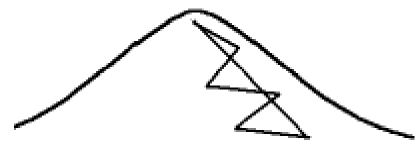
Conceptual Questions

1. A girl with a heavy backpack wants to climb to the top of a hill. The path straight up the hill is 100 m long. Rather than going straight up she chooses a zigzag path 200 m long. The work she does on the backpack is ___ the work she does on the backpack going up in a straight line.



   a) ¼ of b) ⅓ of c) ½ of d) equal to e) twice

   The force (and its direction) required to lift the backpack upwards against gravity is the same in each case, as is the displacement of the pack, so therefore the work done on it is also the same. The path taken has no effect on the work done on the pack.

2. Can the normal force on an object ever do work? Explain.
   The normal force can do work on an object if the normal force has a component in the direction of displacement of an object. If someone were to jump up in the air, then the floor pushing upward on the person (the normal force) would do positive work and increase the person's kinetic energy. Likewise when they hit the floor coming back down, the force of the floor pushing upwards (the normal force) would do negative work and decrease the person's kinetic energy.

3. A woman swimming upstream s not moving with respect to the shore
   a) Is she doing work?
      The woman does work by moving the water with her hands and feet, because she must exert a force to move the water some distance.
   b) If she stops swimming and merely floats, is work done on her?
      As she stops swimming and begins to float in the current, the current does work on her because she gains kinetic energy. Once she is floating the same speed as the water, her kinetic energy does not change, and so no net work is being done on her.

4. A friend of yours describes holding a bucket of water steady with your arms straight out in front of you as hard work. Why would this statement be incorrect? Explain.
   Even though you would be applying a non-zero force on the bucket, its displacement is zero if ot does not move, and so no work is done on it.

5. A sailboat on a lake is slowing down.
   a) Is work being done on the boat? Explain.
      Yes. Since the boat is slowing down, a non-zero net force must be acting on it along the axis of its motion, so (negative) work is being done.
   b) Recognizing that the wind propels the boat forward and the water resists the boat's motion, what does your answer in part a) imply about the work done by the wind's force compared to the work done by the water's resistive force?
      The magnitude of the work done by the water is larger than that of the wind, and so it dominates. Since the work done by the water is negative, the total work done on the sailboat is also negative.

Problems

6. How much work does a boy do if he exerts a net force of 55 N to push a box 18 m along the ground?

$$W = Fd\cos(\theta)$$
$$W = (55\,N)(18\,m)(1)$$
$$W = 990\,J$$

7. If a girl uses 1.0 J of work to lift a 1.0 kg book vertically, how high can she lift the book?

$$W = Fd\cos(\theta)$$
$$d(1) = \frac{W}{F_g}$$
$$d = \frac{1.0\,J}{(1.0\,kg)(9.8\,m/s^2)}$$
$$d = 0.10\,m$$

8. A baseball (m=150 g) travelling at 40 m/s [→] enters a baseball glove horizontally. If the catcher moves his glove backwards a distance of 12 cm while bringing the ball to rest, calculate:

a) the work required to stop the ball

$$W = Fd\cos(\theta)$$
$$W = mad(-1)$$
$$W = m\left(\frac{v_2^2 - v_1^2}{2d}\right)d(-1)$$
$$W = -(0.15\,kg)\left(\left|\frac{0\frac{m}{s} - \left(40\frac{m}{s}\right)^2}{2(0.12\,m)}\right|\right)(0.12\,m)\ *$$
$$W = -120\,J$$

***the magnitude of the acceleration is taken only because its direction has already been taken into consideration in the angle ϴ**

b) the force that the glove exerts on the ball as the ball comes to rest

$$W = Fd\cos(\theta)$$
$$F = -\frac{W}{d}$$
$$F = -\frac{-120\,J}{0.12\,m}$$
$$F = 1000\,N\,[backward]$$

c) the force the ball exerts on the glove.

Newton's 3rd Law:

$$F_{ball\ on\ glove} = -F_{glove\ on\ ball}$$
$$F_{ball\ on\ glove} = -1000\,N\,[backward]$$
$$F_{ball\ on\ glove} = 1000\,N\,[forward]$$

9. A box of mass 5.0 kg is accelerated from rest across a floor at a rate of 2.0 m/s^2 for 0.70 s. Find the total work done on the box.

$$W = Fd\cos(\theta)$$
$$W = mad$$
$$W = ma(0.5at^2)$$
$$W = 0.5(5.0\,kg)(2.0\,m/s^2)^2(0.70\,s)^2$$
$$W = 4.9\,J$$

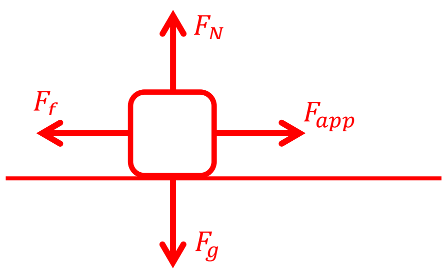
$$\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$$
$$\Delta\vec{d} = \frac{1}{2}\vec{a}\Delta t^2$$

10. Eight books, each 4.3 cm thick with mass 1.7 kg, lie flat on a table. How much work is required to stack them one on top of the other?

$W_{total} = W_{1st\ book} + W_{2nd\ book} + W_{3rd\ book} + W_{4th\ book} + W_{5th\ book} + W_{6th\ book} + W_{7th\ book} + W_{8th\ book}$
$W_{total} = 0\,J + mgt + mg(2t) + mg(3t) + mg(4t) + mg(5t) + mg(6t) + mg(7t)$
$W_{total} = mg(28t)$
$W_{total} = (1.7\,kg)(9.8\,m/s^2)(28(0.043\,m))$
$W_{total} = 20.06\,J = 2.0 \times 10^1\,J$

11. A wagon full of newspapers is pulled at a constant velocity of 0.50 m/s for a distance of 100. m. If the forces of friction add up to 20. N and the papers and the wagon have a combined mass of 40. kg, calculate

a) the net force on the wagon.



$\sum F_y = F_N - F_g = 0$
$\sum F_x = F_{app} - F_f = 0$

b) the applied force on the wagon.

$F_{app} = F_f$
$F_{app} = 20\,N\,[fwd]$

c) the work done on the wagon.

$W = Fd\cos(\theta)$
$W = (0\,N)(100\,m)$
$W = 0\,J$

d) the work done by the "puller".

$W = Fd\cos(\theta)$
$W = (20\,N)(100\,m)$
$W = 2000\,J$

12. An object A moving horizontally with a kinetic energy of 0.80 kJ experiences a constant horizontal opposing force of magnitude of 100. N while moving from a place X to a place Y, where XY is 2.0 m.

a) What is the energy of A at Y?

$W_{NC} = \Delta E_K + \Delta E_P$
$Fd\cos(\theta) = E_{K_Y} - E_{K_X}$
$E_{K_Y} = Fd\cos(\theta) + E_{K_X}$
$E_{K_Y} = -(100\,N)(2.0\,m) + 800\,J$
$E_{K_Y} = 600\,J$
$E_{K_Y} = 6.0 \times 10^2\,J$

b) In what further distance will A come to rest, if this opposing force continues to act on A?

$W_{NC} = \Delta E_K + \Delta E_P$

$Fd\cos(\theta) = 0\,j - E_{K_Y}$

$d = \frac{E_{K_Y}}{F}$

$d = \frac{600\,J}{100\,N}$

$d = 6.0\,m$

13. A husband and wife take turns pulling their child in a wagon along a horizontal sidewalk. Each exerts a constant force and pulls the wagon through the same displacement. They do the same amount of work, but the husband's pulling force is directed 58° above the horizontal, and the wife's pulling force is directed 38° above the horizontal. The husband pulls with a force whose magnitude is 67 N. What is the magnitude of the pulling force exerted by his wife?

$W_{wife} = W_{husband}$

$F_w d\cos(\theta_w) = F_h d\cos(\theta_h)$

$F_w = \frac{F_h\cos(\theta_h)}{\cos(\theta_w)}$

$F_w = \frac{(67\,N)\cos(58°)}{\cos(38°)}$

$F_w = 45\,N$

14. A 35-kg box needs to be lifted to the top of a loading dock, which is also accessible by ramp. The ramp is 5.0 m long and has a vertical height of 1.7 m.

a) What minimum force is required to lift the box straight up onto the loading dock?

$W = Fd\cos(\theta) = mgh$

$F = mg$

$F = (35\,kg)(9.8\,m/s^2)$

$F = 340\,N\,[up]$

b) What minimum amount of work is required to lift the crate straight up onto the loading dock?

$W = Fd\cos(\theta)$

$W = (340\,N)(1.7\,m)$

$W = 580\,J$

c) What force is required to push the crate up the ramp such that the amount of work is the same as in b)? Assume no friction.

$W = Fd\cos(\theta)$

$F = -\frac{W}{d}$

$F = -\frac{580\,J}{5\,m}$

$F = 120\,N\,[along\ ramp]$