Gravitational Potential Energy
SPH3U

If you lift an object a distance Δh at a *constant velocity*, the vertical forces must be balanced, so the applied force that does the work must be equal in magnitude but opposite in direction to the force of gravity:

$$W = F\,\Delta d = F_g\,\Delta h = m\,g\,\Delta h$$

The energy that this work is increasing is the object's **gravitational potential energy**.

$$\Delta E_g = m\,g\,\Delta h$$

Gravitational potential energy itself is often written as $E_g = m\,g\,h$ where *h* is understood as being relative to some reference point.

(Note that although ground level is often the reference point, there is no designated spot on Earth that is your reference point with zero height. You must designate the reference point.)

Example 1: An object of mass 3.0 kg is lifted at constant velocity from a height of 1.0 m to a height of 2.5 m. Find the increase in gravitational potential energy of the object.

Givens: $m = 3.0\,kg$ $\quad g = 9.8\,\frac{m}{s^2}$ $\quad \Delta h = 2.5\,m - 1.0\,m = 1.5\,m$

Unknown: ΔE_g = ?

Select: $\Delta E_g = m\,g\,\Delta h$

Solve: $\Delta E_g = (3.0\,kg)(9.8\,\frac{m}{s^2})(1.5\,m) = 44\,J$

Power is the rate at which work is done: $P = \frac{W}{\Delta t}$

It is measured in units of J/s or Watts (W). Note that power is also a scalar.

Example 2: An object of mass 3.0 kg is lifted at constant velocity from a height of 1.0 m to a height of 2.5 m in 2.0 s. Find the power output.

Givens: $m = 3.0\,kg \qquad g = 9.8\frac{m}{s^2} \qquad \Delta h = 2.5\,m - 1.0\,m = 1.5\,m \qquad \Delta t = 2.0\,s$

Unknown: P = ?

Select: $P = \frac{\Delta E_g}{\Delta t} = \frac{mg\Delta h}{\Delta t}$

Solve: $P = \frac{(3.0\,kg)(9.8\frac{m}{s^2})(1.5\,m)}{2.0\,s} = 22\,W$

It is also possible to calculate the power output without first calculating the energy. . . .

Example 3: An object of mass 3.0 kg is lifted at a constant velocity of 0.75 m/s [up]. Find the power output.

Givens: $m = 3.0\,kg \qquad g = 9.8\frac{m}{s^2} \qquad v = 0.75\frac{m}{s}$

Unknown: P = ?

Select: $P = \frac{\Delta E_g}{\Delta t} = \frac{mg\Delta h}{\Delta t} = mgv$ since $\frac{\Delta h}{\Delta t} = \frac{\Delta d}{\Delta t} = v$

Solve: $P = (3.0\,kg)(9.8\frac{m}{s^2})(0.75) = 22\,W$

Power can also be expressed in other units, e.g., horsepower (hp). 1 hp = 745.7 W.

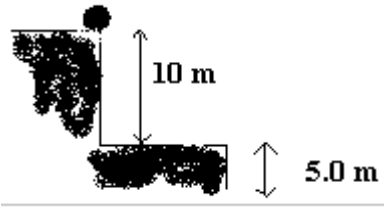
To convert 22 W to hp:

$$22\,W \times (\frac{1\,hp}{745.7\,W}) = 0.030\,hp$$

Lab Activity: Going the (Vertical) Distance: An Inquiry Activity

More Practice

1. Given the diagram at right, what is the gravitational potential energy of the 1.0-kg ball relative to the first step?



A. 10 J
B. 50 J
C. 100 J
D. 150 J

2. Which of the following has a greater gravitational potential energy?

A. a 10 kg mass at a height of 1 m
B. a 5 kg mass at a height of 2 m
C. Both have the same E_g
D. It cannot be determined.

3. An object of mass 2.5 kg is lifted at constant velocity from a height of 2.0 m to a height of 5.4 m. Find the increase in gravitational potential energy of the object.

4. A crane lifts a 450 kg beam straight up at a constant velocity of 0.50 m/s [up]. Calculate the mechanical power output of the crane.

5. A container factory uses a motor to operate a conveyor belt that lifts containers from one floor to another. To lift 250 1-kg containers a vertical distance of 3.6 m, the motor runs for 45 s. What is the power output of the motor?