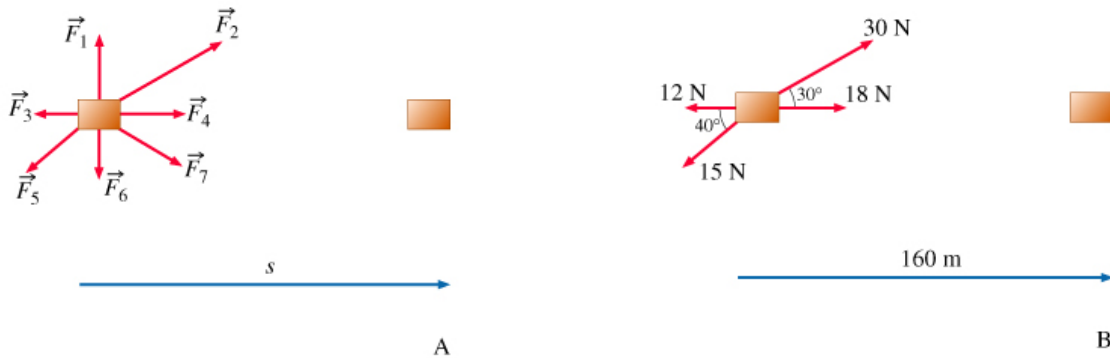


Phys 100A
Homework 6 – Chapter 7

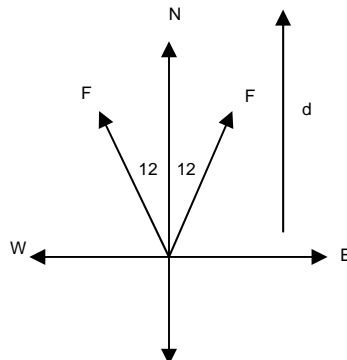
All Work and No Play



- A) The work by \vec{F}_1 is zero. The force is perpendicular to the displacement.
- B) The work by \vec{F}_2 is positive. The projection of the force on the direction of the displacement is positive.
- C) The work by \vec{F}_3 is negative. The force is opposite to the displacement.
- D) The work by \vec{F}_4 is positive. The force is parallel to the displacement.
- E) The work by \vec{F}_5 is negative. The projection of the force on the direction of the displacement is negative.
- F) The work by \vec{F}_6 is zero. The force is perpendicular to the displacement.
- G) The work by \vec{F}_7 is positive. The projection of the force on the direction of the displacement is positive.
- H) $W = Fd \cos \theta = (18)(160) = 2880 = 2.9 \times 10^3\text{ J}$
- I) $W = Fd \cos \theta = (30)(160) \cos 30 = 4157 = 4.2 \times 10^3\text{ J}$
- J) $W = Fd \cos \theta = (12)(160) \cos 180 = -1920 = -1.9 \times 10^3\text{ J}$
- K) $W = Fd \cos \theta = (15)(160) \cos(180 + 40) = (15)(160) \cos 220 = -1839 = -1.8 \times 10^3\text{ J}$

Work Done in Pulling a Supertanker

Two tugboats pull a disabled supertanker. Each tug exerts a constant force of $1.60 \times 10^6\text{ N}$, one at an angle 12.0° west of north, and the other at an angle 12.0° east of north, as they pull the tanker a distance 0.640 km toward the north.



Both forces produce the same work.

$$W_{total} = 2W_F = 2Fd \cos(12) = 2(16 \times 10^6)(0.64 \times 10^3) \cos(12) = 200 \times 10^9 \text{ J}$$

Conceptual 7.3 A pendulum bob swings from point II to point III along the circular arc indicated in the figure .

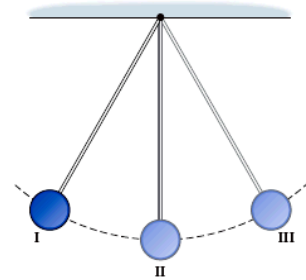
3. **Picture the Problem:** A pendulum bob swings from point II to point III along the circular arc indicated in the figure at right.

Strategy: Apply equation 7-3, which says that the work done on an object is positive if the force and the displacement are along the same direction, but zero if the force is perpendicular to the displacement.

Solution: 1. (a) As the pendulum bob swings from point II to point III, the force of gravity points downward and a component of the displacement is upward. Therefore, the work done on the bob by gravity is negative.

2. (b) As the pendulum bob swings, the force exerted by the string is radial (toward the pivot point) but the displacement is tangential, perpendicular to the force. We conclude that the work done on the bob by the string is zero.

Insight: The work done by the Earth is positive if the bob swings from point I to point II because a component of the displacement is downward and the force is downward.



7.6 Early one October, you go to a pumpkin patch to select your Halloween pumpkin. You lift the 3.2 kg pumpkin to a height of 1.2 m, then carry it 50.0 m (on level ground) to the check-out stand.

6. **Picture the Problem:** The pumpkin is lifted vertically then carried horizontally.

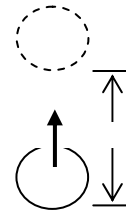
Strategy: Multiply the force by the distance because during the lift the two point along the same direction.

Solution: 1. (a) Apply equation 7-1 directly:

$$W = mgd = (3.2 \text{ kg})(9.81 \text{ m/s}^2)(1.2 \text{ m}) = \boxed{38 \text{ J}}$$

2. (b) The force is perpendicular to the displacement so $W = \boxed{0}$.

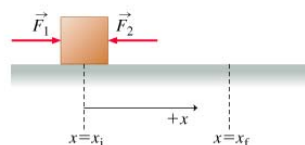
Insight: You can still get tired carrying a pumpkin horizontally even though you're doing no work!



Note: The force of gravity points always down. You exert a force pointing up to oppose the force of gravity. You exert positive work while gravity exerts negative work.

When Push Comes to Shove

Two forces, of magnitudes $F_1 = 70.0 \text{ N}$ and $F_2 = 50.0 \text{ N}$, act in opposite directions on a block, which sits atop a frictionless surface, as shown in the figure. Initially, the center of the block is at position $x_i = -5.00 \text{ cm}$. At some later time, the block has moved to the right, and its center is at a new position, $x_f = 6.00 \text{ cm}$.



$\vec{d} = (x_f - x_i)\hat{x}$ The displacement points to the right when the quantity $(x_f - x_i)$ is positive.

$$\vec{d} = (x_f - x_i)\hat{x} = (600 - (-500)) \times 10^{-2} \text{ m}\hat{x} = 0.11 \text{ m}\hat{x}$$

A) $W_1 = F_1 d \cos 0 = (70)(0.11) = 7.7 \text{ J}$

B) $W_2 = F_2 d \cos 180 = -(50)(0.11) = -5.5 \text{ J}$

C) $W_{net} = W_1 + W_2 = 7.7 - 5.5 = 2.2 \text{ J}$

D) $\Delta K = W_{net} = 2.2 \text{ J}$

Conceptual 7.23 Jogger A has a mass m and a speed v , jogger B has a mass $(m/2)$ and a speed $3v$, jogger C has a mass $3m$ and a speed $(v/2)$, and jogger D has a mass $4m$ and a speed $(v/2)$.

23. **Picture the Problem:** Four joggers have a variety of masses and speeds.

Strategy: Use the definition of kinetic energy to determine the relative magnitudes of the kinetic energies.

Solution: 1. Calculate the kinetic energies of each jogger.

2. $K_A = \frac{1}{2}(m)(v)^2 = \frac{1}{2}mv^2$

3. $K_B = \frac{1}{2}\left(\frac{1}{2}m\right)(3v)^2 = \frac{9}{2}\left(\frac{1}{2}mv^2\right)$

4. $K_C = \frac{1}{2}(3m)\left(\frac{1}{2}v\right)^2 = \frac{3}{4}\left(\frac{1}{2}mv^2\right)$

5. $K_D = \frac{1}{2}(4m)\left(\frac{1}{2}v\right)^2 = \frac{1}{2}mv^2$

6. By comparing the magnitudes of the kinetic energies we arrive at the ranking $\boxed{C < A = D < B}$.

Insight: Even with three times the mass of jogger A, jogger C has only three-fourths the kinetic energy because the kinetic energy is proportional to the square of the speed.

7.19 How much work is needed for a 73 kg runner to accelerate from rest to 7.7 m/s?

19. **Picture the Problem:** The runner accelerates horizontally and runs in a straight line.

Strategy: The work done equals the change in kinetic energy.

Solution: Find the change in kinetic energy: $W = \Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}(73 \text{ kg})[(7.7 \text{ m/s})^2 - 0] = 2200 \text{ J} = \boxed{2.2 \text{ kJ}}$

Insight: The runner's kinetic energy comes from the forces his muscles exert on his center of mass over the distance which his center of mass moves.

7.25 A 0.14 kg pinecone falls 16 m to the ground, where it lands with a speed of 13 m/s.

25. **Picture the Problem:** The pine cone falls straight down for 16 m under the influence of gravity.

Strategy: The work done by air resistance is the difference in kinetic energies between the air resistance and no air resistance cases. The work done by gravity is positive when the object is moving down $W_g = mgh$.

Solution: 1. (a) The total work is equal to the work of gravity plus the work of air resistance. The total work is also equal to the change in kinetic energy. The initial kinetic energy is zero.

$$W_{total} = W_g + W_f = \Delta K = K_f - K_i$$

$$W_f = K_f - W_g = \frac{1}{2}mv_f^2 - mgh$$

$$= (0.140 \text{ kg})\left[\frac{1}{2}(13 \text{ m/s})^2 - (9.81 \text{ m/s}^2)(16 \text{ m})\right] = \boxed{-10 \text{ J}}$$

2. (b) The work done by air resistance equals the average force of air resistance times the distance the pine cone falls. It is negative because the upward force is opposite to the downward distance traveled.

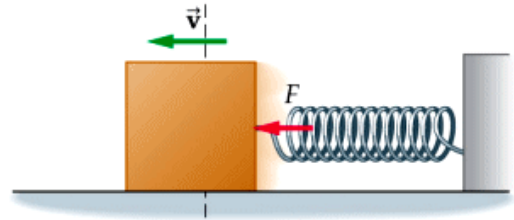
$$W = -Fd \text{ so that } F = -\frac{W}{d} = -\frac{W}{h} = \frac{-(-10 \text{ J})}{16 \text{ m}} = \boxed{0.63 \text{ N upward}}$$

Insight: Kinetic friction always does negative work because the force is always opposite to the direction of motion.

7.33 A 1.2 kg block is held against a spring of force constant 1.0×10^4 N/m, compressing it a distance of 0.10 m.

33. **Picture the Problem:** The compressed spring pushes the block from rest horizontally on a frictionless surface. The block slides to the left as indicated in the figure.

Strategy: The spring force points to the left and the displacement is to the left so the work done by the spring a distance x is $\frac{1}{2}kx^2$. The work done by the spring equals the kinetic energy gained by the block.



Solution: 1. Apply equations 7-7 and 7-8: $W = \frac{1}{2}kx^2 = \Delta K = \frac{1}{2}mv_f^2 - 0$

2. Now solve for v_f : $v_f = \left(\sqrt{\frac{k}{m}} \right) x = \left(\sqrt{\frac{1.0 \times 10^4 \text{ N/m}}{1.2 \text{ kg}}} \right) (0.15 \text{ m}) = \boxed{14 \text{ m/s}}$

Insight: The work done on the spring in order to compress it becomes stored potential energy. That stored energy becomes the kinetic energy of the block as the spring accelerates it.

Fat: The Fuel of Migrating Birds

Consider a bird that flies at an average speed of 10.7 m/s and releases energy from its body fat reserves at an average rate of 3.70 W (this rate represents the power consumption of the bird). Assume that the bird consumes 4g of fat to fly over a distance d_b without stopping for feeding. How far will the bird fly before feeding again?

1 g fat = 9.4 food Calories

1 food Calorie = 1000 calories mechanical work = 4,186 J

A) $4\text{g} = 4 \text{ g} (9.4 \text{ Calorie/g}) (4,186 \text{ J/Calorie}) = 15.7 \times 10^4 \text{ J}$

The power work relation:

$$P = \frac{W}{t} \quad t = \frac{W}{P} = \frac{15.7 \times 10^4}{3.70} = 42.5 \times 10^3 \text{ s}$$

$$d_b = vt = (10.7)(42.5 \times 10^3) = 455 \times 10^3 \text{ m} = 455 \text{ km}$$

B) Now we “invert” the problem to end with the mass of carbohydrates:

1g carbohydrate = 4.2 Calories

$$m_{\text{carb}} = 15.7 \times 10^4 \text{ J} (1 \text{ Calorie}/4,186 \text{ J}) (1 \text{ g carbohydrate}/4.2 \text{ Calories}) = 8.93 \text{ g}$$

C) First we can find the time for the crossing

$$t = \frac{d}{v} = \frac{800}{40.0} = 20 \text{ hr} (3600 \text{ s/hr}) = 7.2 \times 10^6 \text{ s}$$

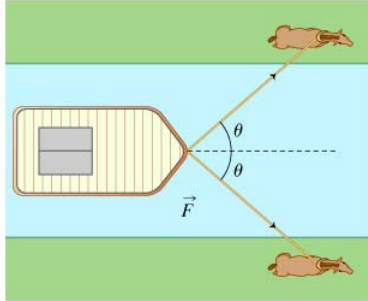
And the work

$$W = Pt = (1.70)(7.2 \times 10^6) = 12.2 \times 10^4 \text{ J}$$

$$m_{fat} = 12.2 \times 10^4 \text{ J} (1 \text{ Calorie}/4,186 \text{ J}) (1 \text{ g carbohydrate}/9.4 \text{ Calories}) = 3.11 \text{ g}$$

Work Horses on Erie Canal

Two workhorses tow a barge along a straight canal. Each horse exerts a constant force of magnitude F , and the tow ropes make an angle θ with the direction of motion of the horses and the barge. Each horse is traveling at a constant speed v .



A) How much work W is done by *each* horse in a time t ?

The work per unit time is precisely the power. For each horse

$$P = \frac{W}{t} = \frac{Fd \cos \theta}{t} = F \cos \theta \left(\frac{d}{t} \right) = F \cos \theta v$$

$$W = Pt = F v t \cos \theta$$

B) How much power does each horse provide?

Answered above

7.46 An ice cube is placed in a microwave oven. Suppose the oven delivers 105 W of power to the ice cube and that it takes $32,200 \text{ J}$ to melt it.

How long does it take for the ice cube to melt?

46. **Picture the Problem:** The microwave oven delivers energy to the ice cube via electromagnetic waves.

Strategy: The power required is the energy delivered divided by the time.

Solution: Solve equation 7-10 for t :

$$t = \frac{W}{P} = \frac{32200 \text{ J}}{105 \text{ W}} = 307 \text{ s} = \boxed{5.11 \text{ min}}$$

Insight: Power can be regarded as the rate of energy transfer because work is essentially transferred energy. We'll learn more about melting ice cubes in Chapter 17 and electromagnetic waves in Chapter 25.