



Work, Energy and Power!

The Calculations and
Equations

James Joule



- British physicist James Joule is best known for his work in electricity and thermodynamics. Together with the physicist William Thomson (later Baron Kelvin), Joule found that the **temperature of a gas falls when it expands** without doing any work. This principle, which became known as the Joule-Thomson effect, underlies the operation of common refrigeration and air conditioning systems.
- The metric system **unit of energy** is the joule (J), after James Joule.



Mechanical

- **Mechanical energy** is the energy which is possessed by an object due to its motion or its stored energy of position
 - **Kinetic energy** : is the energy of motion
 - **Potential Energy** : an object can store energy as the result of its position or elastic source

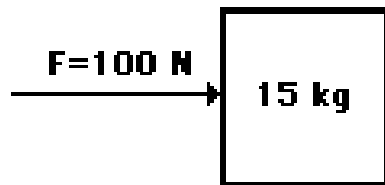


Work Concept

- **Work** is defined as a force acting upon an object to cause a displacement
- Mathematically, work can be expressed by the following equation.
- $W = F \times d \cos \theta$ ($\cos 0^\circ = 1$)
- where F = force, d = displacement, and the angle (θ) is defined as the angle between the force and the displacement vector

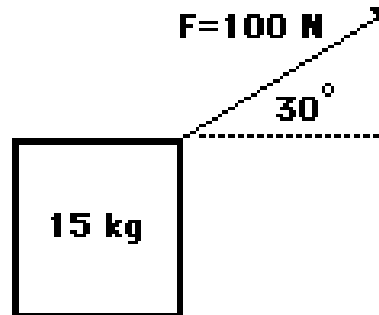
Work Calculations

Diagram A



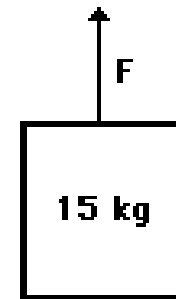
A 100 N force is applied to move a 15 kg object a horizontal distance of 5 meters at constant speed.

Diagram B



A 100 N force is applied at an angle of 30° to the horizontal to move a 15 kg object at a constant speed for a horizontal distance of 5 m.

Diagram C



An upward force is applied to lift a 15 kg object to a height of 5 meters at constant speed.

$$W = F \times d$$

$$= 100\text{ N} \times 5\text{ m}$$

$$= 500\text{ N m}$$

$$W = F \times d \cos 30^\circ$$

$$= 100\text{ N} \times 5\text{ m} \times .87$$

$$= 413\text{ N m}$$

$$W = F \times d$$

$$= 15\text{ Kg}(10\text{ m/s}^2) \times 5\text{ m}$$

$$= 750\text{ N m}$$

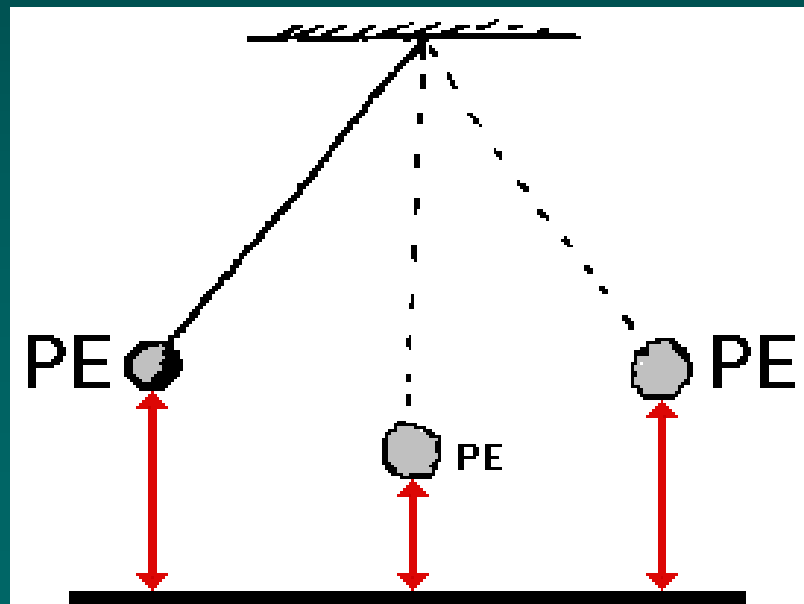
Gravitational Potential Energy

- After an object has been lifted to a height, work is done.



- $PE = W = F \times d = mgh$

Potential Energy is maximum at the maximum HEIGHT





Potential Energy Calculation

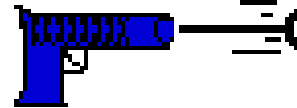
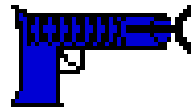
- How much potential energy is lost by a 5Kg object to kinetic energy due a decrease in height of 4.5 m
- $PE = mgh$
- $PE = (5\text{Kg})(10 \text{ m/s}^2)(4.5 \text{ m})$
- $PE = 225 \text{ Kg m}^2/\text{s}^2$
- $PE = 225 \text{ J}$



Kinetic Energy Calculation

- The energy of motion
- $\Delta KE = W = F \times d = mah = \frac{1}{2} mv^2$
- Find the kinetic energy of an 4 Kg object moving at 5m/s.
- $KE = \frac{1}{2} mv^2$
- $KE = \frac{1}{2} (4Kg)(5m/s)^2$
- $KE = 50 \text{ Kg m}^2 / \text{s}^2$
- $KE = 50 \text{ J}$

Elastic potential energy



The compressed springs of a dart gun store elastic potential energy. When the trigger is pulled, the springs apply a force to do work on the dart.

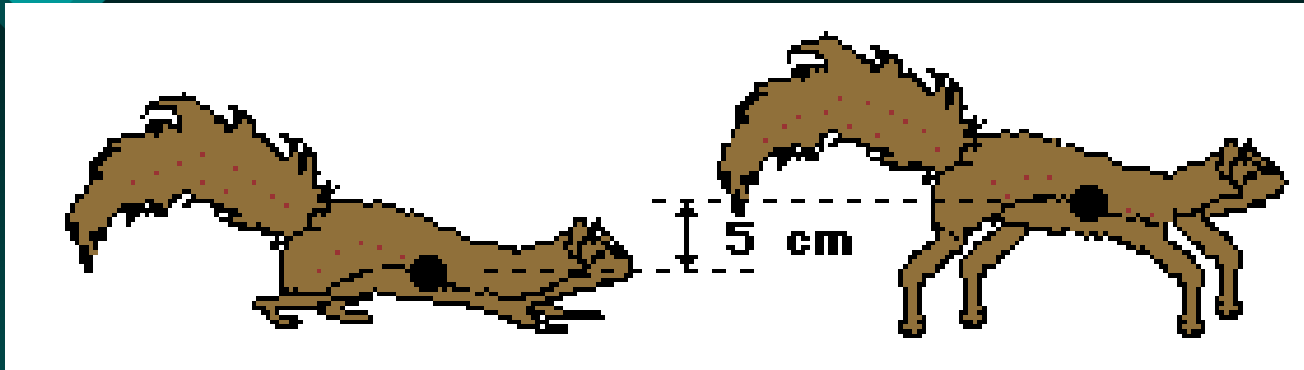
$$F_{\text{spring}} = k \times x$$

$$PE_{\text{spring}} = \frac{1}{2} \times k \times x^2$$

where k = spring constant

x = amount of compression
(relative to equilibrium pos'n)

Spring constant Calculation



A tired squirrel (mass of 1 kg) does push-ups by applying a force to elevate its center-of-mass by 5 cm. (A) Determine the number of push-ups which a tired squirrel must do in order to do a mere 5.0 Joules of work. (B) Determine the squirrel's spring constant.

Spring Constant Calculation

- $W = F \times d = 10 \text{ N} \times (.05\text{m}) = .5 \text{ N m}$
- $W = .5 \text{ J}$ (each push up)
- 10 pushups = 5 J
- $PE = \frac{1}{2} k x^2$
- $.5 \text{ J} = \frac{1}{2} k (.05\text{m})^2$
- $.5 \text{ J} = \frac{1}{2} k (.003\text{m}^2)$
- $.5 \text{ J} = .0015 \text{ m}^2$
- $333.3 \text{ J/m}^2 = k$





Power!

- Power is the rate that we use energy.
- Power = Work or Energy / Time
- $P = W/t = F \times d/t = F v$
- The units for power :
 - J/s
 - $\text{Kg m}^2 / \text{s}^2 / \text{s}$
 - $\text{N m} / \text{s}$



Power Calculation

- A 5 Kg Cart is pushed by a 30 N force against friction for a distance of 10m in 5 seconds. Determine the Power needed to move the cart.
- $P = F \times d / t$
- $P = 30 \text{ N} (10 \text{ m}) / 5 \text{ s}$
- $P = 60 \text{ N m /s}$
- $P = 60 \text{ watts}$



Summary

- Energy is the ability to move
- Potential is stored energy (Statics)
 - Dependant on height
- Kinetic is moving energy (Dynamics)
 - Dependant on velocity
- Springs store energy dependant on distance and constant