Kinetic Energy

Kinetic energy E_K is the name given to the energy that a body possesses because of its motion. You can think of E_K as being the work needed to give a body a certain velocity when it started from rest.

$u=0$

$$\Delta W = Fs$$

from Newton's second law: $F = ma$

$$\Delta W = mas$$

If $u=0$, $v^2 = \cancel{u^2}^{\,0} + 2as$

$$s = \frac{v^2}{2a}$$

$$\Delta W = m\cancel{a}\left(\frac{v^2}{2\cancel{a}}\right)$$

$$\Delta W = \frac{1}{2}mv^2$$

The work needed to give a body a velocity v when starting from rest.

Kinetic Energy

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

Example:

Determine the kinetic energy of:

$kg \cdot m^2 s^{-2} = N \cdot m = J$

- a billiard ball of mass 0.20 kg moving at $3.0\,ms^{-1}$

  0.90 J

- an electron of mass 9.1×10^{-31} kg moving at $2.0 \times 10^{7}\,ms^{-1}$

  1.8×10^{-16} J

Example

How much work is done in changing the speed of a vehicle of mass 5.0×10^3 kg from $20\,ms^{-1}$ to $30\,ms^{-1}$?

$$\Delta W = \Delta E_k$$

$$\Delta W = E_{k_2} - E_{k_1}$$

$$\Delta W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$$\Delta W = \frac{1}{2}m(v^2 - u^2)$$

$(\Delta v)^2 \neq v^2 - u^2$

$(v-u)^2 \neq v^2 - u^2$

BE CAREFUL!

(DO NOT USE Δv!)

$$\Delta W = \frac{1}{2}(5.0 \times 10^3\,kg)\left((30\,ms^{-1})^2 - (20\,ms^{-1})^2\right)$$

$$\Delta W = \frac{1}{2}(5.0 \times 10^3\,kg)(500\,m^2s^{-2})$$

$$\boxed{\Delta W = 1.3 \times 10^6\,J}$$

$kg\,m^2s^{-2} = J$

How are momentum and kinetic energy related?

(magnitude)
Momentum: $p = mv$

Kinetic energy: $E_K = \frac{1}{2}mv^2$

$$E_K = \frac{mv^2}{2}\left(\frac{m}{m}\right)$$

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

$$E_K = \frac{(mv)^2}{2m}$$

Not in your data booklet.

In your data booklet →

$$E_K = \frac{p^2}{2m} \quad \text{or} \quad p = \sqrt{2mE_K}$$

Example

$p = 1.0\ kg \cdot ms^{-1}$

A trolley of mass 0.50kg moving at 2.0 ms^{-1} east collides with and sticks to a second identical trolley which is initially at rest.

Calculate the kinetic energy of the two trolleys after the collision.

Recall the Law of Conservation of Momentum:

$$p_{total(before)} = p_{total(after)}$$

∴ The momentum of the two trolleys after the collision is $1.0\ kg \cdot ms^{-1}$

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

$$E_K = \frac{(1.0\ kg\,ms^{-1})^2}{2(0.50kg + 0.50kg)}$$

$$E_K = 0.50\ J$$

Gravitational Potential Energy

Gravitational potential energy E_p is the name given to the energy of a body because of its position in a gravitational field or, if we are concerned with the Earth, because of its location with respect to the Earth.

The problem => the zero is totally arbitrary

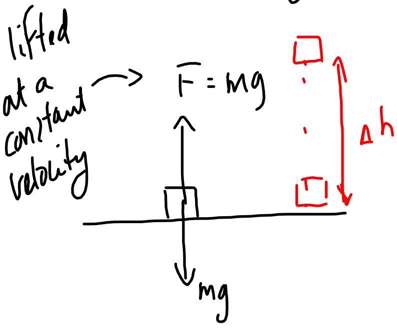
To get around this problem, we deal with the change in gravitational potential energy. We do not need to establish a zero.

Change in gravitational potential energy

Change in gravitational potential energy ΔE_p is the change in energy that a body has due to a change in its position in the direction of a gravitational force. Work must be done in order to change a body's gravitational potential energy.

$$\Delta W = \Delta E_p$$

Consider lifting a mass m a height Δh



$$\Delta W = Fs$$

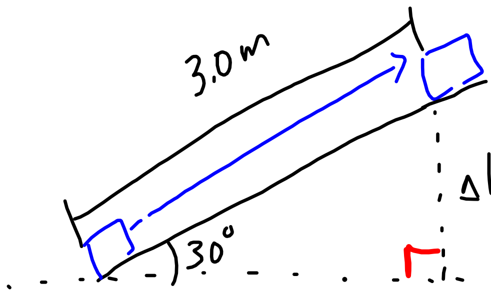
$$\Delta W = mg\Delta h$$

$$\therefore \boxed{\Delta E_p = mg\Delta h}$$

In your data booklet

Example

Calculate the increase in the gravitational potential energy of a body of mass 2.0kg which is moved a distance of 3.0m at an angle of 30° upwards from the horizontal.

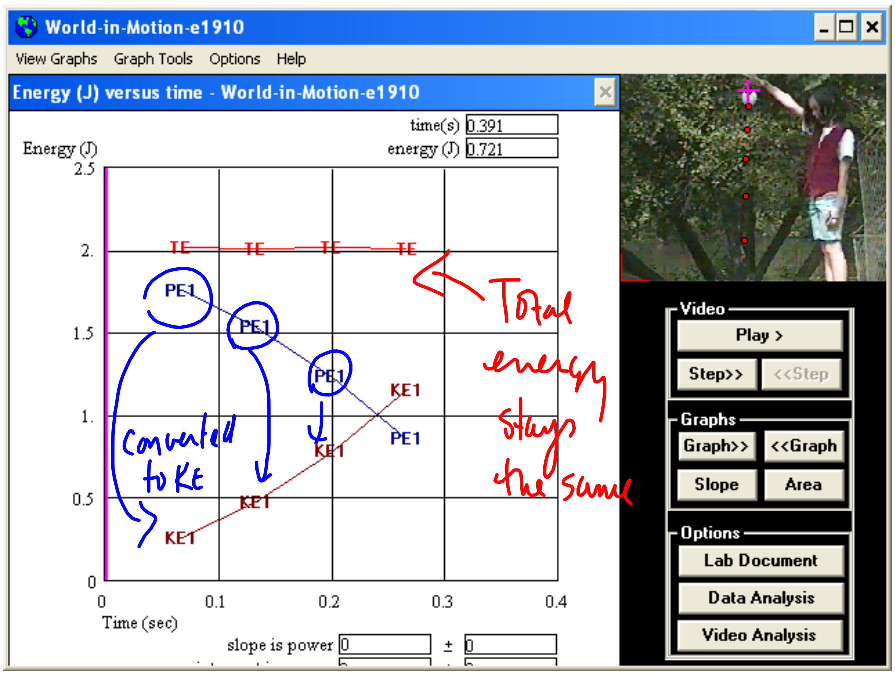


$\Delta h = (3.0\text{m})(\sin 30^\circ) = 1.5\text{m}$

$\Delta E_p = mg\Delta h$

$\Delta E_p = (2.0\text{kg})(9.81\text{ms}^{-2})(1.5\text{m})$

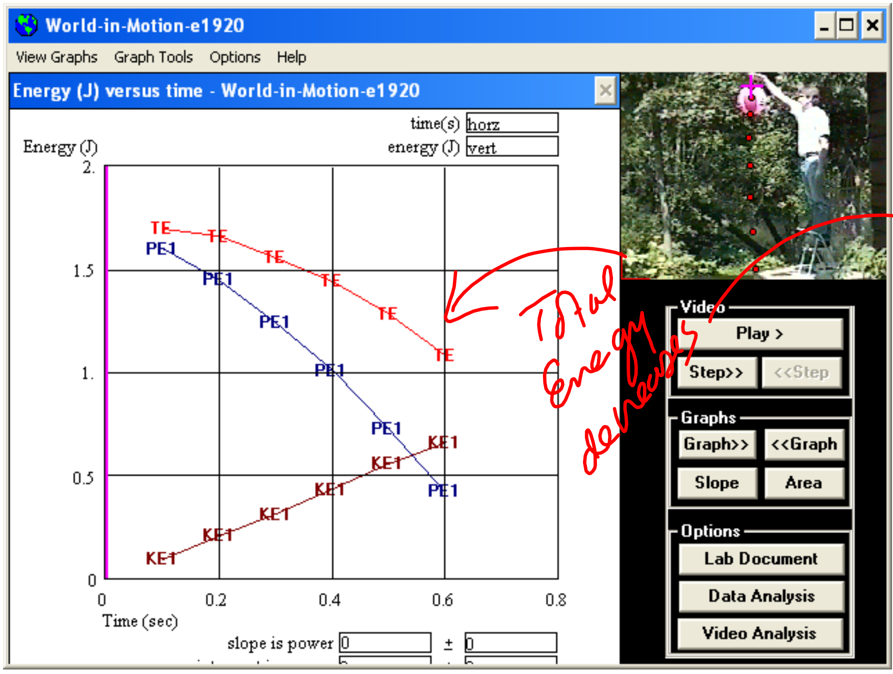
$\Delta E_p = 29\text{J}$



Falling Object

The total energy stays the same in an isolated system.

(no air resistance or friction)



→ goes into Internal

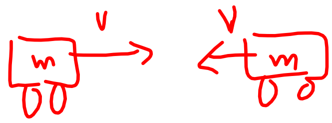
(negative work is being done by air resistance)

Momentum & energy conservation in collisions

Both momentum and ***total*** energy are conserved in any collision

Consider a collision between two cars that come to a stop after the collision. Each car had kinetic energy before the collision, but there is no kinetic energy after the collision. Where did the kinetic energy go? internal

The total energy remains the same even though the kinetic energy does not.



Elastic & inelastic collisions

An elastic collision is one in which the *kinetic energy* is conserved; that is, in which the total kinetic energy is the same before and after the collision.

An inelastic collision is one in which the *kinetic energy* is **not** conserved; that is, in which the total kinetic energy is different before and after the collision.

In all collisions, the total energy is always conserved, but that is not true of kinetic energy.
In all collisions, total momentum is always conserved.

Most collisions are inelastic!!!......there are varying degrees of elasticity

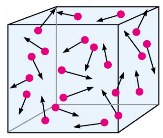
Perfectly elastic

Nearly elastic

Inelastic

Completely inelastic

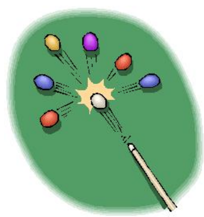
Atoms or molecules colliding in a gas



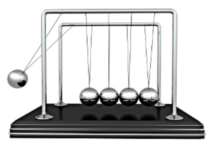
Gliders with repelling magnets

Gliders with springs that compress and repel on contact

Billiard ball collisions



Steel balls colliding and bouncing apart



Golf club striking a golf ball

Gliders that stick together on impact