Answer to Essential Question 6.7: The average power output can be found by dividing the energy by the time. The energy in question is the energy for one day, so we use one day as the time period. To obtain power in watts, we should express time in seconds. There are 86400 s in one day. Thus, the average power is:

$$P_{av} = \frac{Energy}{time} = \frac{1\times10^7 \text{ J}}{86400 \text{ s}} \approx \frac{1\times10^7 \text{ J}}{1\times10^5 \text{ s}} = 100 \text{ W}.$$

On average, we're about as bright as your average light bulb, and our power output is generally considerably less than what the world-class athlete is capable of sustaining. In our defense, this 100 W is averaged over the entire day, including the time we are sleeping.

Chapter Summary

Essential Idea about the Link between Force, Momentum, and Energy

In this chapter, we extended our understanding of force by connecting force to both momentum and energy. A net force applied over a particular time interval is directly connected to a change in momentum. A net force applied over a particular distance is directly connected to a change in kinetic energy.

Momentum

There are four key points to remember about momentum:

1. Momentum equals mass multiplied by velocity: $\vec{p} = m\vec{v}$. (Equation 6.2)
2. Momentum is a vector.
3. If no net force acts on a system, the system's momentum is conserved--the system's net momentum maintains its value.
4. If there is a net force acting on a system the system's momentum changes according to equation 6.3: $\Delta\vec{p} = \vec{F}_{net}\Delta t$, which is known as an ***impulse.***

Momentum conservation is a consequence of Newton's third law. Whenever two objects collide, the force that one object exerts on the second object is always equal in magnitude, and opposite in direction, to the force that the second object exerts back on the first object. If we combine the two objects into one system, the forces between the objects cancel out, and the system's momentum is conserved as long as no net external force acts on the system.

Solving a Problem Involving Impulse and Momentum

A general method for solving a problem that relates a net force acting on an object over some time interval to the change in momentum (or velocity) of that object is:

1. Draw a diagram of the situation.
2. Add a coordinate system to the diagram, showing the positive direction(s). The coordinate system helps to remind us that force and momentum are vector quantities.
3. Organize what is known, perhaps by drawing a free-body diagram of the object, or drawing a graph of the net force as a function of time.
4. Apply equation 6.3 $\left(\vec{F}_{net}\Delta t = \Delta(m\vec{v})\right)$ to solve the problem.

Center of Mass

The center of mass of an object is the point that moves as though the entire mass of the object was concentrated there. For a uniform object, the center of mass is located at the geometric center. When no net external force acts on a system, the system's momentum is conserved, and the motion of the center of mass continues unchanged.

The *x*-coordinate of the center of mass can be found using the equation:

$$X_{CM} = \frac{x_1 m_1 + x_2 m_2 + x_3 m_3 + \ldots}{m_1 + m_2 + m_3 + \ldots} \qquad \text{(Equation 6.4)}$$

The *y*-coordinate of the center of mass is given by an equivalent equation.

Work and Energy

Energy is a scalar. The MKS unit of energy is the joule (J).

The kinetic energy of an object is given by: $K = \frac{1}{2}mv^2$. (Equation 6.6: **Kinetic energy**)

The work done by a force is the displacement, multiplied by the component of the force in the direction of the displacement:

$W = F\Delta r \cos\theta$, (Equation 6.7: **Work**)

where θ is the angle between the force and the displacement.

Solving a Problem Involving Work and Kinetic Energy

A general method for solving a problem that relates a net force acting on an object over some distance to the change in kinetic energy of that object is:

1. Draw a diagram of the situation.
2. Add a coordinate system to the diagram, showing the positive direction(s). Doing so helps remind us that force and displacement are vector quantities.
3. Organize what is known, perhaps by drawing a free-body diagram of the object, or drawing a graph of the net force as a function of position.
4. Apply equation 6.8 $(F_{net}\,\Delta r \cos\theta = \Delta K)$ to solve the problem.

Gravitational Potential Energy

Near the surface of the Earth (or at any location where the acceleration due to gravity is constant), gravitational potential energy is defined as:

$U_g = mgh$, (Equation 6.10: **Gravitational potential energy**)

where *h* is the height that the object is above some reference level. We can choose any convenient level to be the reference level. The change in potential energy is more important than the value of the potential energy.

Power

Power is the rate at which work is done: $P = \frac{Work}{\Delta t} = Fv\cos\theta$. (Eq. 6.11: **Power**)

The unit of power is the watt (W). 1 W = 1 J/s.