,m/s\,[S])$

$= 7.2\,N \cdot s$ ← units for impulse

b) What is the average force applied by the stick to the puck?

$Ft = 7.2\,N \cdot s$

$\vec{F} = \frac{7.2}{0.002\,s} = 3600\,N\,[S]$

original.

PHYSICS 11 MOMENTUM ETC. WORKSHEET 1

1. A 75 g mouse runs across the floor with a speed of 2.6 m/s. What is its momentum?

2. What is the impulse of a 55 N force exerted over a time interval of 1.0 ms (= 0.001 s)?

3. a) What impulse is needed to change the speed of a 10.0 kg object from 12.6 m/s to 25.5 m/s?
   b) If the impulse takes place in a time interval of 5.00 s, what force acts on this object?

4. a) What impulse must act on a 100 g baseball to change its velocity from 40.0 m/s to -50.0 m/s?
   b) If the impulse takes place in 1.20 ms, what force has acted on the baseball?

5. An unbalanced force of 25 N acts for 5.0 s on an object originally at rest. If the object has a mass of 0.150 kg,
   a) what impulse is delivered to the object?
   b) what speed does the object obtain at the end of the 5 seconds?

6. When Roger Federer serves a tennis ball, it leaves his racket with a velocity of 65.0 m/s. If the ball's mass is 60.0 g and is in contact with the racket for 0.030 s,
   a) what is the average force on the ball?
   b) what is the impulse of this force?

7. A mass of 6.3 kg, traveling at 6 m/s, is given an impulse of -31.5 N·s. What is the velocity of the mass after the impulse?

8. A 90.0 kg fullback is running at a speed of 5.0 m/s and is stopped by a tackler in 0.5 s. Calculate:
   a) the <u>original</u> momentum of the fullback.
   b) the impulse imparted to the tackler.
   c) the average force exerted on the tackler.

9. a) Calculate the impulse "suffered" by a 70.0 kg man who lands on firm ground after jumping from a height of 5.0 m. (hint: first find the speed at which the man hits the ground by using kinematics)
   b) What average force would be exerted on the man in the collision if he bent his knees and absorbed the fall over 0.15 s?
   c) What average force would be exerted on the man in the collision if he locked his knees and absorbed the fall over 0.0002 s?

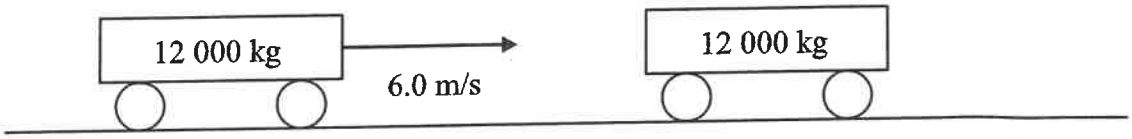
1. 0.195 kg-m/s 2. 0.055 N-s 3. a) 129 N-s b) 25.8 N 4. a) -9.0 N-s b) -7500 N 5. a) 125 Ns b) 833 m/s
6. a) 130 N b) 3.9 N-s 7. 1.0 m/s 8. a) 450 kg-m/s b) -450 N-s c) -900 N 9. a) -693 N-s b) -4620 N
c) -3.465×10^6 N

original.

PHYSICS 11 MOMENTUM ETC. WORKSHEET 2

1. A rifle bullet of mass 60 g leaves the muzzle of a rifle with a velocity of 600 m/s. If the rifle is held very loosely, with what velocity will it recoil if its mass is 3.0 kg?

2. A railroad car of mass 12 000 kg is traveling at a speed of 6.0 m/s when it collides with an identical car at rest. If the two cars lock together, what is their common speed after the collision?



3. A bowling ball of mass 8.0 kg is traveling at 10.0 m/s when it strikes a 1.5 kg bowling pin. After being hit by the ball, the pin flies backward (in the direction that the ball was travelling) at 20.0 m/s, while the ball continues forward in the same direction. What is the velocity of the ball after impact?

4. A loaded freight car of mass 5000 kg breaks away and moves down the track with a speed of 4.0 m/s. It finally collides with two stationary freight cars of mass 1500 kg <u>each</u>. If they all couple together, at what rate do they move down the track?

5. A 92 kg hockey player skates with a velocity of 8.0 m/s in order to slam into a member of the opposing team who is standing still. They become tangled together and move down the ice with a velocity of 5.0 m/s. What is the mass of the other player?

6. A 53.0 kg skateboarder on a 2.0 kg skateboard is coasting along at 1.6 m/s. If the skateboarder collides with another stationary skateboarder of mass 43.0 kg who is on an identical skateboard and the two skateboarders become entangled and coast off in the direction of motion of the 53.0 kg skateboarder, what velocity will the combined skateboarders have?

7. A 1.5×10^3 kg car traveling at 44.0 m/s collides head-on with a 1.0×10^3 kg car traveling 22.0 m/s in the opposite direction. If the cars stick together on impact, what is the velocity of the wreckage immediately after impact?

8. Professor Frink designs a lightweight gun that shoots heavy bullets. The 50.0 N bullets leave the 40.0 N gun with a velocity of 200.0 m/s.
   a) What is the recoil velocity of this gun?
   b) Should Frink patent his invention? Explain.

5.1 Review

Summary

- Linear momentum is the product of an object's mass and its velocity, expressed in units of kilograms times metres per second (kg·m/s): $\vec{p} = m\vec{v}$.
- Impulse is the change in momentum caused by the application of a force over a time interval, expressed in units of newton seconds (N·s): $\vec{F}\Delta t = \Delta\vec{p}$.
- The magnitude of an impulse can be found by measuring the area under a force–time curve.

Questions

1. Calculate the momentum of each of the following: K/U
   (a) a male moose of mass 4.25×10^2 kg running at 6.9 m/s [N]
   (b) a city bus of mass 9.97×10^3 kg moving at 5 km/h [forward]
   (c) a flying squirrel of mass 995 g gliding at 16 m/s [S]
2. In your own words, describe what impulse is. K/U C
3. A bicycle and rider have a combined mass of 79.3 kg and a momentum of 2.16×10^3 kg·m/s [W]. Determine the velocity of the bicycle. K/U
4. A projectile travelling at 9.0×10^2 m/s [W] has a momentum of 4.5 kg·m/s [W]. What is the mass of the projectile? K/U
5. A downhill skier travelling at a constant velocity of 29.5 m/s [forward] has a momentum of 2.31×10^3 kg·m/s [forward]. Determine the mass of the skier. T/I
6. Explain how increasing the time interval over which a force is applied can affect performance in sports. Use a sport not discussed in this section in your answer. K/U A
7. A teacher drops a tennis ball and a basketball from the same height onto the floor. The force from the floor produces an impulse on each ball. If the basketball is heavier than the tennis ball, which impulse is larger? Explain your answer. T/I C A
8. A hockey player passes a puck that is initially at rest. The force exerted by the stick on the puck is 1100.0 N [forward], and the stick is in contact with the puck for 5.0 ms. T/I
   (a) Determine the impulse imparted by the stick to the puck.
   (b) If the puck has a mass of 0.12 kg, calculate the speed of the puck just after it leaves the hockey stick.
9. You accidentally drop a cellphone, which has a mass of 225 g, from a height of 74 cm. T/I A
   (a) Calculate the cellphone's momentum at the moment of impact with the sidewalk.
   (b) If the cellphone lands on a grassy lawn, is its momentum less, the same, or greater? Explain your answer.
10. A rubber ball with a mass of 0.25 kg is dropped from a height of 1.5 m onto the floor. Just after bouncing from the floor, the ball has a velocity of 4.0 m/s [up]. T/I
    (a) Determine the impulse imparted by the floor to the ball.
    (b) If the average force of the floor on the ball is 18 N [up], for how long is the ball in contact with the floor?
11. An archer shoots an arrow with a mass of 0.030 kg. The arrow leaves the bow with a horizontal velocity of 88 m/s. T/I
    (a) Determine the impulse imparted to the arrow.
    (b) If the arrow is in contact with the bowstring for 0.015 s after the archer releases, what is the approximate average force of the bowstring on the arrow?
12. A tennis player hits a serve at a speed of 63 m/s [W], and the opponent returns the 0.057 kg tennis ball to the server with a speed of 41 m/s [E]. T/I
    (a) Calculate the magnitude of the impulse imparted to the ball by the opponent.
    (b) Calculate the approximate average force on the ball if the opponent's racquet is in contact with the ball for 0.023 s.

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1. (a) 2.9×10^3 kg·m/s [N]
   (b) 1.4×10^4 kg·m/s [forward]
   (c) 16 N·s [S]
3. 27.2 m/s [W]
4. 5.0 g
5. 78.3 kg
8. (a) 5.5 N·s [forward]
   (b) 46 m/s
9. (a) 0.86 kg·m/s [down]
   (b) same
10. (a) 2.4 N·s [up]
    (b) 0.13 s
11. (a) 2.6 N·s [forward]
    (b) 1.8×10^2 N [forward]
12. (a) 5.9 N·s
    (b) 2.6×10^2 N [E]