Chapter 5: Work and Energy

1. A 58-kg gymnast is performing a giant swing. The velocity of her center of mass is 1.3 m/s. Her height is 3.7 m. Her body is stretched 11 cm with a stiffness of 5 kN/m. What is:

   a. Her kinetic energy

   $$KE = \frac{1}{2}mv^2 = \frac{1}{2}(58)(1.3^2) = 49 \text{ J}$$

   b. Her gravitational potential energy

   $$GPE = -mgh = -58(-9.8)(3.7) = 2103 \text{ J}$$

   c. Her strain potential energy

   $$SPE = \frac{1}{2}k\Delta x^2 = \frac{1}{2}(5000)(0.11^2) = 30 \text{ J}$$

   d. Her total mechanical energy

   $$E = KE + GPE + SPE = 49 + 2103 + 30 = 2182 \text{ J}$$

2. A 70-kg pole vaulter has a horizontal velocity of 8.8 m/s at the completion of his approach and his center of gravity is 1.1 m high. Estimate how high he should be able to bring his center of gravity if all of his kinetic and gravitational potential energy is converted to gravitational potential energy. Ignore the mass of the pole in this problem.

   $$KE = \frac{1}{2}mv^2 = \frac{1}{2}(70)(8.8^2) = 2710 \text{ J}$$

   $$GPE_{initial} = -mgh = -70(-9.8)(1.1) = 755 \text{ J}$$

   $$E = 2710 + 755 = 3465 \text{ J}$$

   $$E = GPE_{final} = -mgh$$

   $$h = \frac{GPE_{final}}{-mg} = \frac{3465}{-70(-9.8)} = 5.05 \text{ m}$$

3. A 0.15-kg baseball strikes the catcher's glove with a horizontal velocity of 40 m/s. The displacement of the baseball due to the deformation of the catcher's glove and the movement of the catcher's hand is 8 cm in a horizontal direction from the instant it first makes contact with the glove until it stops.

   a. How much kinetic energy does the baseball possess just before it strikes the glove?

   $$KE = \frac{1}{2}mv^2 = \frac{1}{2}(0.15)(40^2) = 120 \text{ J}$$

   b. How much work does the catcher do on the baseball during the catch?

Since work is equal to the change in energy and there is not change in height or strain energy, then $U = \Delta E = \Delta KE$ = -120 J

c. What is the average impact force exerted by the glove on the baseball?

$$U = Fd$$

$$F = \frac{U}{d}$$

$$F = \frac{-120}{-0.08} = 1500 \text{ N}$$

d. Is the work done positive or negative?

The work is negative since energy is decreasing.

4. Nick generates a horizontal release velocity of 18 m/s on a 2.0 kg discus. If he applies force to the disc for 0.58 s, what is the average horizontal power the thrower exerted on the disc?

Step 1: $KE = \frac{1}{2}mv^2 = \frac{1}{2}(2)(18^2) = 324$ J

Step 2: Since we are only considering the horizontal direction:

$$U = \Delta E = \Delta KE$$

$$P = \frac{U}{t} = \frac{324J}{0.58} = 559 \text{ W}$$