Conceptual Physics Review (Chapters 7 & 8) — Solutions
Momentum & Energy

<u>Sample Calculations</u>

1. Tiger Woods hits a 0.050-kg golf ball, giving it a speed of 75.0 m/s.

    a) What change in momentum does the golf ball undergo?

    $\Delta p = p_f - p_i = (0.050\text{kg})(75\text{m/s}) - (0.050\text{kg})(0\text{m/s}) = \boxed{3.75\text{kg} \bullet \text{m/s}}$

    b) What impulse does Tiger impart to the ball?

    Impulse = change in momentum. (Note that the units are written differently, but they are equivalent.).
    So, impulse here is $\boxed{3.75\ N \bullet s}$

    c) Why is it impossible to determine what impact force Tiger exerts on the ball?

    Impulse = force x time, and we do not know the time so we cannot calculate the force.

2. Compare the momentums of the following pairs of objects, stating whether their momentums are the same, or stating which one has greater momentum, or stating that it is impossible to tell from the information given.

    a) A jogging elephant and a sprinting elephant, each with the same mass.

    Since their masses are the same, the elephant with a greater velocity (the sprinting elephant) has more momentum. Momentum is directly proportional to mass and also directly proportional to velocity.

    b) A jogging elephant and a sprinting gazelle.

    Since the elephant has more mass but the gazelle has a greater velocity, it is impossible to tell without additional information whose momentum is greater.

    c) A mouse and an elephant traveling at the same speed.

    Presumably, an elephant has much more mass than a mouse. Therefore, since their velocities are the same the elephant has a greater momentum.

    d) A 5-kg dog running at 3 m/s and a 7.5-kg dog running at 2 m/s.

    For this one I have actual values for mass and velocity of each, so I will simply calculate their respective momentums to decide which is greater.

    $p_1 = m_1v_1 = (5\text{kg})(3\text{m/s}) = 15\text{kg} \bullet \text{m/s}$

    $p_2 = m_2v_2 = (7.5\text{kg})(2\text{m/s}) = 15\text{kg} \bullet \text{m/s}$

    After calculating their momentums, it turns out they are the same!

3. A 0.060-kg tennis ball is traveling at 10.0 m/s toward Venus Williams's tennis racket. She hits the ball and sends it in the opposite direction with a speed of 36.0 m/s.

a) What change in momentum does the tennis ball undergo? (Don't forget that it changes direction.)

$\Delta p = p_f - p_i$

$= mv_f - mv_i$

$=(0.060\text{kg})(-36.0\text{m/s})-(0.060\text{kg})(10.0\text{m/s})$

$= \boxed{-2.76 \text{ kg} \bullet \text{m/s}}$

b) If the ball is in contact with the racket for 0.020 seconds, with what average force of impact has Venus hit the ball?

$Ft = m\Delta v = \Delta p$

$$F = \frac{\Delta p}{t} = \frac{-2.76kg \bullet m/s}{0.020s} = \boxed{-138N}$$

4. If a 1000.0-kg car is sent toward a cement wall (in a crash test) with a speed of 14.0 m/s and the impact brings it to a stop in 8.00 x 10^{-2} s, with what average force is it brought to rest?

$$F = \frac{m(v_f - v_i)}{t} = \frac{1000.0kg(0-14.0m/s)}{8.00e-2s} = \boxed{-1.75x10^5 N}$$

What could you do differently to decrease the average force of impact?

The change in momentum is going to be the same, but if we <u>increase</u> *the length of time that the force is applied for, the force will be* <u>decreased.</u>

5. Tubby and his twin brother Chubby have a combined mass of 200.0 kg and are zooming along in a 100.0-kg amusement park bumper car at 10.0 m/s. They bump Melinda's car (also 100.0 kg), which is sitting still. Melinda has a mass of 25.0 kg. After the collision, the twins continue ahead with a speed of 4.12 m/s. How fast is Melinda's car bumped across the floor? (She moves in the same direction as the twins.)

$$m_{twins}v_{twins} + m_{melinda}v_{melinda} = m_{twins}v'_{twins} + m_{melinda}v'_{melinda}$$

$$(200.0kg+100.0kg)(10.0m/s)+(25.0kg+100.0kg)(0m/s)=(300.0kg)(4.12)+(125)v'_{melinda}$$

$$v'_{melinda} = \boxed{14.1m/s}$$

6. If an 800.0-kg sports car slows to 13.0 m/s to check out an accident scene and the 1200.0 -kg pickup truck behind him continues traveling at 25.0 m/s, with what velocity will the two move if they lock bumpers after a rear-end collision?

$$m_{sportscar}v_{sportscar} + m_{truck}v_{truck} = (m_{sportscar} + m_{truck})v'$$

$$(800.0kg)(13.0m/s)+(1200.0kg)(25.0m/s)=(800.0kg+1200.0)v'$$

$$10400kg \bullet m/s + 30000kg \bullet m/s = (2000kg)v'$$

$$v' = \boxed{20.2m/s}$$

7. Charlotte, a 65.0-kg skin diver, shoots a 2.0-kg spear with a speed of 15.0 m/s at a fish that darts away quickly without getting hit. How fast does Charlotte move backwards when the spear is shot?

$$(m_{Charlotte} + m_{spear})v = m_{Charlotte}v'_{Charlotte} + m_{spear}v'_{spear}$$

$$(65.0kg + 2.0kg)(0m/s) = (65.0kg)v'_{Charlotte} + (2.0kg)(15.0m/s)$$

$$v'_{Charlotte} = \boxed{-0.46m/s}$$

The minus sign indicates that Charlotte is recoiling in the opposite direction of the spear.

8. Peggy, a moonlighting professional wrestler (The Waitress) with a mass of 150.0 kg, jumps on her opponent, Tara the Terrible. How much work does she do on Tara when she knocks her to the ground, 2.0 m below?

Work done = change in GPE

$$W = mgh = (150.0)(10m/s^2)(2.0m) = \boxed{3000J}$$

or

$$\text{W} = \text{Force} \times \text{distance} = (\text{mg}) \times \text{d}$$

$$= (150.0\text{kg})(10\text{m/s}^2)(2.0\text{m}) = \boxed{3000\text{J}}$$

9. After eating dinner, Marcus pulls his 75.0-kg body out of the dining room chair and climbs up the 6.00-m-high flight of stairs to his bedroom.

a) How much work does Marcus do in ascending the stairs?

$$\text{W} = \text{Force} \times \text{distance} = (\text{mg}) \times \text{d}$$

$$= (75\text{kg})(10\text{m/s}^2)(6.0m) = \boxed{4500J}$$

b) What is Marcus' potential energy relative to the dining room floor once he is upstairs?

$$GPE = mgh$$

$$= (75\text{kg})(10\text{m/s}^2)(6.0m) = \boxed{4500J}$$

c) If it took him 45.0 seconds to climb the flight of stairs (he was really full from dinner), how much power did he generate?

$$P = \frac{W}{t} = \frac{4500J}{45s} = \boxed{100W}$$

d) The next night, he runs up the same flight of stairs in 5.0 seconds. Is the amount of ***work*** done by him less than, the same as, or greater than the night before? What about the amount of ***power*** he generates?

The work done is exactly the same, because Work doesn't depend on how quickly the Force is applied along the distance.

The amount of Power applied is greater, though, because the Work was done in less time.

10. Marissa does 3.2 J of work to lower the window shade in her bedroom a distance of 0.8 m. How much force must Marissa exert on the window shade?

$$\text{W} = \text{Force} \times \text{distance, so}$$

$$\text{F} = \frac{\text{Work}}{\text{distance}} = \frac{3.2\text{J}}{0.8\text{m}} = \boxed{4N}$$

11. Legend has it that Isaac Newton "discovered" gravity when an apple fell from a tree and hit him on the head. If a 0.20-kg apple fell 7.0 m before hitting Newton, what was its *change* in PE during the fall?

$$\Delta GPE = GPE_f - GPE_i$$
$$= mgh_f - mgh_i$$
$$= (0.20kg)(10m/s^2)(0m) - (.20kg)(10m/s^2)(7.0m)$$
$$\boxed{= -14J}$$

12. A greyhound at a racetrack can run at a speed of 16.0 m/s. What is the KE of a 20.0-kg greyhound as it crosses the finish line, traveling at that speed?

$$KE = \frac{1}{2}mv^2$$
$$KE = \frac{1}{2}(20.0kg)(16.0m/s)^2$$
$$KE \boxed{= 2560J}$$

13. In a wild shot, Bo flings a pool ball of mass 0.50 kg off the edge of a 0.68-m-high pool table, and the ball hits the floor with a speed of 6.0 m/s.

a) What is the kinetic energy of the pool ball just before it hits the floor?

$$KE = \frac{1}{2}mv^2$$
$$KE = \frac{1}{2}(0.50kg)(6.0m/s)^2$$
$$KE \boxed{= 9.0J}$$

b) What is the gravitational potential energy of the pool ball just before it hits the floor?

$$GPE = mgh$$
$$GPE = (0.50kg)(10m/s^2)(0) = 0J!$$

c) What is the total mechanical energy of the pool ball just before it hits the floor?

Mechanical energy = GPE + KE $\boxed{= 9.0\ J}$

d) How much potential energy did the pool ball have (relative to the floor) when it was on the table?

$$GPE = mgh$$
$$GPE = (0.50kg)(10m/s^2)(0.68m) \boxed{= 3.4J}$$

e) Assuming a negligible (too little to notice) amount of mechanical energy was converted to thermal energy (heat) during the pool ball's fall, how much kinetic energy did the pool ball have when it first left the table? (Hint: Use the Law of Conservation of Energy)

$$GPE_{table} + KE_{table} = GPE_{floor} + KE_{floor}$$
$$3.4J + KE_{table} = 0 + 9.0J$$
$$KE_{table} = 9.0 - 3.4 \boxed{= 5.6J}$$

f) How fast was it going when it left the table? (Hint: Use your answer from part e)

$$KE_{table} = \frac{1}{2}mv^2$$

$$5.6J = \frac{1}{2}(0.50kg)v^2$$

$$v = \sqrt{2 \bullet 5.6/0.5} = \boxed{4.7m/s}$$

14. A 500.0-kg pig is standing on the top of a muddy hill on a rainy day. The hill is 100.0 m long with a vertical drop of 30.0 m. The pig slips and begins to slide down the hill. What is the pig's speed at the bottom of the hill? (Hint: Use the law of conservation of energy, meaning the total of the potential energy and kinetic energy for the pig remains constant, whether the pig is at the top of the hill or at the bottom.)

Some initial remarks: that's one really large pig--over half a ton! *They don't mention friction in the problem, and it's a slick muddy hill so I'll assume the friction is so small as to be negligible. GPE at the top of the hill is converted completely to KE at the bottom of the hill, so...*

$$GPE_{top} = KE_{bottom}$$

$$mgh = \frac{1}{2}mv^2$$

$$(500.0kg)(10\,m/s^2)(30.0m) = \frac{1}{2}(500.0kg)v^2$$

$$v = \boxed{24.5m/s}$$

It's interesting to note that this is the same velocity the pig would have had if it had been free-falling the 30.0 m distance!