WORK, ENERGY, AND POWER

CHAPTER 10

STANDARDS

- SP3. Students will evaluate the forms and transformations of energy.
  - a. Analyze, evaluate, and apply the principle of conservation of energy and measure the components of work-energy theorem by describing total energy in a closed system.
    - identifying different types of potential energy.
    - calculating kinetic energy given mass and velocity.
    - relating transformations between potential and kinetic energy.
  - g. Analyze and measure power.

WHAT IS WORK?

- Simple form: work = force × distance

$$W = \mathbf{F} \cdot \mathbf{d}$$

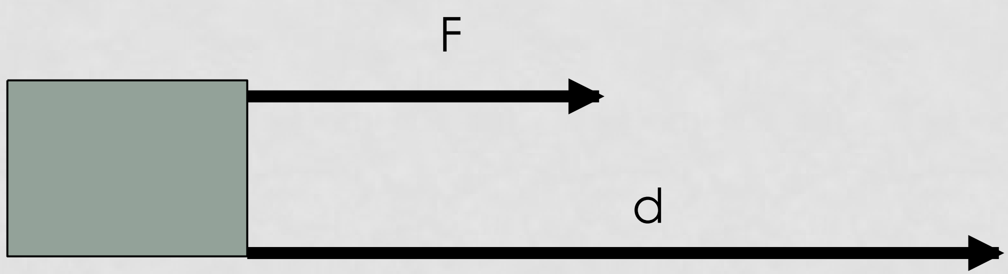
- Work can be done *by* you, as well as *on* you
  - Are you the *pusher* or the *pushee?*
- Work is a measure of expended energy
  - Work makes you tired
- Unit of work: Joules (j)
- Work is a *scalar* quantity

WORK DEPENDS ON

- The amount of force applied to the object.
- The distance that the object moves while the force is applied.
- The direction of the force with respect to the direction the object moves.

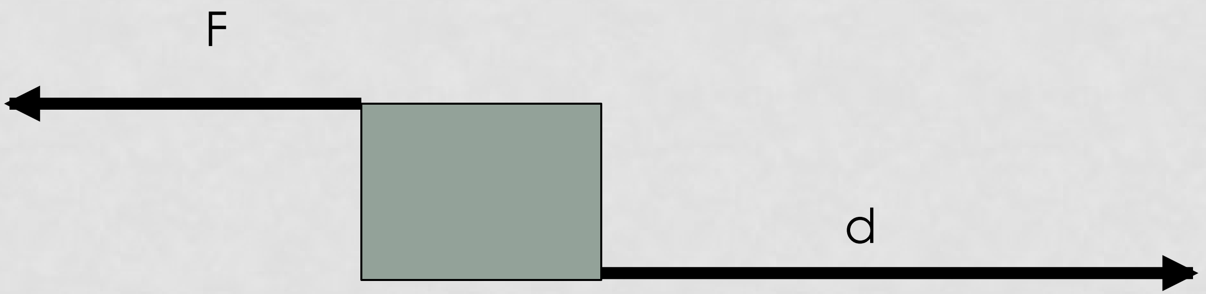
CALCULATING WORK

- If the force on the object is in the direction the object moves, the work done is:
- W= f x d



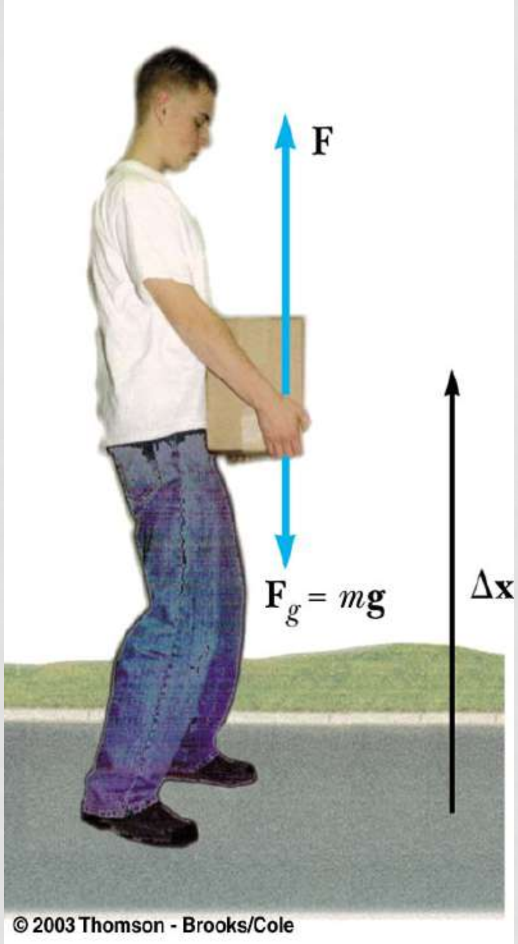
CALCULATING WORK

- If the direction of the force is ***opposite*** the direction the object moves, work is:
- W = - f x d



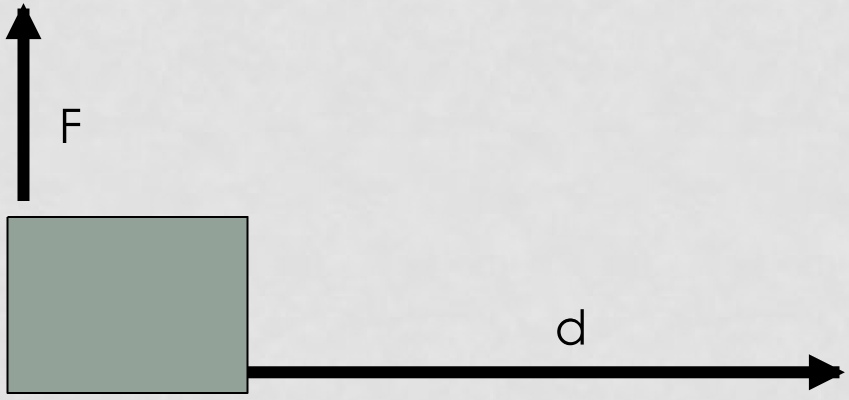
CALCULATING WORK

- Work can be positive or negative
- Man does positive work lifting box
- Man does negative work lowering box
- Gravity does positive work when box lowers
- Gravity does negative work when box is raised



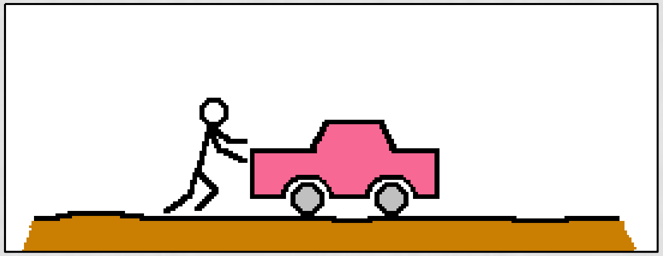
FORCE AND WORK

- Force and Work do not mean the same thing
- If the force is ***perpendicular*** to the direction the object moves, the work done is ***0***.
- If the object ***doesn't move***, the work done is ***0***.
- W = 0



EXAMPLE

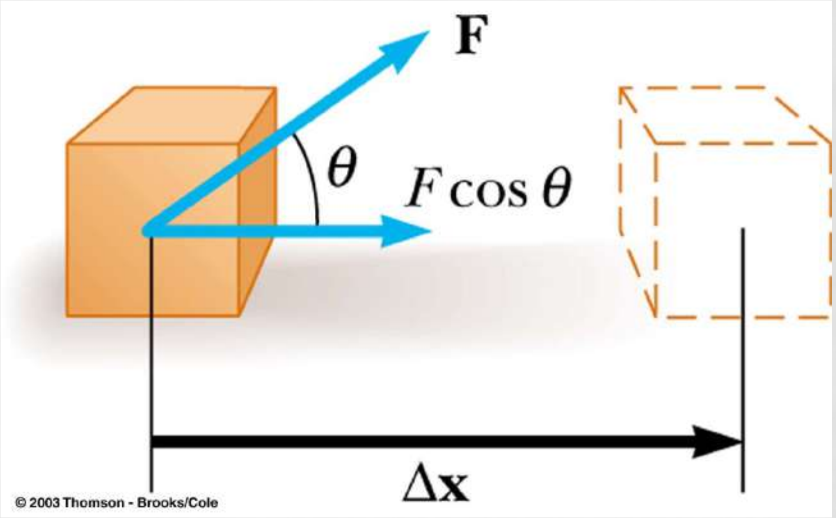
- A person pushes a car with a 110 N force for a distance of 30 m. How much work was done?



- W = f x d
- W = 110 N x 30m
- W = 3300 Nm or 3300 j

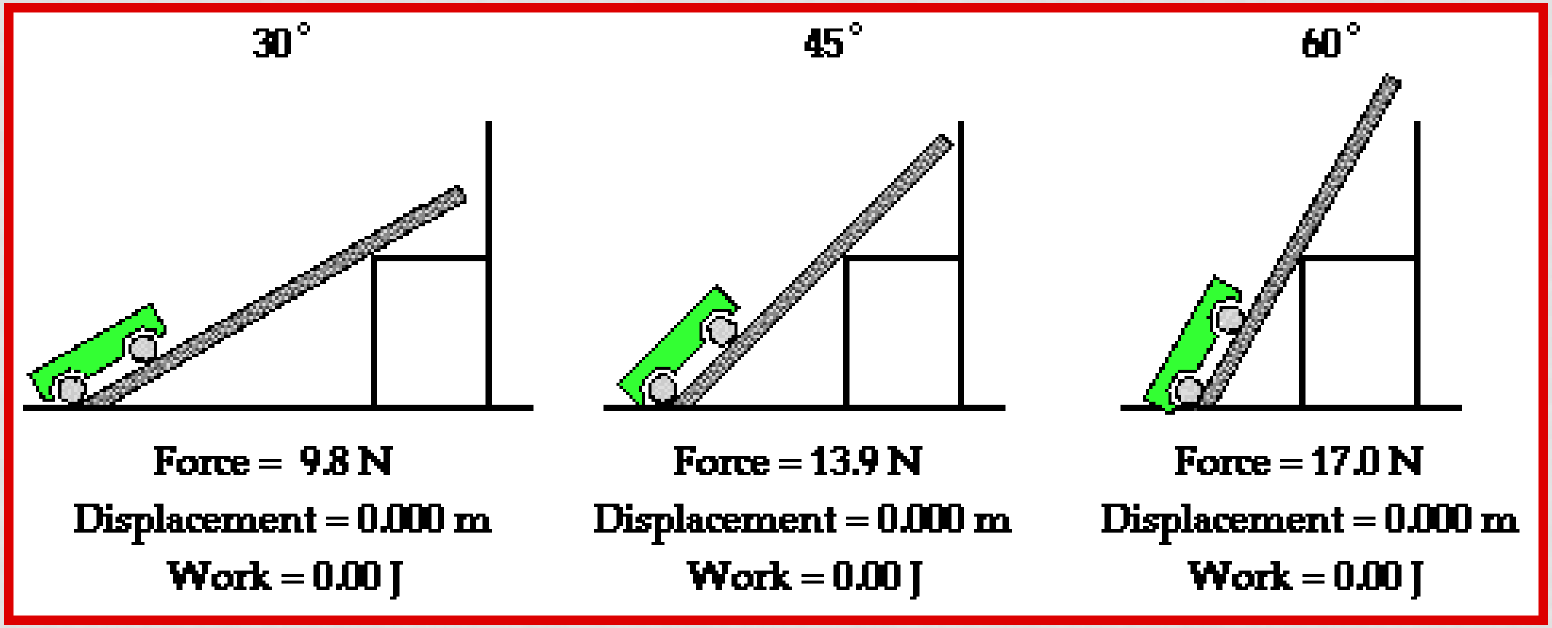
WHAT IF THERE IS AN ANGLE?

- Sometimes there is an angle between force and displacement
- The equation becomes:
- W = f x d x cosθ



ANGLE AND WORK

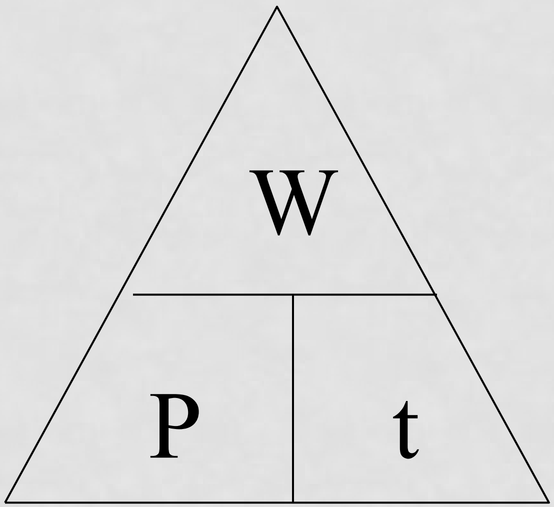
- Same amount of work, however the force needed is greater



WHAT IS POWER?

- Power is energy exchanged per unit of time
  - How fast you get work done
- Power = work over time

$$P = \frac{W}{t}$$



UNITS OF POWER

- Units of power: 1 Joule/sec = 1 ***Watt***
- 1000 Watts = 1 ***kilowatt***
- Power is a ***scalar*** quantity.
- 1 horsepower = 746 watts

EXAMPLE

- The minimum work required to raise a 800 N person up 10 m, is:
  - W = F x d
  - W = (800 N) (10 m) = 8000 J
- If this work is done in 60 sec, then what is the power?

$$P = \frac{W}{t} = \frac{8000\ J}{60\ sec} = 133\frac{J}{sec} = 133\ watts$$

EXAMPLE

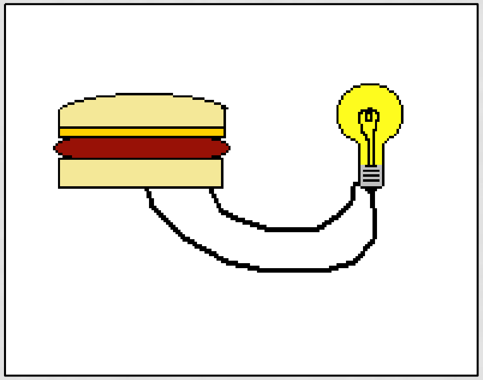
- A 'Big Mac' contains about 2,000,000 J of chemical energy. If all this energy could be used to power a 60 watt light bulb, how long could it run?

$$P = \frac{E}{t}$$

$$t = \frac{E}{P} = \frac{2{,}000{,}000\ \text{J}}{60\ \text{watt}}$$

$$t = 33{,}000\ \frac{\text{J}}{\text{J/sec}}$$

$$t = 33{,}000\ \text{sec} \qquad (\sim 9\ \text{hr})$$



WHAT IS ENERGY?

- *Energy* is the *capacity* to do work
- Two main categories of energy
  - Kinetic Energy: Energy of motion
  - Potential Energy: Stored (latent) capacity to do work
- Energy can be converted between types

KINETIC ENERGY

- Energy of motion
- An object's ***kinetic energy*** depends on:
- the object's ***mass***.
  - Kinetic energy is ***directly proportional*** to mass.
- the object's ***speed***.
  - Kinetic energy is ***directly proportional*** to the ***square*** of the object's speed.

$$KE = \frac{1}{2}mv^2$$

WORK-ENERGY THEOREM

- Work is equal to the change in kinetic energy.

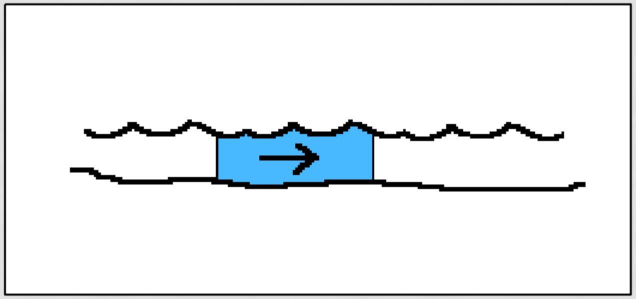
$$W = \Delta KE$$

KINETIC ENERGY

- Kinetic energy is a ***scalar*** quantity.
- Common units of kinetic energy: ***Joules***

EXAMPLE

What is the KE of 100 kg of water moving at 1.2 m/sec?



$$E_K = \frac{1}{2} mv^2$$

$$E_K = \frac{1}{2} (100 \text{ kg})(1.2 \text{ m/s})^2$$

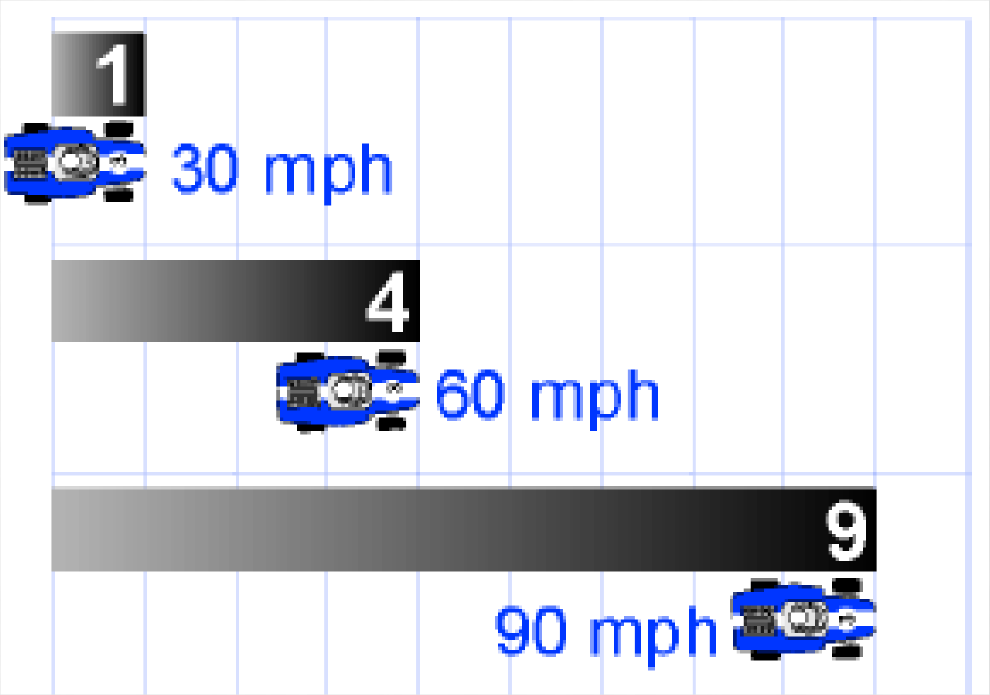
$$E_K = \frac{1}{2} (100 \text{ kg})(1.44 \text{ m}^2/\text{s}^2)$$

$$E_K = 72 (\text{kg m}^2)/\text{s}^2$$

$$E_K = 72 \text{ J}$$

STOPPING DISTANCE

- Kinetic energy becomes important in calculating braking distance.

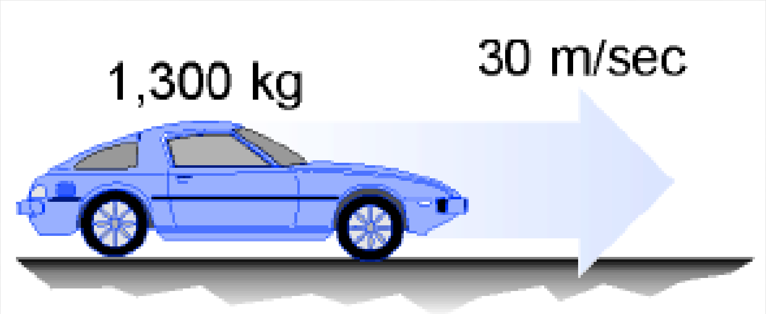


EXAMPLE

- A car with a mass of 1,300 kg is going straight ahead at a speed of 30 m/sec (67 mph).
- The brakes can supply a force of 9,500 N.
- Calculate:

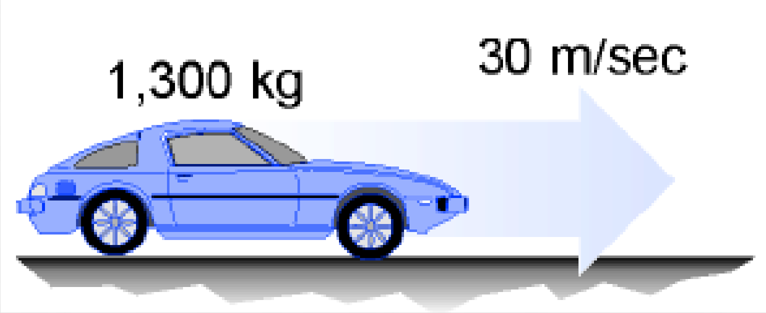
  a) The kinetic energy of the car.

  b) The distance it takes to stop.



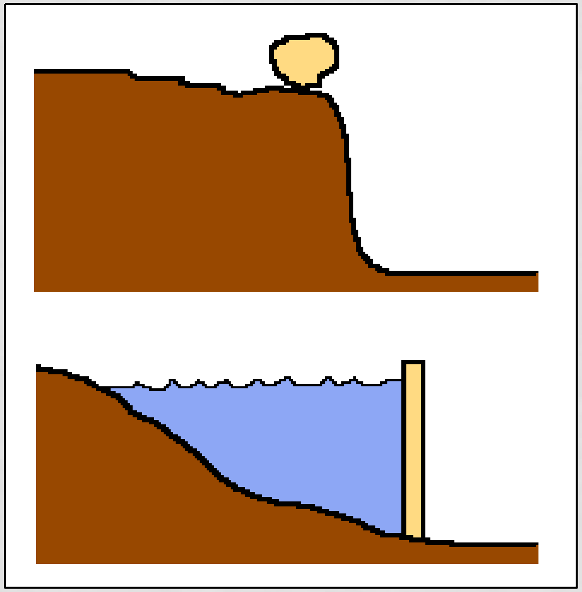
EXAMPLE

- Kinetic energy KE = 1/2 mv^2
- KE = (1/2)(1,300 kg)(30 m/sec)^2
- KE = 585,000 J
- To stop the car, the kinetic energy must be reduced to zero by work done by the brakes.
- Work, W = Fd
- 585,000 J = (9,500 N) × d
- d = 62 meters



POTENTIAL ENERGY

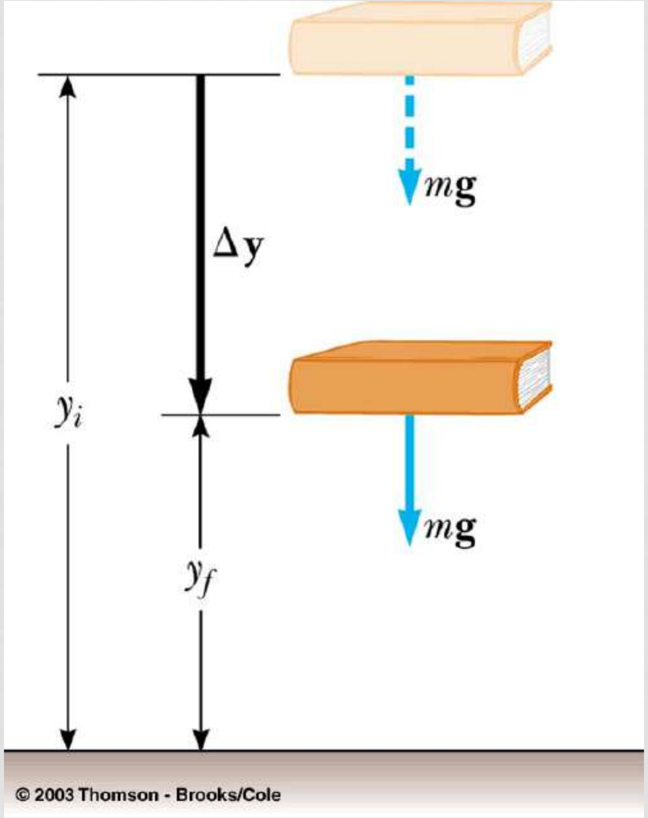
- Sometimes work is ***not*** converted directly into kinetic energy. Instead it is "stored", or "hidden".
- ***Potential energy*** is ***stored energy*** or ***stored work***.
- ***Potential energy*** is energy that an object (system) has due to its ***position*** or ***arrangement***.



GRAVITATIONAL POTENTIAL ENERGY

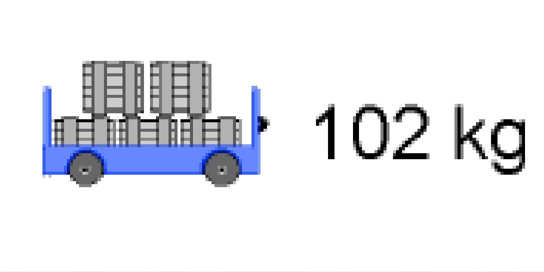
- Potential energy that is dependent on mass, height, and acceleration due to gravity
- Essentially this is work done against gravity

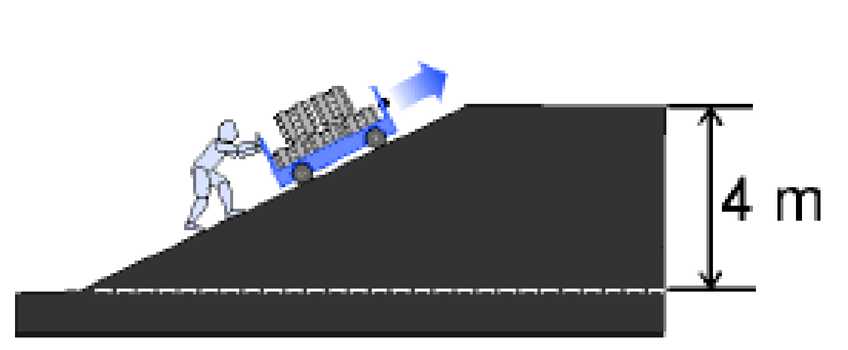
GPE = mgh



EXAMPLE

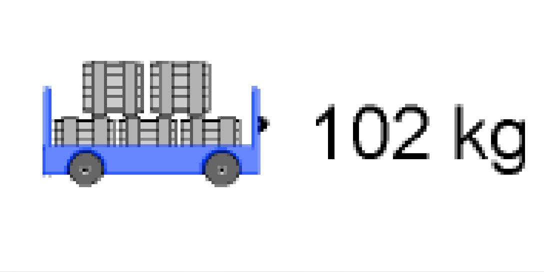
- A cart with a mass of 102 kg is pushed up a ramp.
- The top of the ramp is 4 meters higher than the bottom.
- How much potential energy is gained by the cart?
- If an average student can do 50 joules of work each second, how much time does it take to get up the ramp?

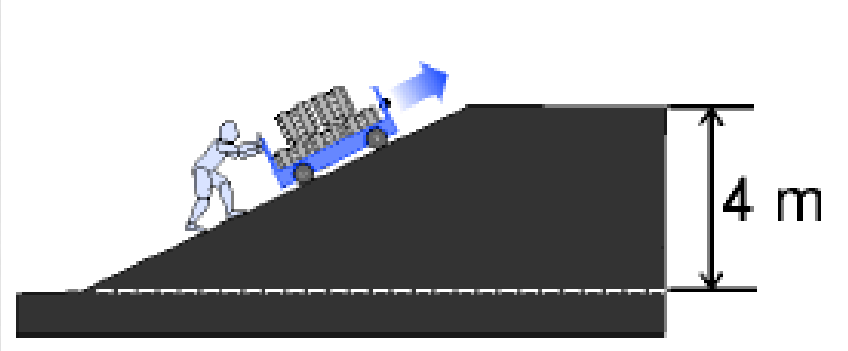




EXAMPLE, CONT

- Use the formula for potential energy PE = mgh.
- PE = (102 kg)(9.8 N/kg)(4 m)
- PE = 3,998 J
- At a rate of 50 J/sec, it takes:
- 3,998 ÷ 50
- 80 seconds to push the cart up the ramp.





RELATIONSHIP OF PE AND KE