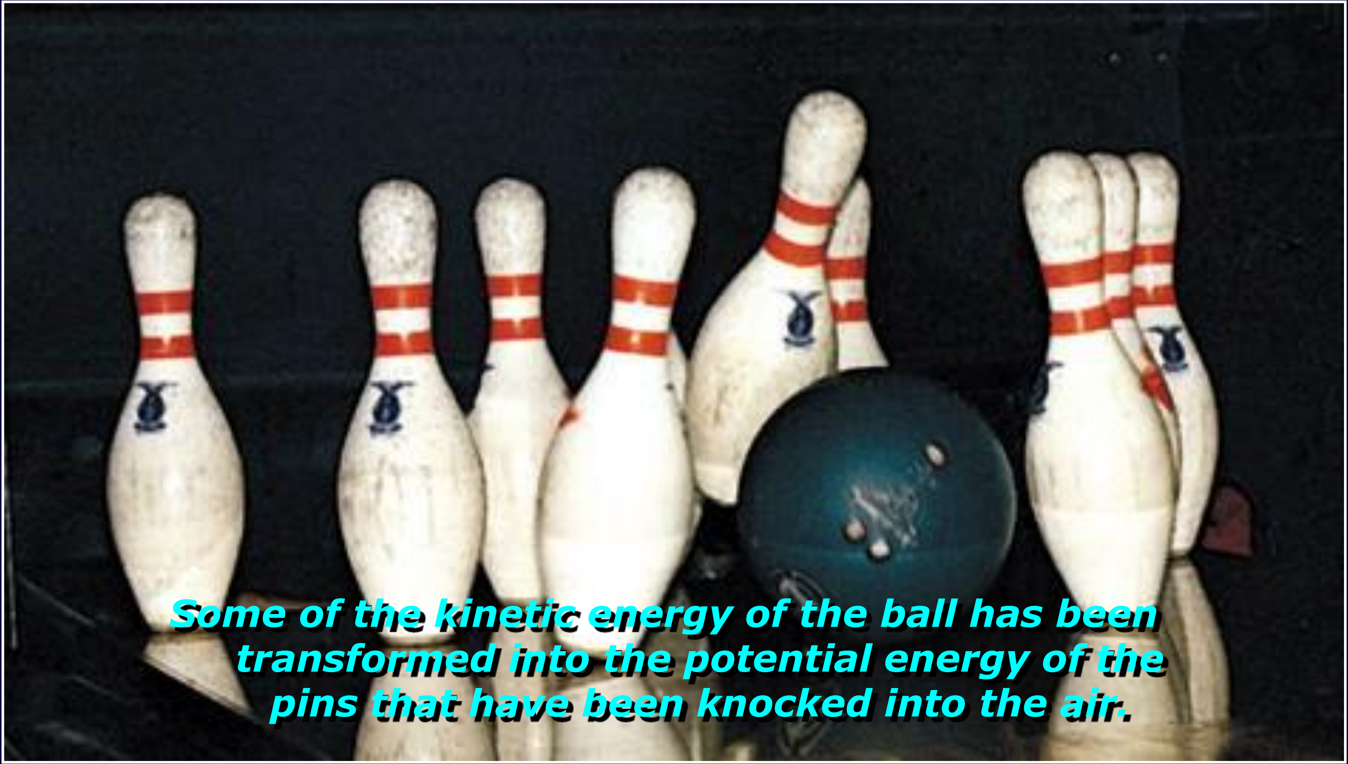
Topic 2.3



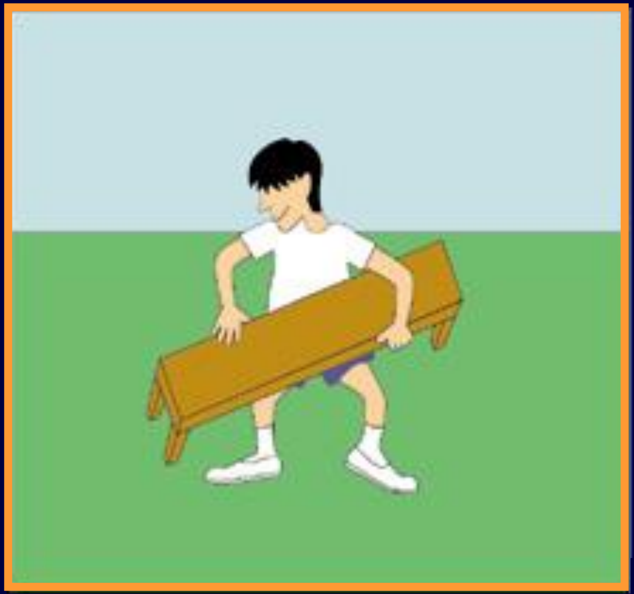
Work, Energy & Power

contents

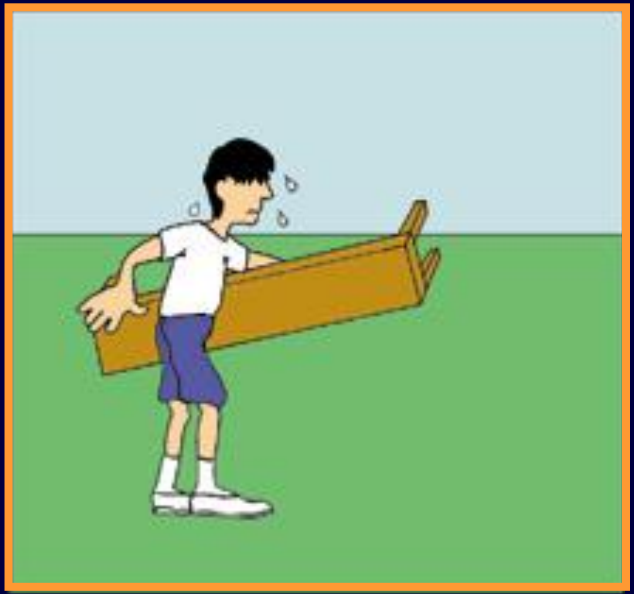
Work

Work is defined as the force multiplied by displacement in the direction of the force.

- has a SI unit of Joule (J)



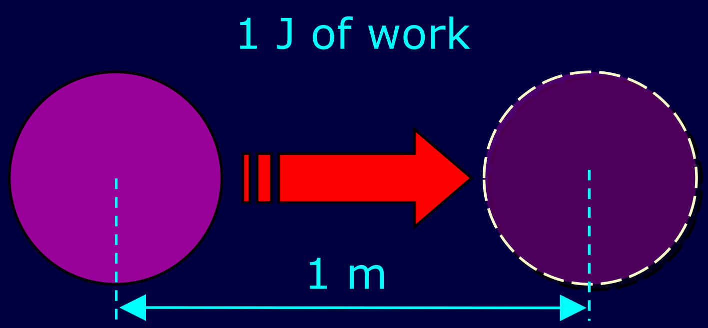
You are doing work when you lift up a bench from the ground or carry it walking.



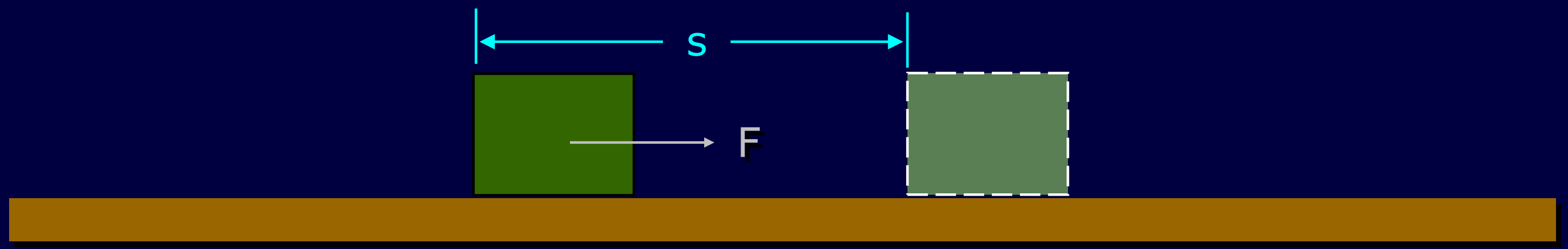
You are not doing work if you are just standing still with a bench in your hands.

Work

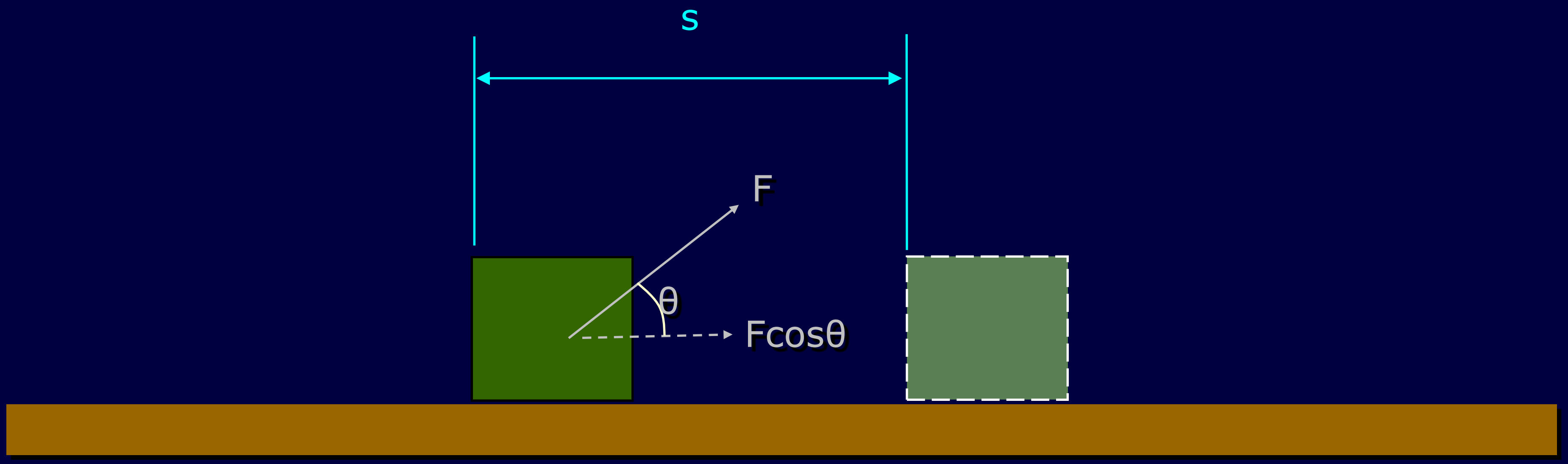
- One joule of work is done when a force of one newton moves through a distance of one metre in the direction of the force



work = force x distance moved in the direction of the force



Work

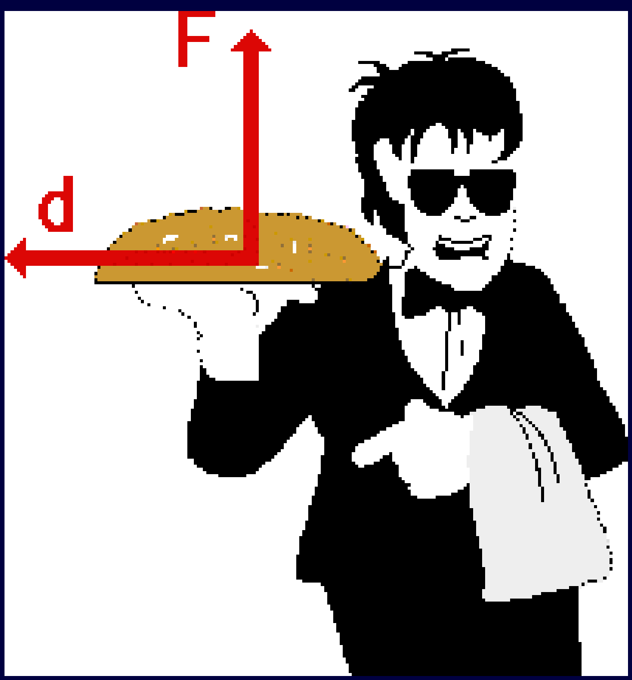


$$W = Fs\cos\theta$$

Work

Energy and work are both measured in joules. When work is done, energy is also used up.

The amount of work done is simply the energy that is transferred or used.



Question:

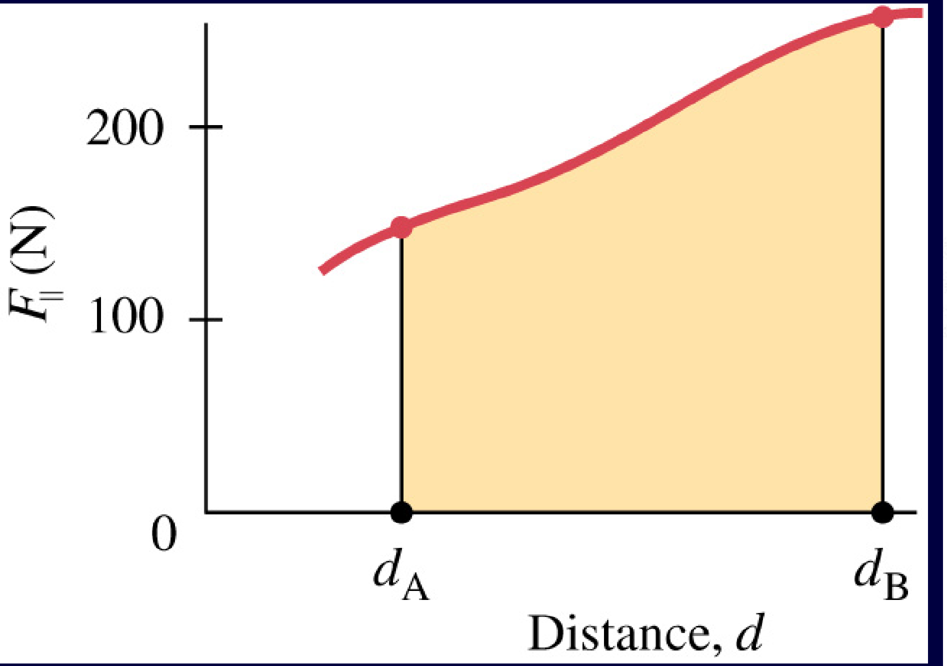
Consider a waiter carries a tray full of meals above his head by one arm across the room, does he do any work upon the tray?

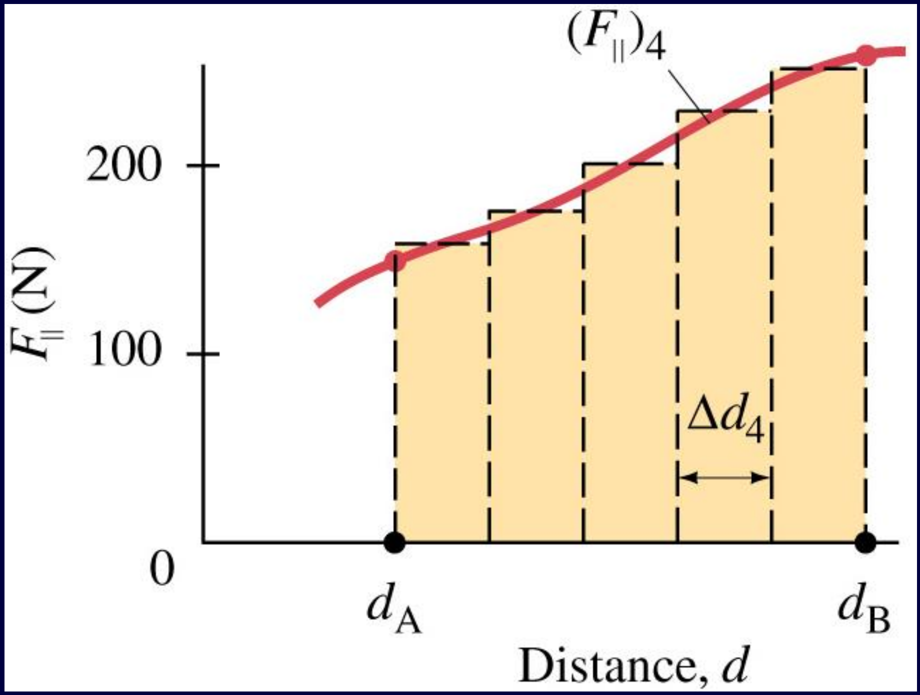
Work or Not Work?

Example	Direction of force	Direction of motion	Doing work?
	→	→	YES
	↑	→	NO
	↑	↑	YES
	↑	→	NO

Work Done by a Varying Force

For a force that varies, the work can be approximated by dividing the distance up into small pieces, finding the work done during each, and adding them up. As the pieces become very narrow, the <u>work done is equal to the area under the force vs. distance curve.</u>





Forms of energy

Energy

- The capacity to do work
- SI Unit: Joule (J)
- Scalar Quantity
- Energy can be converted from one form to another OR

  Transferred from one body to another through work done or heat exchange

Forms of energy

Mechanical Energy

- Kinetic Energy

  - is the energy by virtue of its motion

- Potential Energy (PE)

  - possessed by objects due to its

    (a) Position

    Raised object has Gravitational PE

    (b) Condition

    Stretched elastic band has Elastic PE

Mechanical Energy

Kinetic Energy

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

E_k : Kinetic Energy (J)

m : mass of body (kg)

v : velocity of body (ms^{-1})

Question:

A 750 kg compact car moving at 100 km h^{-1} has approximately 290 000 Joules of kinetic energy. What is the kinetic energy of the same car if it is moving at 50 km h^{-1}? 72 500 J

Mechanical Energy

Another form of the Kinetic Energy Formula

$$E_K = \frac{p^2}{2m}$$

E_k : Kinetic Energy (J)

p : Momentum ($kg\ m\ s^{-1}$)

m : mass of body (kg)

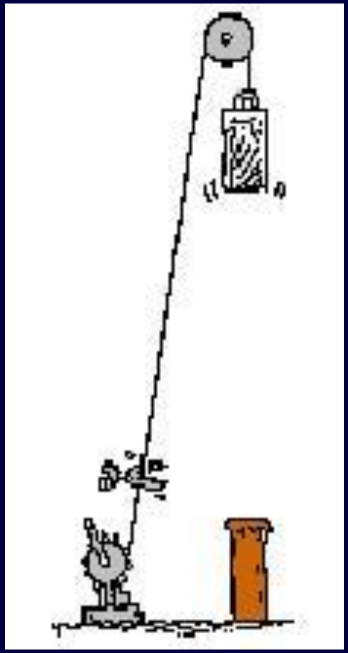
Can you derive this equation from the previous one?

Mechanical Energy

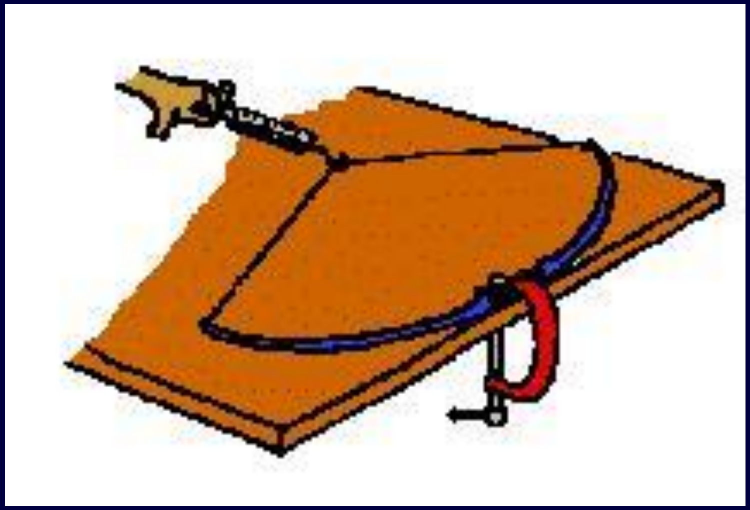
Potential Energy (PE)

Potential energy is the energy stored in a body as a consequence of its a body possessed by

- position, shape or state

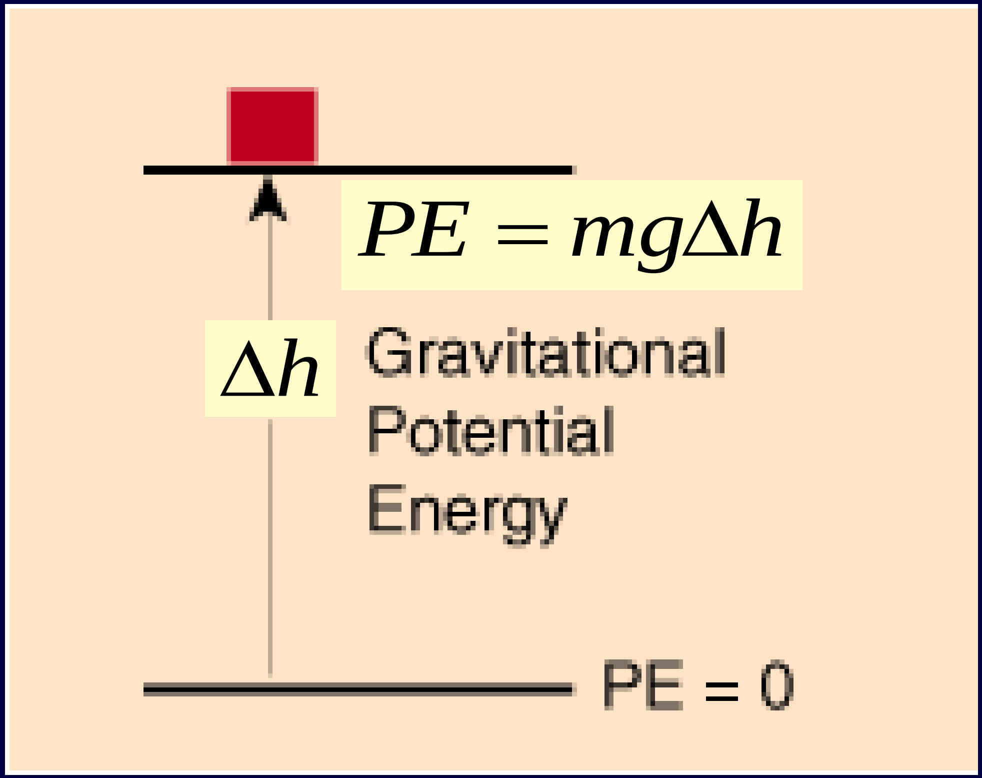


Gravitational PE



Elastic PE

Gravitational Potential Energy (GPE)



$$\Delta E_p = mg\Delta h$$

ΔE_p : Change in Potential Energy (J)

m : mass of body (kg)

g : acceleration due to gravity (9.81 m s^{-2})

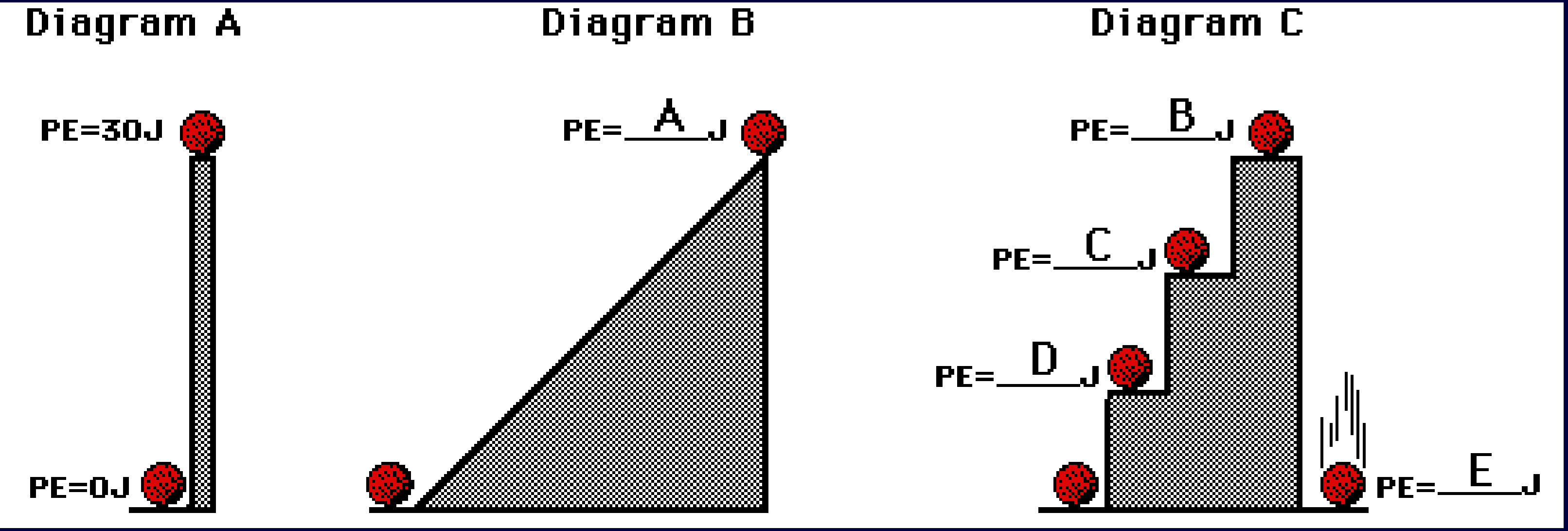
Δh : height of body from reference level (m)

Gravitational Potential Energy (GPE)

- For a body near the surface of Earth at a height h, GPE is defined as
  - amount of work done in order to raise the body to the height *h* from a reference level

Question:

What are the GPE for the following positions shown below?



Energy conversion and conservation

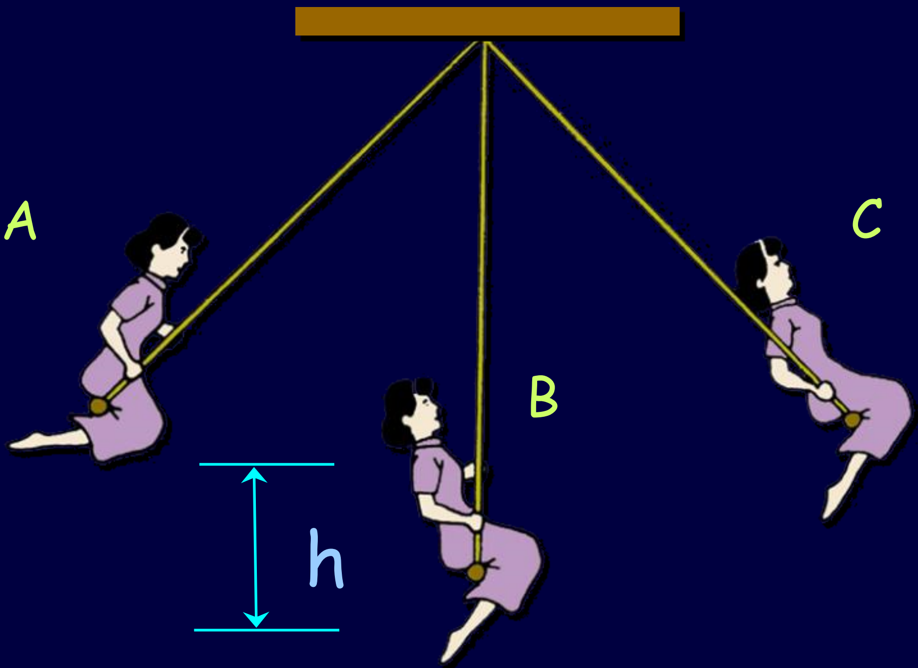
Principle of Conservation of Energy

The **Principle of Conservation of Energy** states that energy cannot be created or destroyed but may be converted from one form to another but the total amount remains constant

Energy conversion and conservation

Principle of Conservation of Energy

Ignoring effects of friction and air resistance



$PE_A = PE_{max}$

$= mgh$

$KE_A = 0\ J$

$V_A = 0\ ms^{-1}$

$PE_B = 0$

$KE_B = KE_{max} = PE_A$

$\frac{1}{2}mv_{max}^2 = mgh$

$PE_C = PE_{max}$

$= mgh$

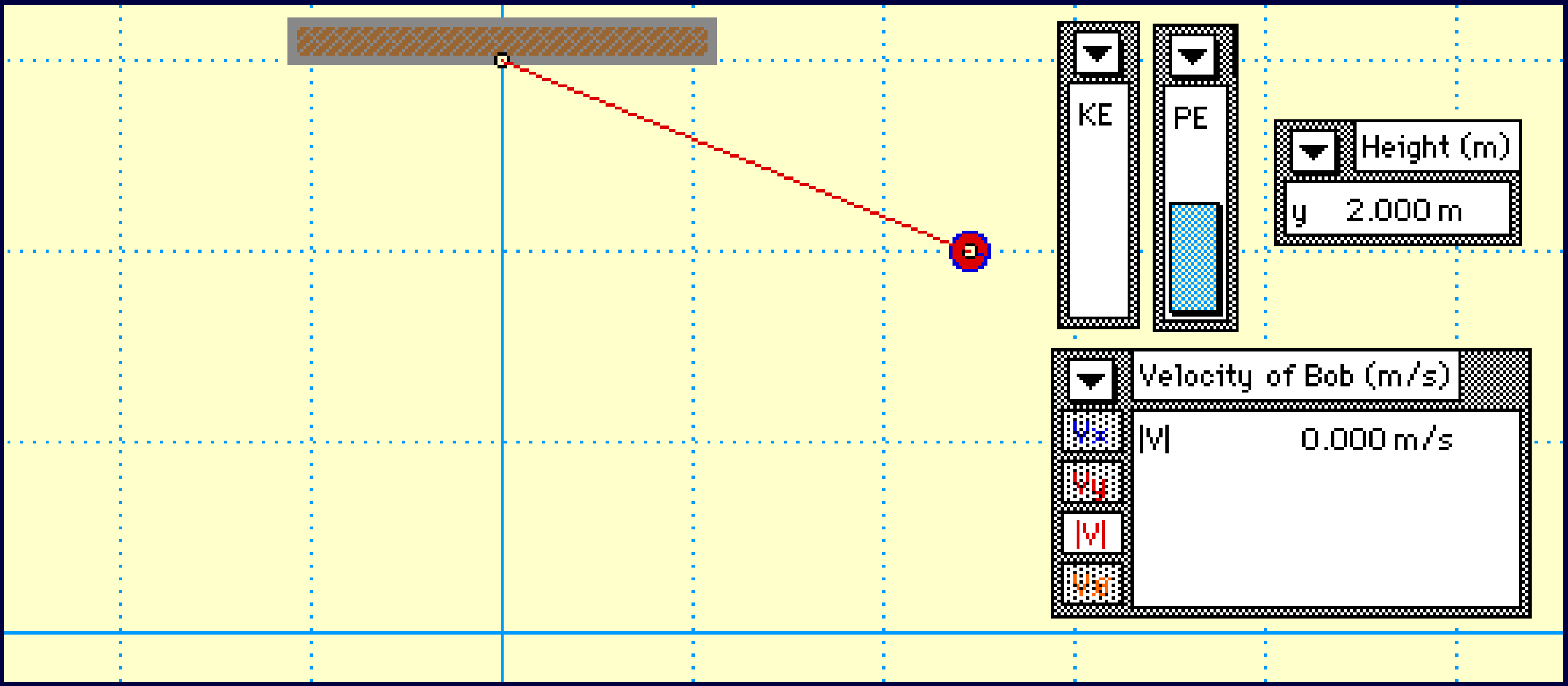
$KE_C = 0\ J$

$V_C = 0\ ms^{-1}$

Energy conversion and conservation

Principle of Conservation of Energy
(Energy Transformation for a pendulum)

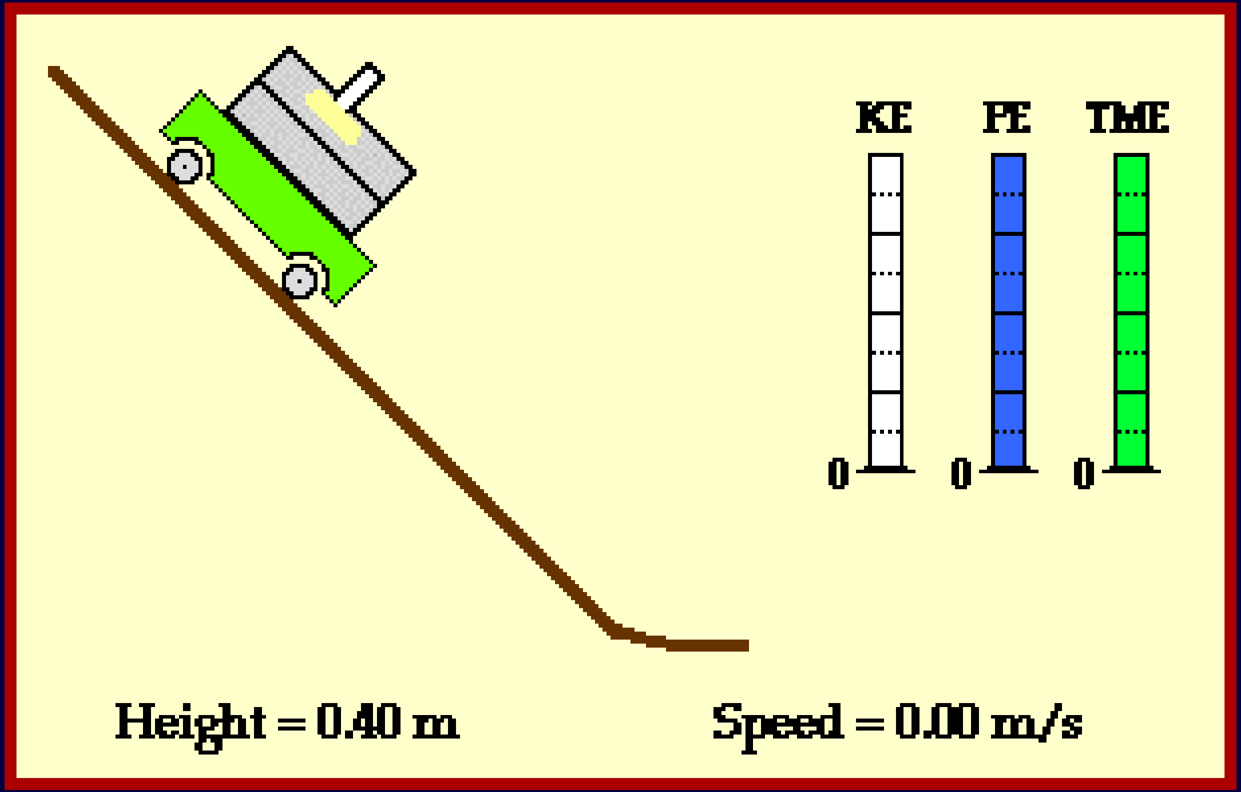
Ignoring effects of friction and air resistance



Energy Conversion and Conservation

Principle of Conservation of Energy (Energy Transformation on an incline)

Ignoring effects of friction and air resistance



Energy Conversion and Conservation

Principle of Conservation of Energy (Energy Transformation of a Dart)

Ignoring effects of friction and air resistance

Energy Conversion and Conservation

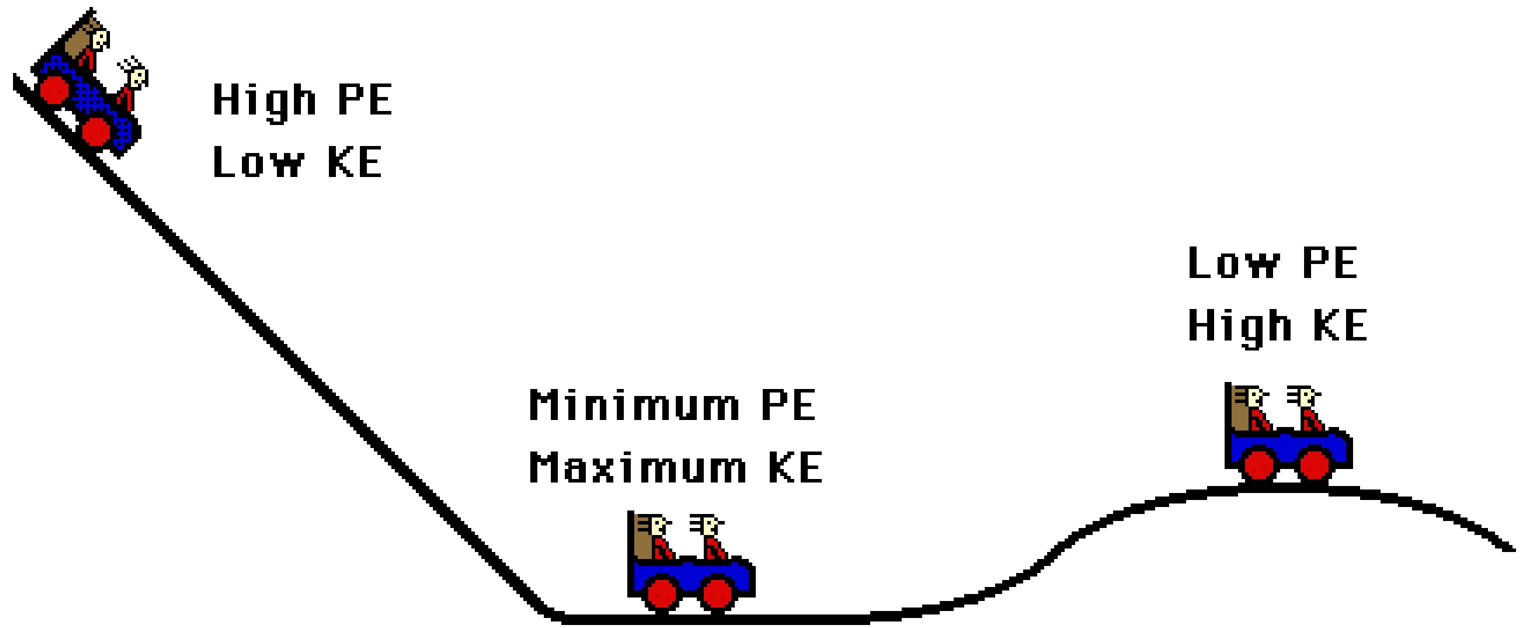
Principle of Conservation of Energy (Energy Transformation of a Dart)

Ignoring effects of friction and air resistance

Energy Conversion and Conservation

Principle of Conservation of Energy (Energy Transformation on an incline)

Ignoring effects of friction and air resistance

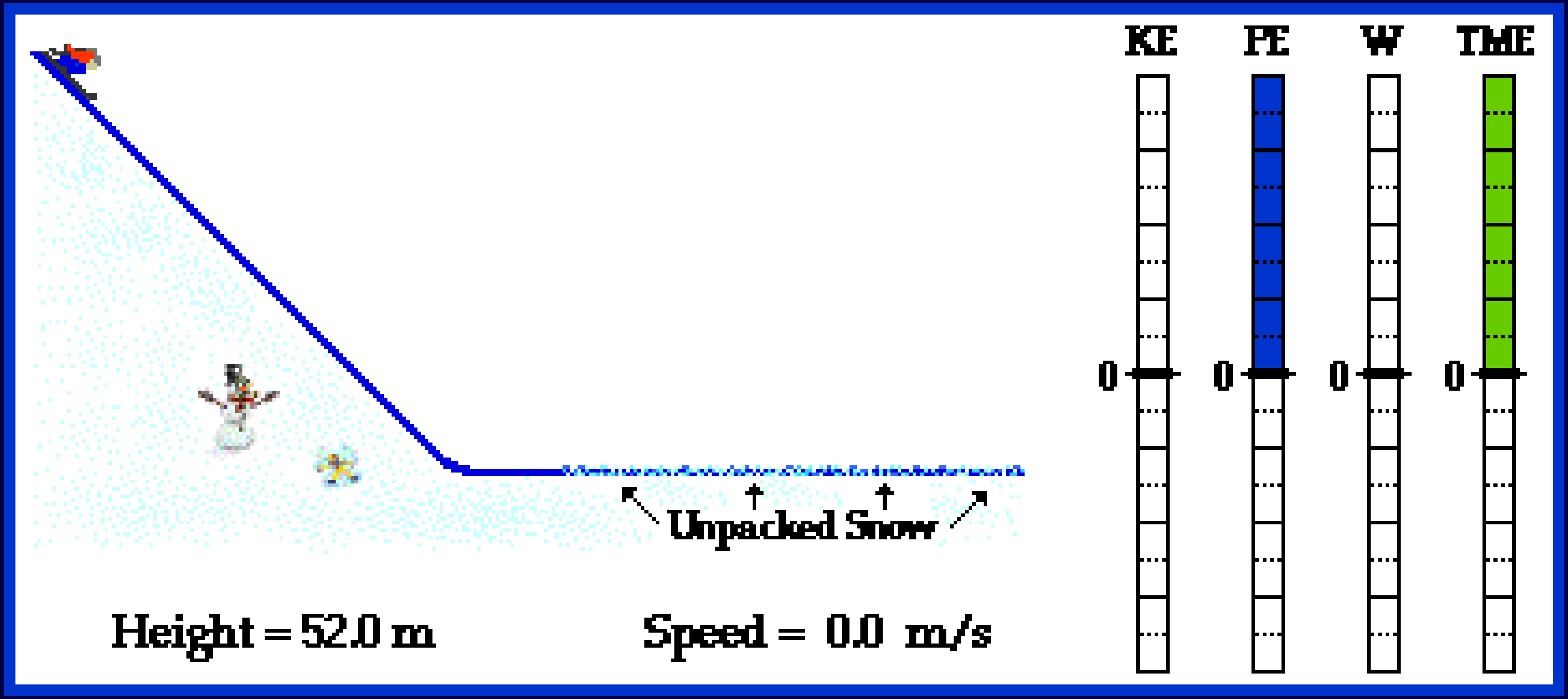


As a coaster car loses height, it gains speed; PE is transformed into KE. As a coaster car gains height it loses speed; KE is transformed into PE. The sum of the KE and PE is a constant.

Energy Conversion and Conservation

Principle of Conservation of Energy
(Energy Transformation of a downhill skiing)

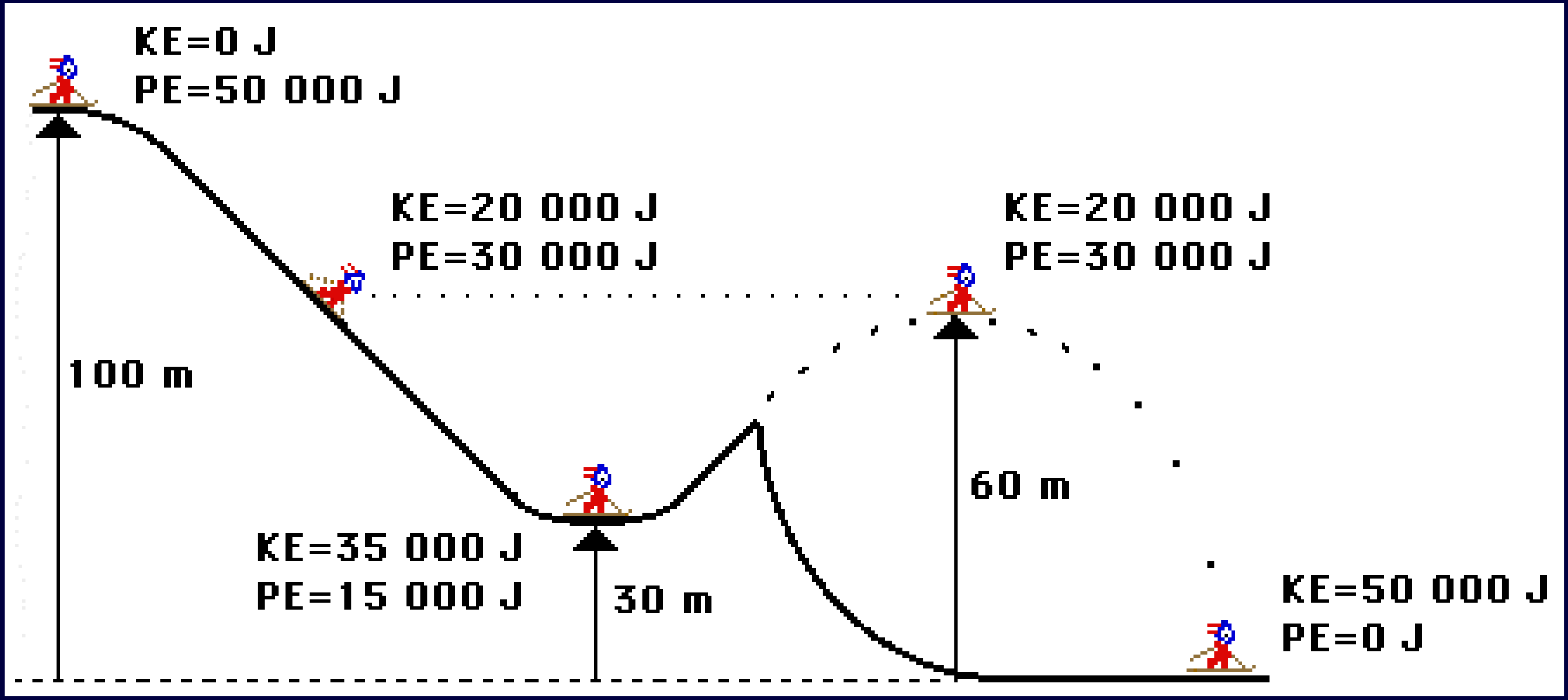
Ignoring effects of friction and air resistance



Energy Conversion and Conservation

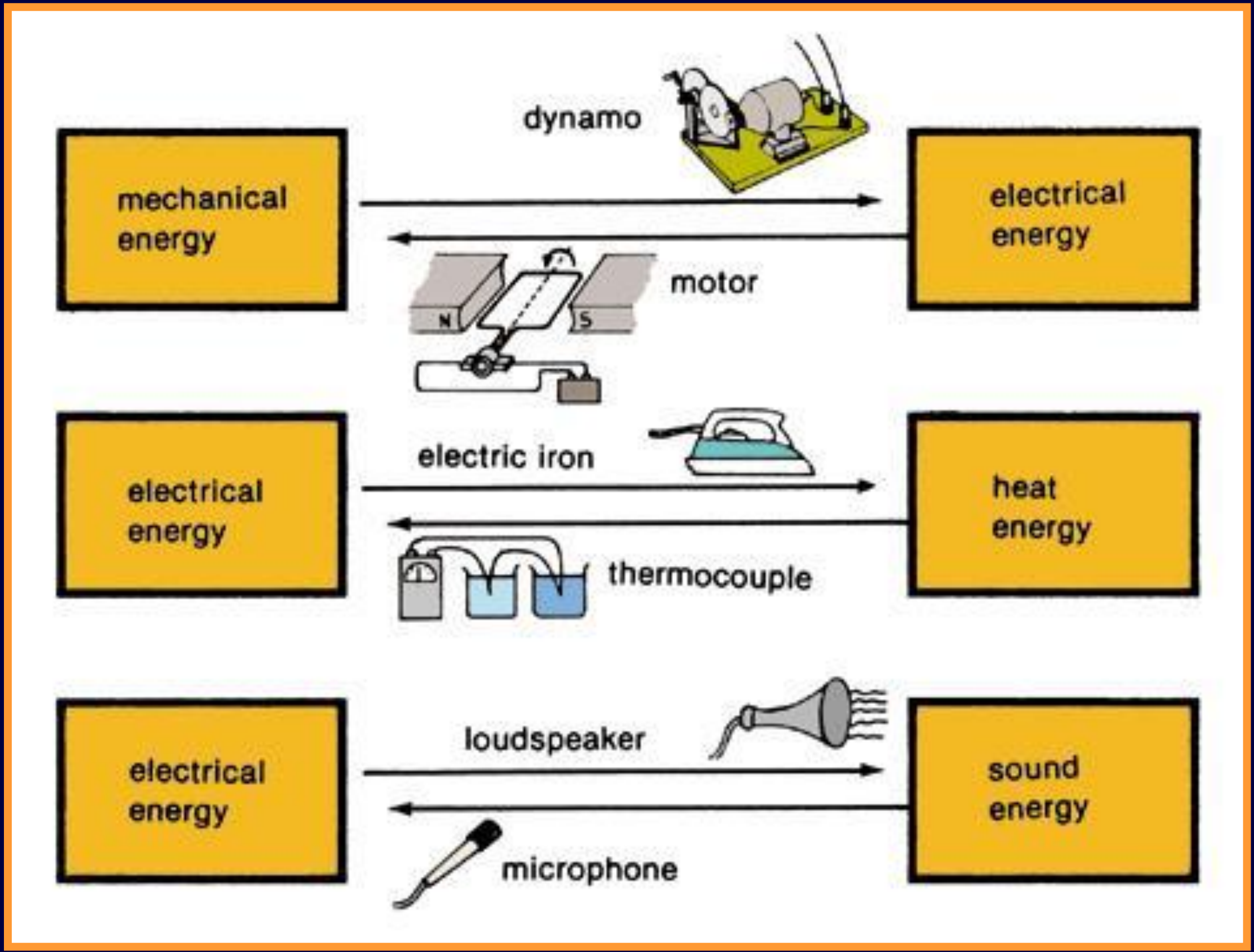
Principle of Conservation of Energy (Energy Transformation of a downhill skiing)

Ignoring effects of friction and air resistance



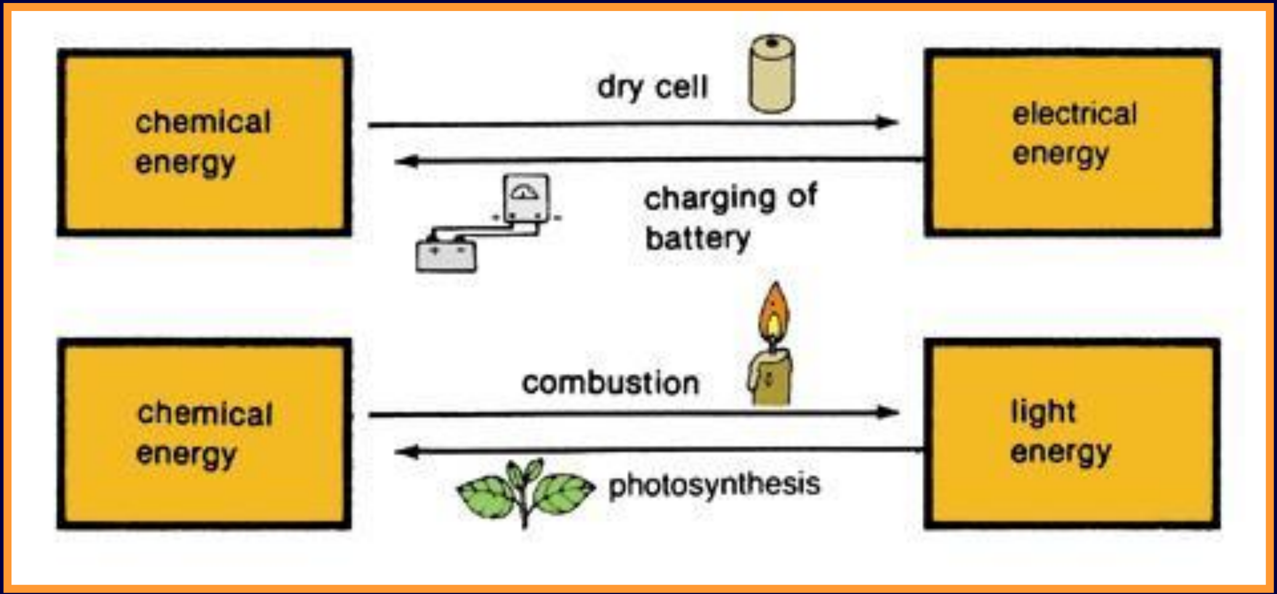
Energy Conversion and Conservation

Conversion of energy



Energy Conversion and Conservation

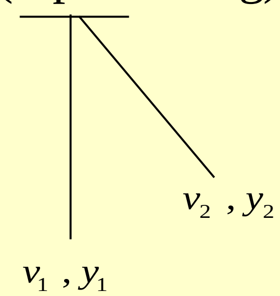
Conversion of energy



Example: Conservation of Energy

Jane, looking for Tarzan, is running at top speed (5.3m s^{-1}) and grabs a vine hanging vertically from a tall tree in the jungle. How high can she swing upward? Does the length of the vine affect your answer? (Giancolio, Chap 6, 33)

The only forces acting on Jane are gravity and the vine tension. The tension pulls in a centripetal direction, and so can do no work – the tension force is perpendicular at all times to her motion. So Jane's mechanical energy is conserved. Subscript 1 represents Jane at the point where she grabs the vine, and subscript 2 represents Jane at the highest point of her swing. The ground is the zero location for PE $(y = 0)$. We have $v_1 = 5.3\,\mathrm{m/s}$, $y_1 = 0$, and $v_2 = 0$ (top of swing). Solve for y_2, the height of her swing.



$$\tfrac{1}{2}mv_1^2 + mgy_1 = \tfrac{1}{2}mv_2^2 + mgy_2 \quad \rightarrow \quad \tfrac{1}{2}mv_1^2 + 0 = 0 + mgy_2 \quad \rightarrow$$

$$y_2 = \frac{v_1^2}{2g} = \frac{(5.3\,\mathrm{m/s})^2}{2(9.8\,\mathrm{m/s^2})} = \boxed{1.4\ \mathrm{m}}$$

$\boxed{\text{No}}$, the length of the vine does not enter into the calculation, unless the vine is less than 0.7 m long. If that were the case, she could not rise 1.4 m high. Instead she would wrap the vine around the tree branch.

Efficiency

Efficiency of a system is defined as the ratio of the useful energy output to the energy input

$$\text{Efficiency} = \frac{\text{Useful energy output}}{\text{Total energy input}} \times 100\%$$

Question to ponder:

What if the efficiency of a system is NOT 100%, does it mean that the Principal of Conservation of Energy has **failed**?

Power

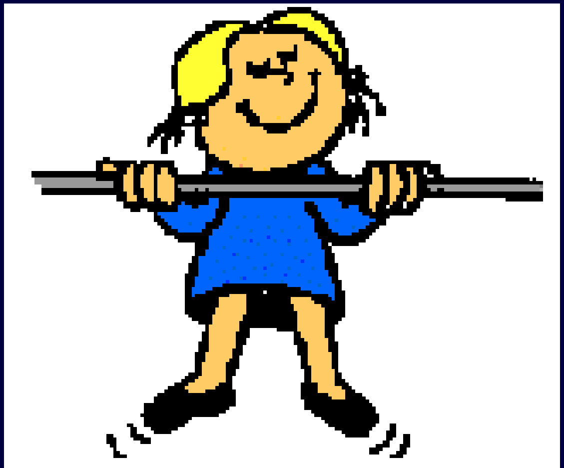
Power is defined as the rate of doing work.

- has a SI unit of watt (W)
- one watt is one joule per second ($1\ W = 1\ J\ s^{-1}$)

$$\text{power} = \frac{\text{work done } or \text{ energy change}}{\text{time taken}}$$

$$power = Fv$$

Can you derive this?



Question:

If little Nellie Newton lifts her 40-kg body a distance of 0.25 m in 2 s, then what is the power delivered by little Nellie's biceps?