Chap 6

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Learning outcome

(a) give examples of energy in different forms, its conversion and conservation, and apply the principle of energy conservation to simple examples.

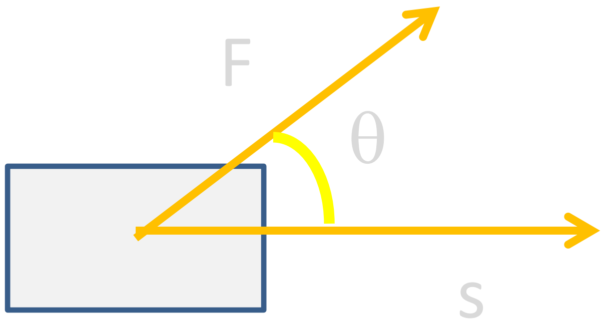
Learning outcome

(b) show an understanding of the concept of work in terms of the product of a force and displacement in the direction of the force

Work

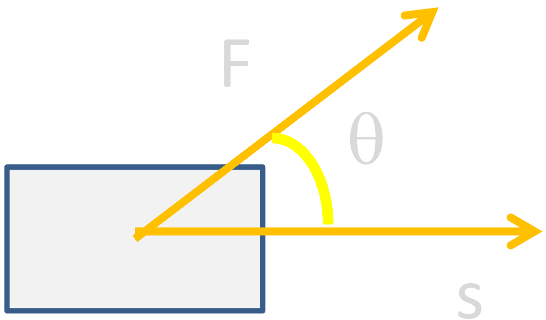
- the product of a force and displacement in the direction of the force.
- $W = Fs \cos \theta$

θ Is the angle between (constant)F and s.

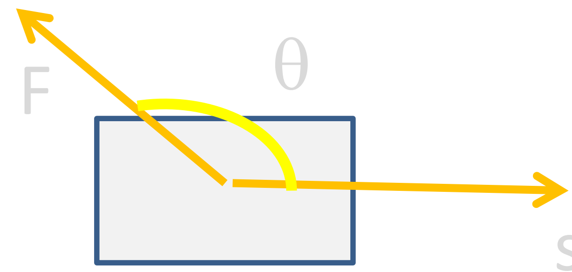


- Nm, J
- scalar quantity
- $W = \langle F \rangle s \cos \theta$; where $\langle F \rangle$ is the average force

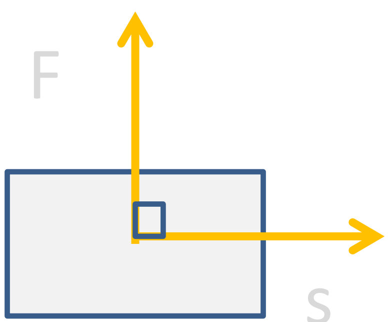
Positive and negative values of work



$0 \leq \theta < 90$; W + ve



$90 < \theta \leq 180$; W –ve



$\theta = 90$; W zero

$W = Fs \cos \theta$

-ve work done extracts energy from the system
+ve work done adds energy to the system

Determine the work done by

example

(i) W sin θ

Work = W sin θ x s x cos 180

(ii) W cos θ

Work = W cos θ x s x cos 90

(iii) Normal reaction force

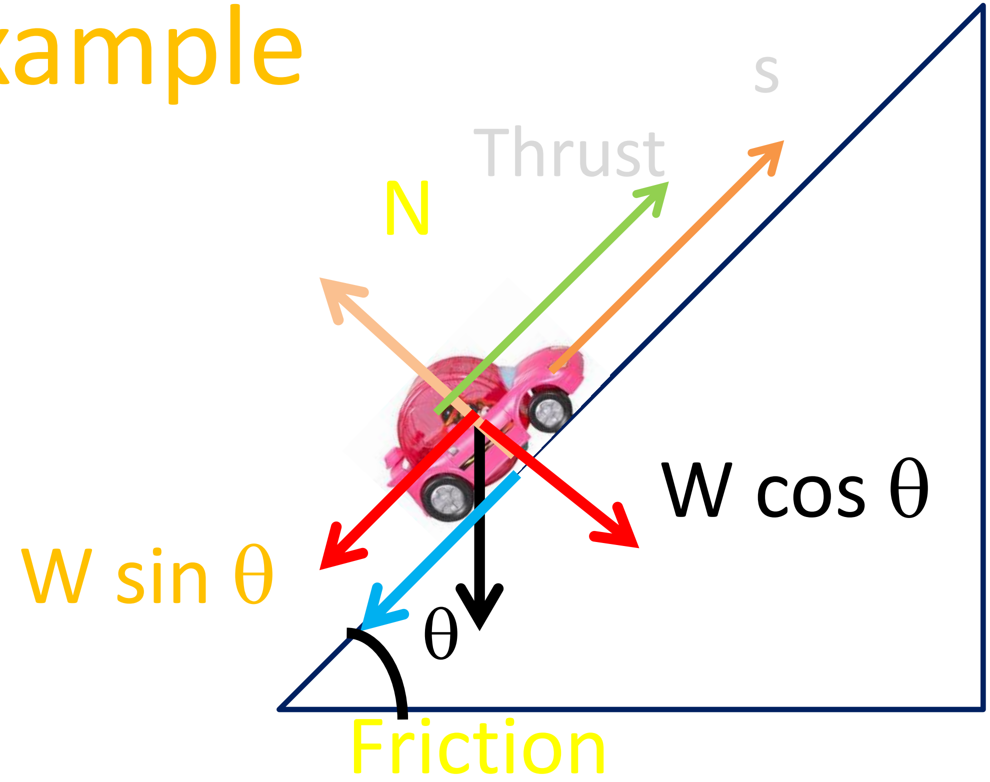
Work = N x s x cos 90

(iv) Friction

Work = friction x s x cos 180

(iv) thrust

Work = thrust x s x cos 0



Thrust - W sin θ - friction = ma

Constant speed, a=0

Thrust = W sin θ + friction

Try this

A toy car of 50 N is moving on a ramp of 2 m with a constant speed 0.4 m s^{-1}. The ramp is 30^o inclined to the horizontal. Constant frictional force 30 N acts on the car. A constant driving force is produced by the engine.

Determine the work done by each of the following forces:

i. the frictional force f exerted by the road on the car

ii. the component of car’s weight Wx down the slope

iii. the reaction force R exerted by the road on the car

iv. the driving force F of the engine

Try this

A toy car of 50 N moves up the slope by 2 m from rest with acceleration 0.8 m s^{-2}. Constant frictional force 30 N acts on the car. A constant driving force is produced by the engine.

Determine the work done by each of the following forces:

i. the frictional force f exerted by the road on the car

ii. the component of car's weight Wx along the slope

iii. the reaction force R exerted by the road on the car

iv. the resultant force

v. the driving force F of the engine

Learning outcomes

(c) calculate the work done in a number of situations including the work done by a gas that is expanding against a constant external pressure: $W = p\,\Delta V$

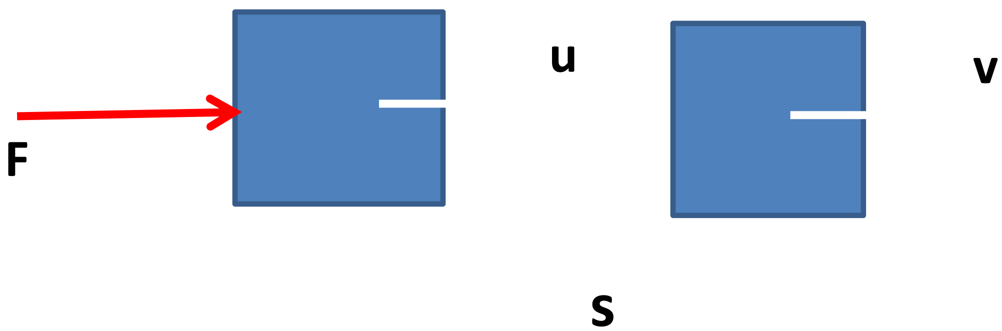
(d) derive, from the equations of motion, the formula Ek = ½ mv^2

(h) derive, from the defining equation W = Fs, the formula Ep = mgh for potential energy changes near the Earth's surface

(i) recall and use the formula Ep = mgh for potential energy changes near the Earth's surface

Work-energy theorem

(1) Work is done to increase KE



$W = Fs$

$= (ma)s$

$v^2 = u^2 + 2as$

$as = (v^2 - u^2)/2$

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

$= \frac{1}{2} mv^2 - \frac{1}{2} m u^2$

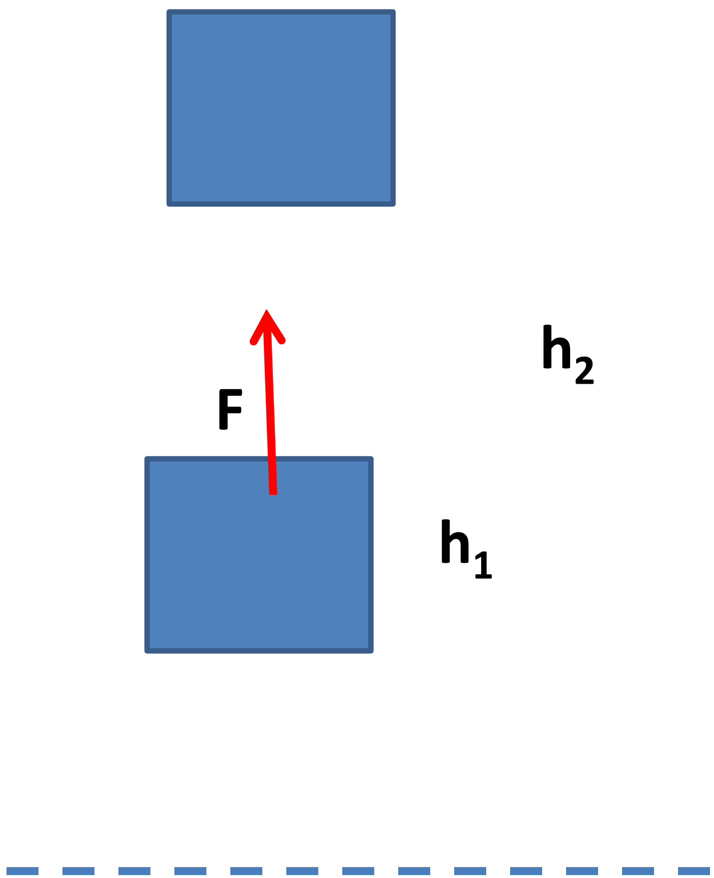
= change in KE

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

Work-energy theorem

(2) Work is done to increase GPE

F = mg while moving with constant speed



$W = Fs$

$= mg(\mathbf{h_2} - \mathbf{h_1})$

$= mg\mathbf{h_2} - mg\mathbf{h_1}$

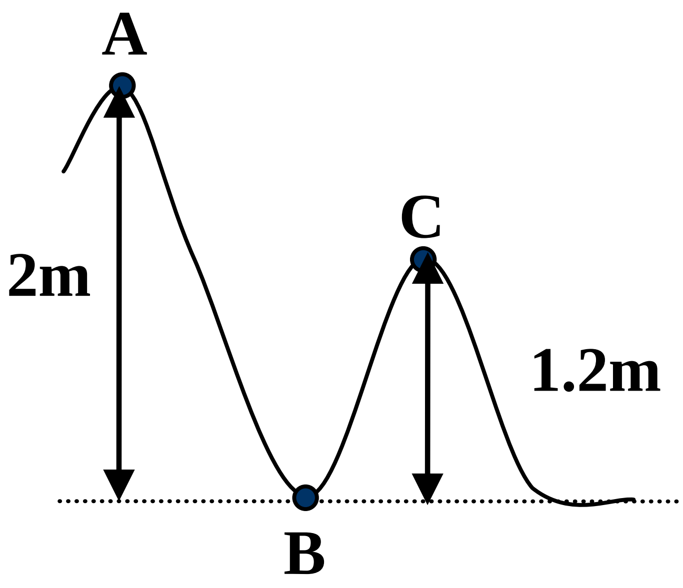
= change in GPE

$\therefore \Delta GPE = mg\Delta h$

Near the surface of the earth

example

A ball of 550 g is rolling down a frictionless track at point A with 3 ms^{-1}. Assuming the ball is always in contact with the track, determine KE & PE of the ball at point A, B and C.



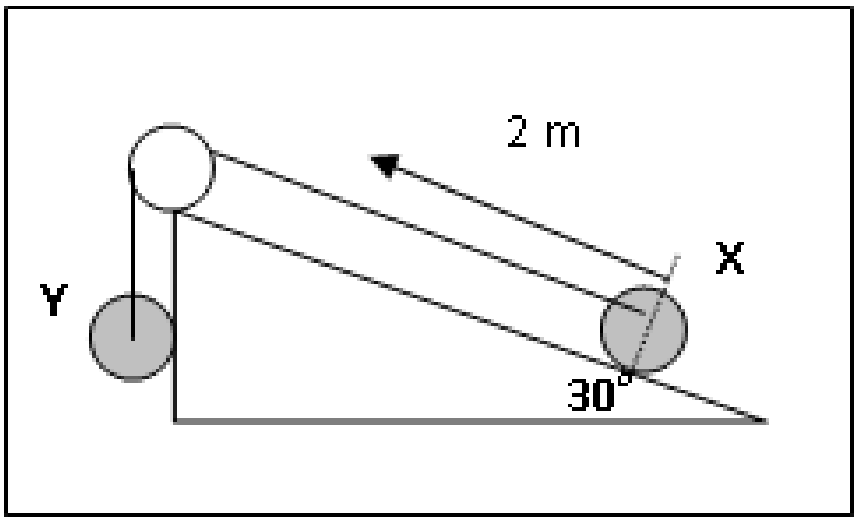
	A	B	C
KE			
GPE			

Total energy of a system is conserved. In this case, at any point, the sum of KE and GPE is conserved.

If 6 J of energy is lost due to friction when the mass moves from A to C, determine the remaining KE at C

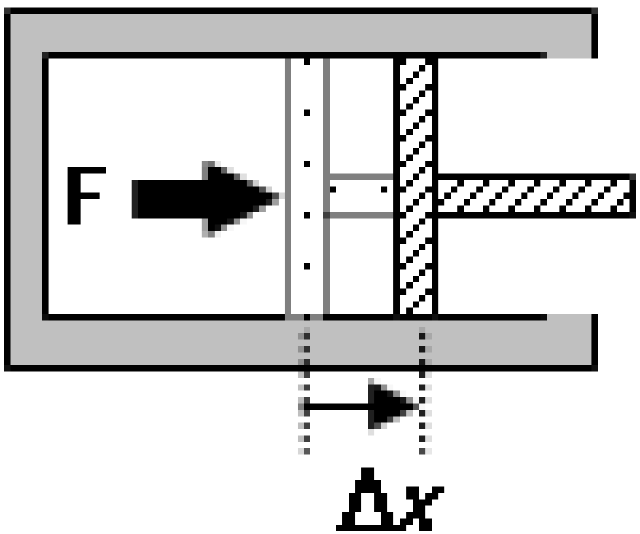
example

X and Y have a mass of 3 kg and 5 kg respectively. When X starts to travel 2.0 m along the plane, what is the total KE gained by the system? [68.7J]



Work-energy theorem

(3) Work is done by gas to expand



W = Fs

W = (pA)Δx

p=F/A

W = p AΔx

A Δx = ΔV

W = pΔV

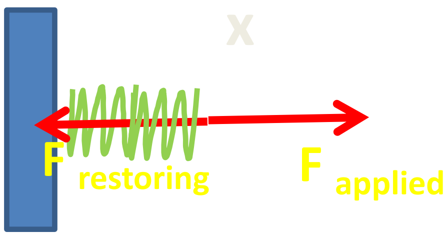
A rigid cylinder filled with gas is heated. The frictionless piston pushes outwardly by 20 cm against the atmospheric pressure. The cross-sectional area of the cylinder is 15 cm^2.

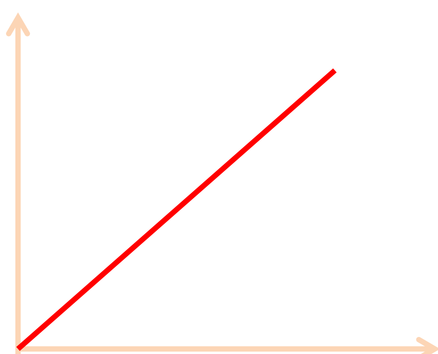
Determine the work done by the gas in this expansion.

$W = p \Delta V = 1.01 \times 10^5 \times 15 \times 10^{-4} \times 0.2 = \ldots\ldots\ldots\ldots$

Work-energy theorem

(4) Work is done to increase Elastic PE





$W = Fs$

$= \langle F \rangle x$

$\langle F \rangle = (F_{max} + F_{min})/2$

$\therefore EPE = \frac{1}{2} Fx$

Learning outcome

(f) distinguish between gravitational potential energy, electric potential energy and elastic potential energy

Potential energy is the energy stored which has the ability to do work when there is an external work done against an opposing force .

GPE, EPE & EPE

1. gravitational potential energy – it is the ability to do work/ energy stored in a mass when it is moved against a gravitational field.

2. electric potential energy - it is the ability to do work/energy stored in a positive charge when it is moved against an electric field.

3. elastic potential energy - it is the ability to do work/ energy stored in an elastic material when there is a change in shape compared to its original shape (work against the restoring force exerted by the material)

Learning outcomes

(e) recall and apply the formula $E_k = \frac{1}{2} mv^2$

(g) show an understanding and use the relationship between force and potential energy in a uniform field to solve problems

Motion up a ramp

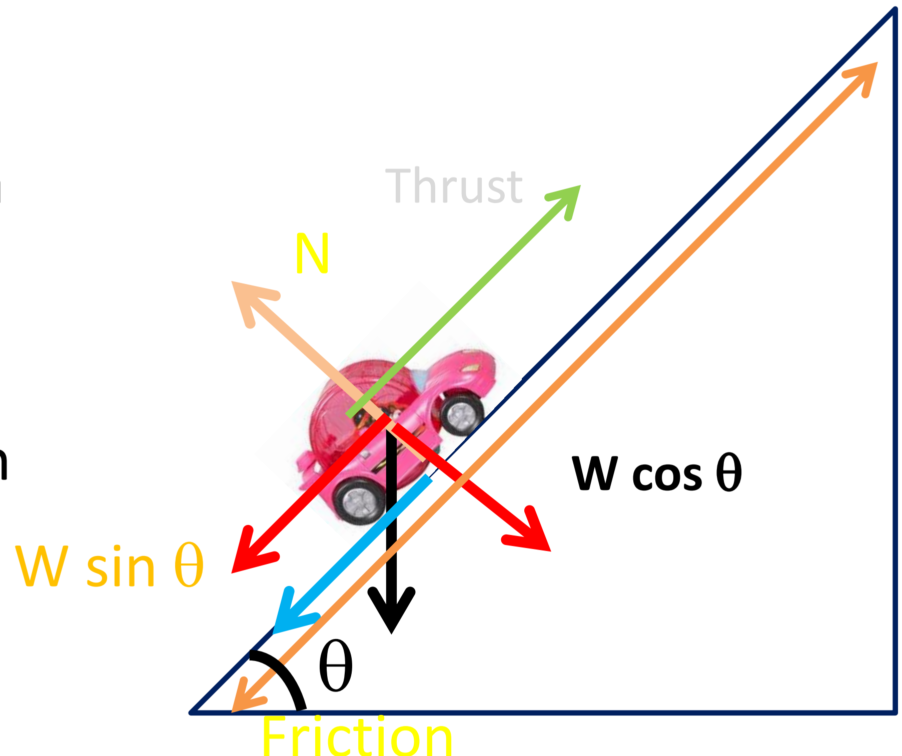
In terms of forces

Thrust - W sin θ - Friction = ma

In terms of energy

Thrust x s- W sin θ x s - Friction x s = ma x s

Thrust x s = W sin θ x s + Friction x s + ma x s



Motion up a ramp

Thrust x s = W sin θ x s + Friction x s + ma x s

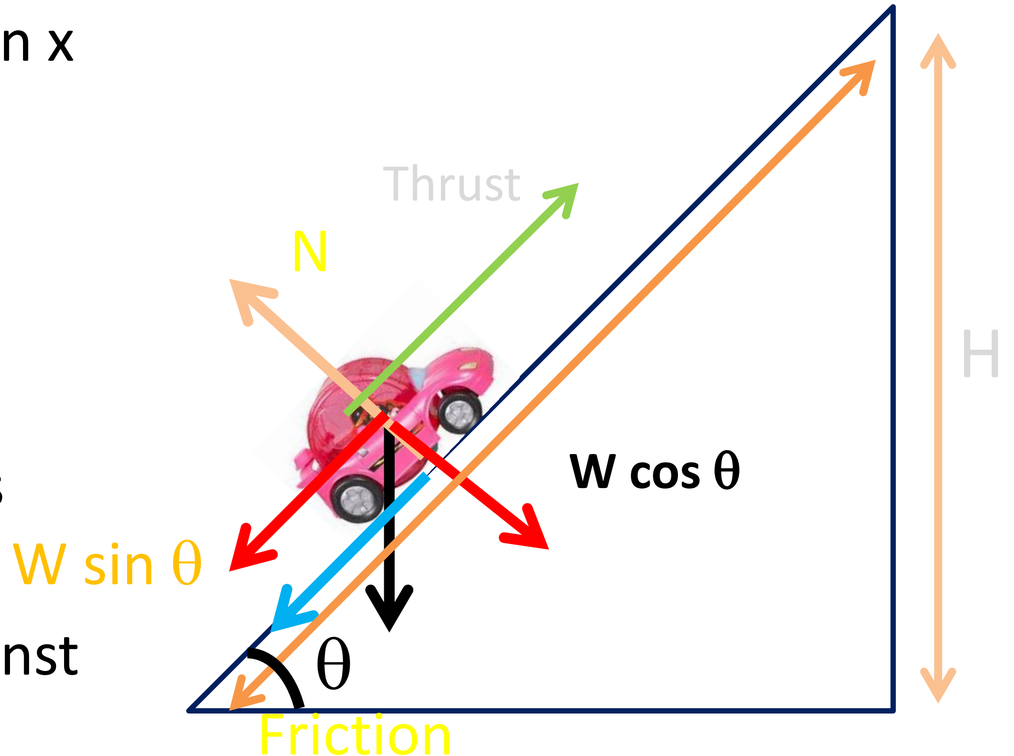
- H/ s = sin θ

  H = s x sin θ

  W sin θ x s = mg x H

  Work done against gravity is stored as GPE.

- Friction x s = work done against friction is dissipated as heat.
- ma x s = m (v^2- u^2)/2 = increase in KE



Thrust x s = W sin θ x s + Friction x s + ma x s

= increase in GPE + heat dissipated + increase in KE

Thrust x s = ??

Total work done, W

Generally,

Total work done = increase in GPE + heat dissipated + increase in KE

Constant velocity, ΔKE = 0

On a horizontal surface , ΔGPE = 0

Smooth surface, no friction, no heat dissipated.

No engine, e.g. a trolley, W = 0

Review…

A toy car of 50 N moves up the slope by 2 m from rest with acceleration 0.8 m s^{-2}. Constant frictional force 30 N acts on the car. A constant driving force is produced by the engine.

Determine the work done by each of the following forces:

i. the frictional force f exerted by the road on the car
ii. the component of car's weight Wx along the slope
iii. the resultant force
iv. the driving force F of the engine

Determine :

i. Heat energy dissipated
ii. Increase in GPE
iii. Increase in KE
iv. work done by engine

Learning outcomes

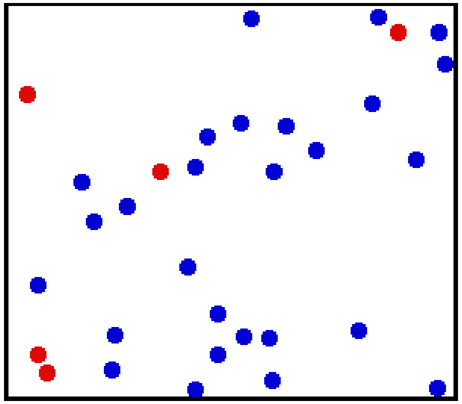
(j) show an understanding of the concept of internal energy

(k) recall and understand that the efficiency of a system is the ratio of useful work done by the system to the total energy input

(l) show an appreciation for the implications of energy losses in practical devices and use the concept of efficiency to solve problems

Internal energy

It is the sum of random distribution of KE and PE of all molecules of a substance.



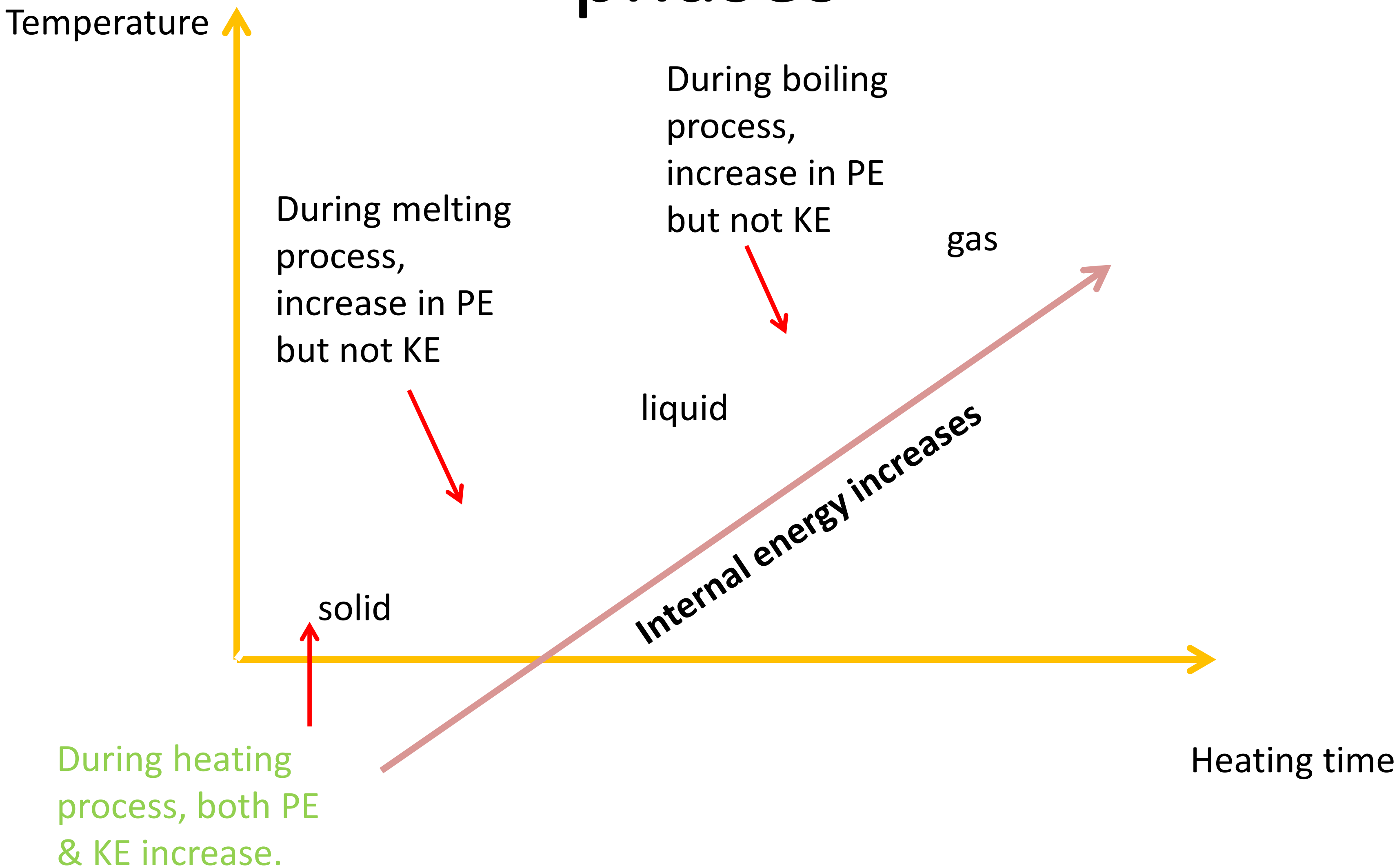
It is the molecular KE, not the KE of the whole object.

Molecular KE can be increased by heating up the substance.

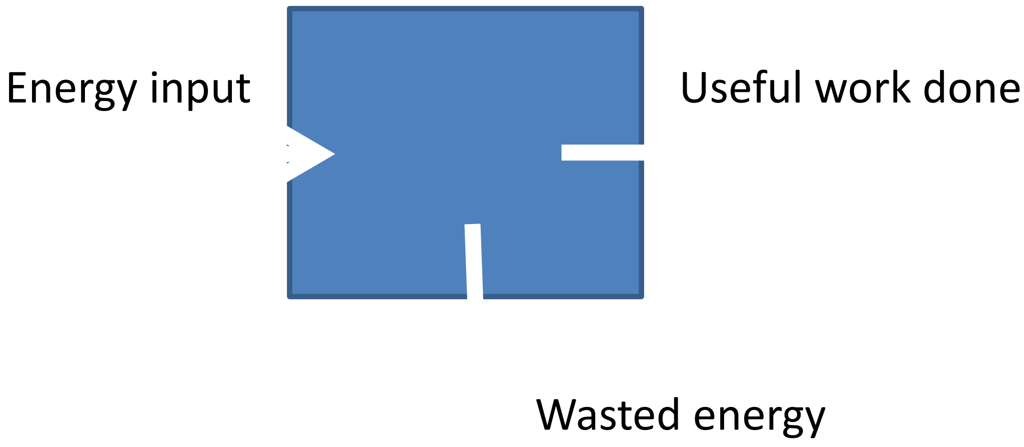
It is the molecular PE (or EPE), not the GPE of the object.

Molecular PE can be increased by changing the shape of the substance/ distance between molecules.

phases


Temperature
During boiling process, increase in PE but not KE
During melting process, increase in PE but not KE
gas
liquid
Internal energy increases
solid
Heating time
During heating process, both PE & KE increase.

Efficiency



- Machine – a device which converts energy from one form to another
- Car engine converts chemical energy (stored in petrol) into KE of moving parts and wheels & to other unwanted forms, e.g. heat & sound.
- It fails to convert all the energy into useful energy. Therefore, the efficiency is not 100%.

Efficiency = useful work done/ energy input

Example

A power supply is connected to a shower unit via a cable.

- Heat energy Q_1 is dissipated from the cable due to its electrical resistance.
- Heat energy Q_2 is supplied dissipated from the heating elements in the shower unit due to its electrical resistance.

Assuming no other loss of energy, the efficiency of the circuit is given by …………………

Learning outcomes

(m) define power as work done per unit time and derive power as the product of force and velocity

(n) solve problems using the relationships P = W/t and $P = Fv$.

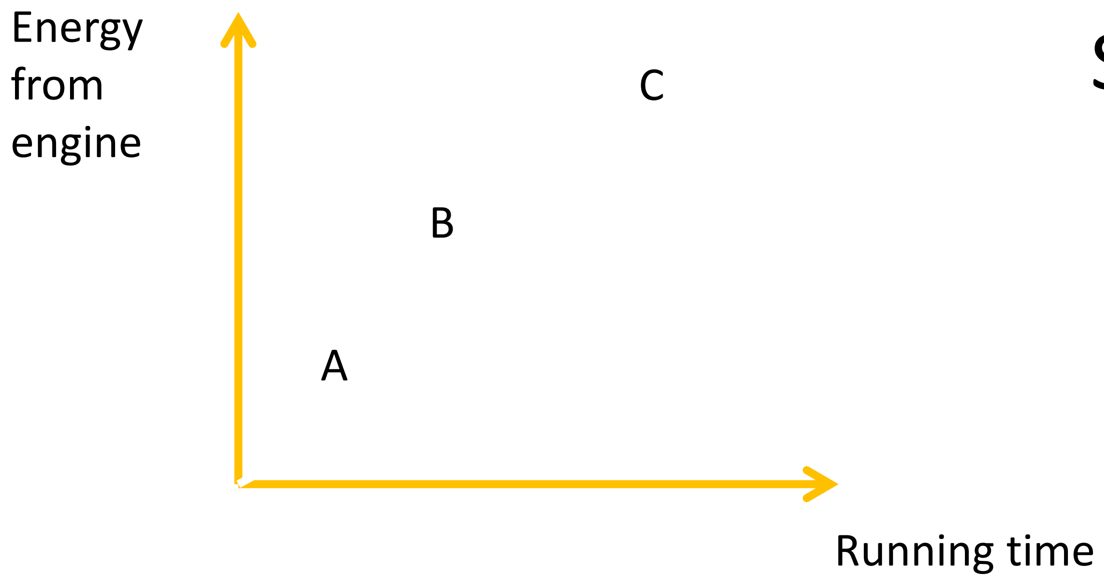
Power

Power is defined as the rate of energy conversion or the rate of work done

$P = dw/dt$

Js^{-1}, W

Scalar quantity



Examples

(1) A power station has an efficiency of 40% and generates 1000MW of electrical power. What are the power input & the wasted power? [2500MW, 1500MW]

(2) An electric motor is required to haul a cage of mass 400 kg up through a vertical height of 1200 m in 2 minutes. What will be the electrical power required if the overall efficiency is 80%? [49kW]

$P = Fv$

$P = dW/dt = d(Fs)/dt$

If force is constant, $P = F\, ds/dt$

Average power $P = F <v>$, where $<v>$ is the average speed.

If speed is constant, $<v> = v$ else $<v> = (v+u)/2$

Instantaneous power $P = Fv$ where v is the Instantaneous speed

example

- The manufacturer claims that the maximum power delivered by the engine of a car of mass 1200 kg is 90 kW. Determine the minimum time in which the car could accelerate from rest to 30 ms^{-1}. [**Ans**: 6s]
- An independent test quotes a rest to 30 ms^{-1} time of 13.4 s. Account for the difference of the time you have calculated.

Try this

An elevator has a mass of 1000 kg and carries a maximum load of 800 kg. A constant frictional force of 4000 N retards its motion upward. What is the maximum power must the motor delivered to lift the fully loaded elevator at a constant speed of 3 ms^{-1}? [65kW]

Problem solving

A car of 500 kg is moving up a ramp with a constant velocity 3 ms^{-1}. The ramp is inclined at 45^o. A constant frictional force acts on the car.

Determine

a) the increase in KE per second

b) the increase in GPE per second

c) Heat dissipated per second

d) output power of the car engine

If the efficiency of the car engine is 65%, determine the input power of the car engine.

The End