What is Physics?

Model the physical universe.

(not spiritual)

Simplest model

↑

visualise

understand

make predictions

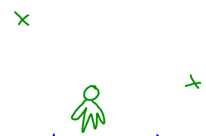
4 Mathematical models

1 2 3 4

1+2=3 Laws

Observation → quantities

Things have different position



Can quantify position by measuring the distance from me.

Need a fixed point

And a Unit of measurement.

— This must be the same for everyone

e.g. Meter

Defined in terms of the speed of light in a vacuum

speed of light ~ 3×10^8 m/s

1 meter - distance travelled in $1/3\times10^8$ s

Time

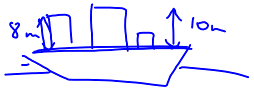
event

The difference between two events that take place at the same position.

Measurement

Based on regularly occuring events

- Sun 14
- moon 1
- dripping water 10,0000
- pendulum 20,000



Unit - second

Based on a certain number of oscillations of the radiation from some Caesium isotope.

4 Dimensions

3 position
1 time

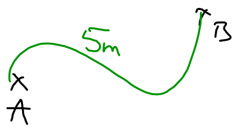
To define position we need 3 distances.
N - S
E - W
up - down.

Motion

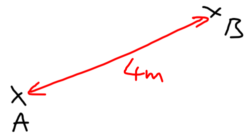
Defining movement.

use position and time

Distance travelled - how far the box moves.



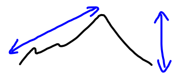
Displacement Distance travelled in a particular direction



We can see that distance and displacement are different quantities

distance - size

displacement - size and direction



All quantities either have size only or size and direction

vector - size + direction ← displacement

scalar - size ← time distance

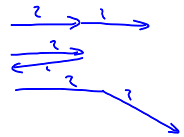
Scalar – time, distance

Represented by a number

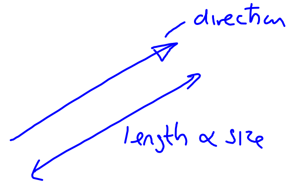
- they add
- subtract

Vector

2+2 not always 4



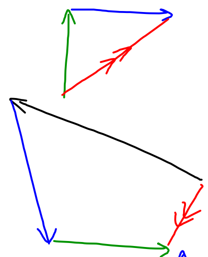
represented by Arrows



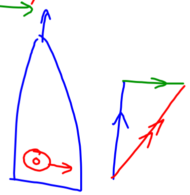
Adding Vectors

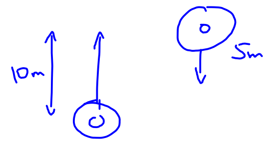
Arrange nose – tail

resultant is the line joining the free tail – free nose



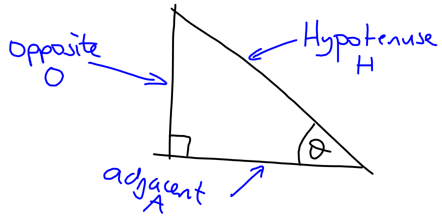
Example





When we add perpendicular vectors we get right angled triangles.

Trigonometry



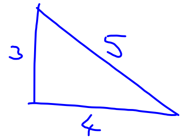
$\sin\theta = \frac{O}{H}$ $\qquad O = H\sin\theta$

$\cos\theta = \frac{A}{H}$ $\qquad A = H\cos\theta$

$\tan\theta = \frac{O}{A}$

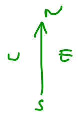
Pythagoras

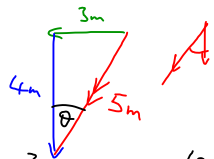
$$H^2 = O^2 + A^2$$



Example

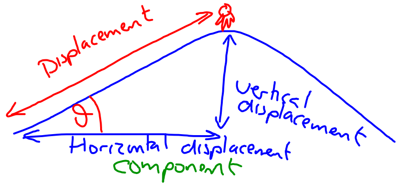
walk 3m W then 4m South

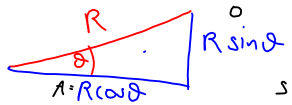




Direction $\sin\theta = \frac{3}{5}$ $\quad$ inv. sin $\left(\frac{3}{5}\right) =$ $\theta = 36.9°$

Taking components (Resolving)





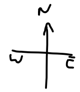
$\cos\theta = \frac{A}{R}$

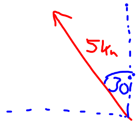
$A = R\cos\theta$

$\sin\theta = \frac{O}{R}$

$O = R\sin\theta$

Example If you walk 5km 30° to the W of N. How far N will you travel?

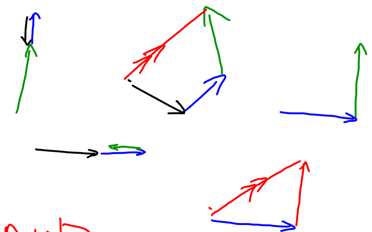




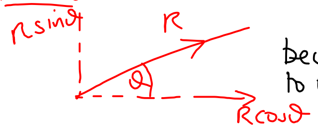
$5\cos 30° = 4.34\text{km}$

We will always take components in convenient ⊥ directions e.g. vertical & horizontal

Why? - Makes adding vectors easier.



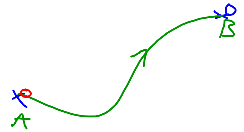
Note



because it's next to the angle

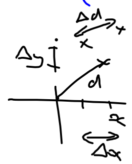
Speed

We observe that the time taken from A to B varies for different bodies



Average Speed $= \dfrac{\text{distance}}{\text{time}} = \dfrac{\Delta d}{\Delta t}$

(how fast)



$\Delta \Rightarrow$ difference

Unit – meter/sec

m/s ms^{-1}

scalar

Example

Flekke → Bergen

150km

time – 3hrs

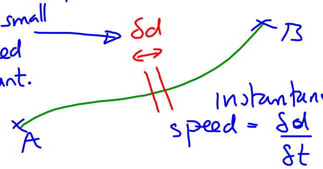
Speed = 50km/hr

$\frac{50000}{3600} \simeq 14\,m/s$

Instantaneous speed

Speed at an instant

Step so small that speed is constant. → δd

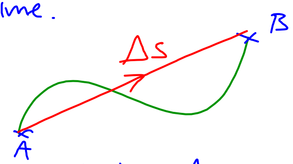


instantaneous speed $= \dfrac{\delta d}{\delta t}$

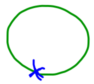
Note if speed constant

Velocity

Displacement per unit time.



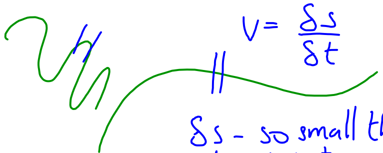
average velocity = $\dfrac{\Delta s}{\Delta t}$



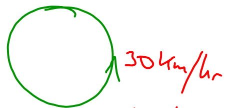
If $\Delta s = 0$ then $v = 0$

Instantaneous velocity

$v = \dfrac{\delta s}{\delta t}$



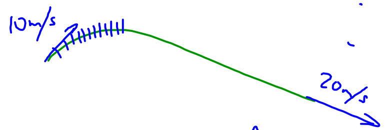
δs - so small that speed and direction - constant



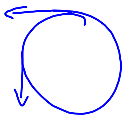
- velocity not constant
- direction changing.

Acceleration (a)

Rate of change of velocity



Average accel. = $\dfrac{\Delta v}{\Delta t}$



Motion with constant acceleration

— In a straight line

Example

a

u v

s

time taken $= t$

Motion in 1 Dimension

Displacement

$-10\,m$ $+10\,m$

Direction is given by the sign.

Velocity

$-10\,m/s$ $+10\,m/s$

acceleration

a

start $5\,m/s$ $10\,m/s$

time $= 10s$

$$a = \frac{10-5}{10} = +0.5\,m/s^2$$

a

start $10\,m/s$ $5\,m/s$

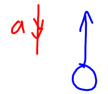
$$a = \frac{5-10}{10} = -0.5\,m/s^2$$

$10\,m/s$ $5\,m/s$ start

$$a = \frac{^{-}10 - {}^{-}5}{10} = -0.5\,m/s^2$$

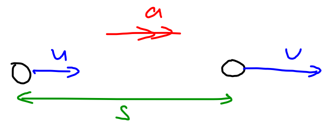
5 10 start

$$a = \frac{^{-}5 - {}^{-}10}{10} = +0.5\,m/s^2$$



$g = -10\,m/s^2$

Equations of motion with constant acceleration



time, t

u - initial
v - final

From definition $a = \dfrac{v-u}{t}$ (1)

average velocity $= \dfrac{u+v}{2} = \dfrac{s}{t}$

$\Rightarrow s = \left(\dfrac{u+v}{2}\right)t$ (2)

from (1) - $t = \dfrac{v-u}{a}$

Substitute into (2)

$$s = \left(\frac{u+v}{2}\right)\left(\frac{v-u}{a}\right)$$

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

$$v^2 = u^2 + 2as \quad (3)$$

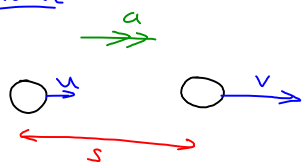
Also from (1) $v = u + at$

substitute into (2)

$s = \left(\dfrac{u+v}{2}\right)t \qquad s = \left(\dfrac{u+u+at}{2}\right)t$

$= ut + \frac{1}{2}at^2$

Suvat



time, t

$a = \frac{v-u}{t}$

$s = \left(\frac{u+v}{2}\right)t$

$s = ut + \frac{1}{2}at^2$

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

example

Free Fall

- ignore air resistance

$a = -10\,m/s^2$

Example

1. A body is thrown up with a velocity of 50m/s. What is its displacement after 3s?

s ?
u 50m/s
v –
a –10m/s²
t – 3s

$s = ut + \frac{1}{2}at^2$

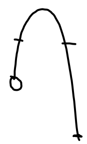
$= 50.3 - \frac{1}{2}10.3^2$

$= 105m$

After 15s?

$s = 50.15 - \frac{1}{2}10.15^2$

$= -375$



Graphical representation of motion

$a = \frac{v-u}{t}$

Displacement – time
velocity – time
acceleration – time

Phet

Displacement – time

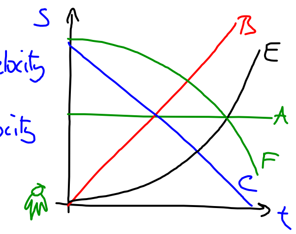
A - stationary

B - constant velocity +ve

C - constant velocity -ve

E - constant acceleration +ve

F - -ve accel.



Note

Gradient of s-t graph = velocity

$v = \frac{\Delta s}{\Delta t}$ $\left(v = \frac{ds}{dt}\right)$

Velocity – time

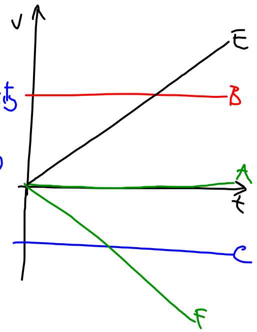
A - stationary

B - constant +ve velocity

C - constant -ve velocity

E - const. accel +ve

F - const accel -ve

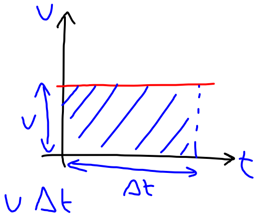


Note

Gradient = accel.

$= \frac{\Delta v}{\Delta t}$ $\left(\frac{dv}{dt}\right)$

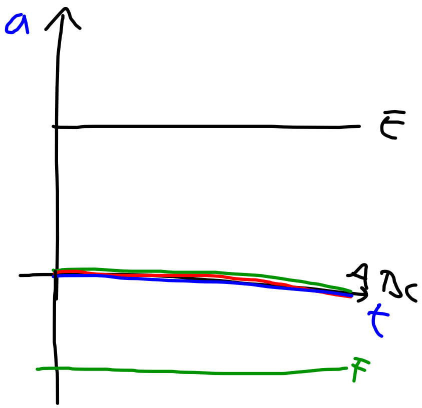
Area under graph



Area = $v\,\Delta t$

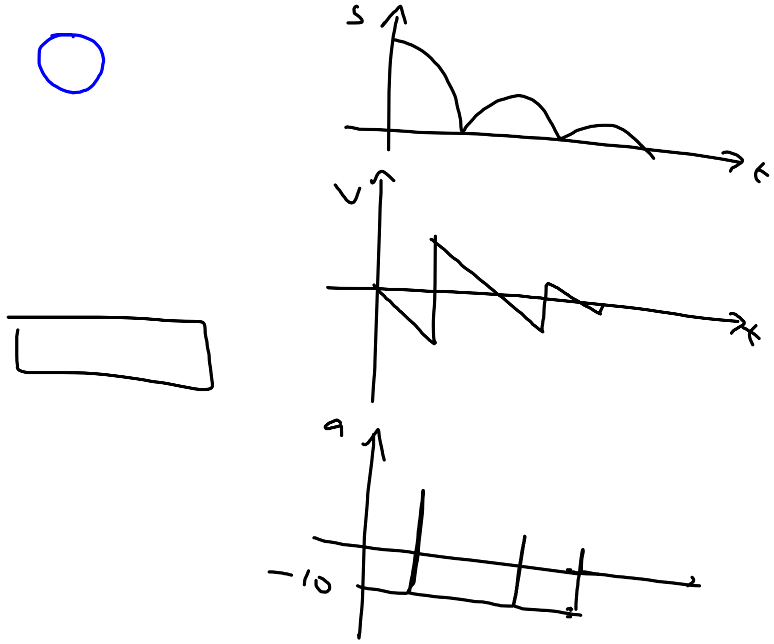
but $v = \frac{\Delta s}{\Delta t} \Rightarrow v\Delta t = \Delta s$

acceleration – time



Example

Bouncing ball



We can now model motion but what causes it?

To move a body it must be pushed or pulled.

Force (F)

- Push or a Pull

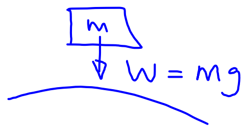
unit - Newton (N)

Vector

Examples

Weight

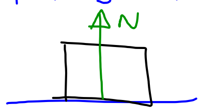
Force towards the centre of the Earth



- Weight acts at the centre of a body.

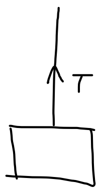
Normal Force (N)

The force acting perpendicular to two touching surfaces

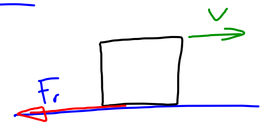


Tension (T)

When the force is exerted with a string



Friction



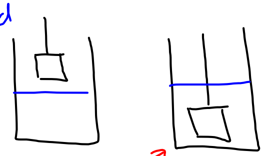
opposes the relative motion between two touching surfaces

depends upon - Normal force
- surfaces

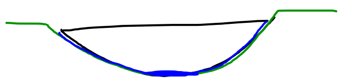
$F_r = \mu N$ μ - coefficient of friction

Upthrust - bouyancy
- Archimedes

When a body is immersed in a fluid it experiences an upward force equal to the weight of fluid displaced



Note: volume displaced = volume of object

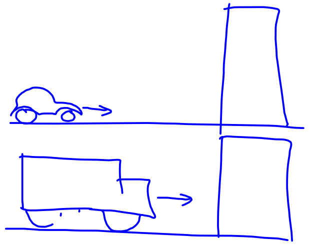


Air Resistance

Opposes motion of bodies through the air.

Depends upon - shape
- speed

Consider this



When determining the force required to stop these bodies we must consider mass and velocity

Momentum = Mass × velocity

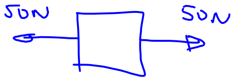
- Vector
- unit kg m/s
  Ns

Newtons Laws of Motion

Newton 1st Law

A body will remain at rest or moving with constant velocity unless acted upon by an unbalanced force.

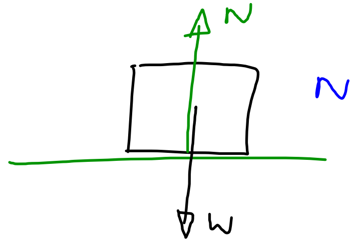
What is an unbalanced force?



balanced ⇒ resultant = 0N

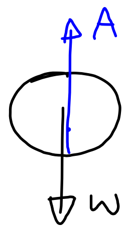
unbalanced

Box at rest $\Rightarrow$ Forces balanced



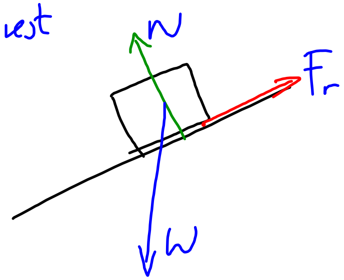
$N = W$

ball falls with constant velocity

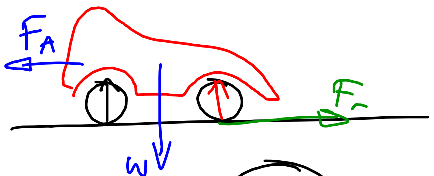


Newt 1
$\Rightarrow A = W$

Box at rest



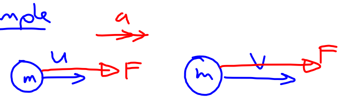
Car accelerates along the road



Newtons 2^{nd} Law

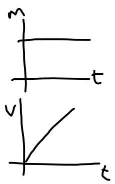
The rate of change of momentum of a body is directly proportional to the unbalanced force and takes place in the same direction.

example



time taken = t

mv



$$F \propto \frac{mv - mu}{t}$$

$$F \propto m\left(\frac{v-u}{t}\right) = ma$$

$\frac{d}{dt}(mv)$

$m\frac{dv}{dt}$

If F – Newtons

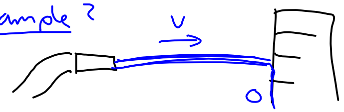
m – kg

u, v – m/s

constant = 1

$$\boxed{F = ma}$$

example 2

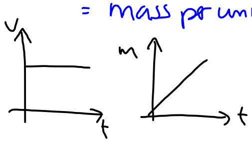


Newt 1 – water experiences F

Newt 2 – Force experienced by water = rate of change of momentum

mv

= mass per unit time × change in velocity

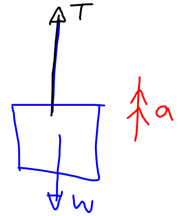


$\frac{d(mv)}{dt}$ $\quad v\frac{dm}{dt}$

Examples

$\frac{\Delta mv}{\Delta t}$

①



Newt 1

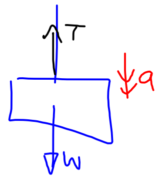
Forces unbalance

$T > W$

Newt 2

$T - W = ma$

$T = ma + W$



$W - T = ma$

$T = W - ma$

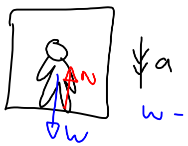
If $T = 0$

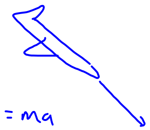
$0 = W - ma$

$W = ma$

$mg = ma$

$g = a$



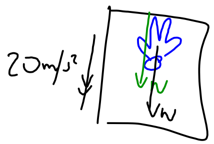


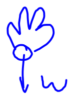
$W - N = ma$

$W = Ma$

$mg = ma$

$g = a$



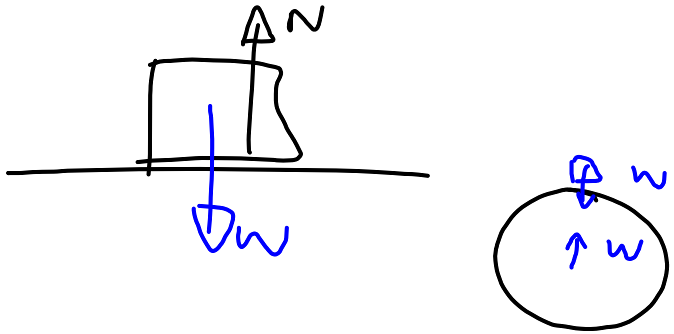


$W = ma$

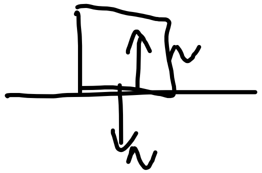
$mg = ma$

Newtons 3rd Law

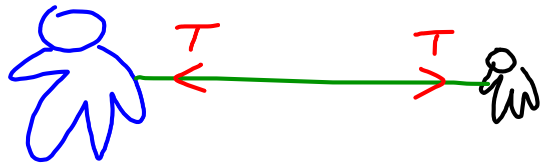
If body A exerts a force on body B then body B exerts an equal and opposite force on A.



earth pulls box down $\Rightarrow$
box pulls earth up.



Spacemen



Title

Introduction

Method (copy + paste)

Diags. (copy)

Results

L_m	t_s
10m	2.6
10m	2.7
10m	2.5
10m	2.6

- Table
- include raw data
- uncertainties
- units

show where from.

length(m) ±0.01m			

Uncertainties

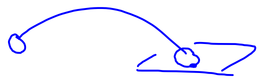
- ½ smallest division

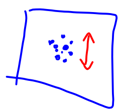
±0.5mm.

Use judgement.

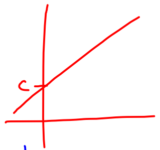
1 sf

repeated measurement



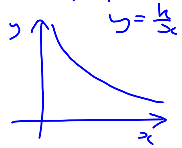


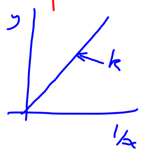
$y = mx + c$



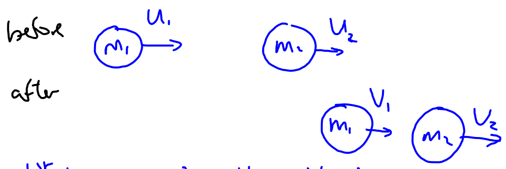
$\Delta T \propto 1/m$

$y = \frac{k}{x}$





Collision



1^{st} Law – When they hit both balls experience an unbalanced force

2^{nd} Law – size of force = rate of change of mom^t

If collision lasts Δt seconds

then change of momentum for ball ① $= \dfrac{m_1v_1 - m_1u_1}{\Delta t}$

for ball ② $= \dfrac{m_2v_2 - m_2u_2}{\Delta t}$

Newt 3

$$\frac{m_1v_1 - m_1u_1}{\cancel{\Delta t}} = -\left(\frac{m_2v_2 - m_2u_2}{\cancel{\Delta t}}\right)$$

$$m_1v_1 - m_1u_1 = -m_2v_2 + m_2u_2$$

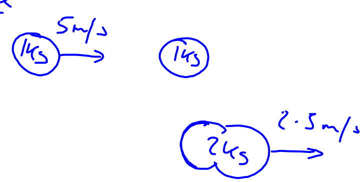
$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Conservation of momentum

Momentum at start = momentum at the end.

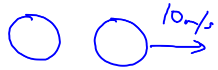
For a group of isolated bodies total momentum = constant.

Example

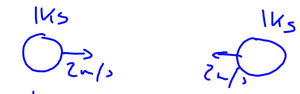


Example 2

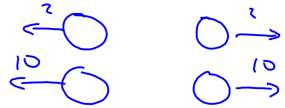
momt. before = 10 kg m/s



Consider this:



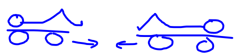
Total momt. = 0



Newtons Law → all are possible but we can't predict which will happen

- The last example we know can't happen. The balls would have to push each other hard

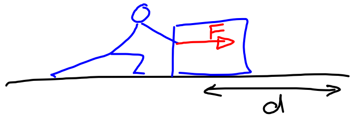
- what enables one ball to push another?



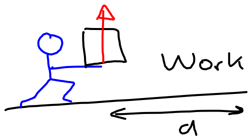
ENERGY

WORK

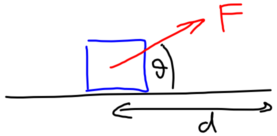
When a force moves its point of application in the direction of the force, WORK IS DONE.



Work done = $F \times d$



Work = 0



Work = $F\cos\theta \cdot d$

Energy

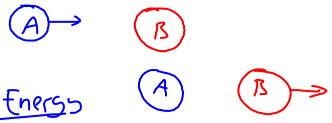
Energy is the quantity that is transferred when work is done.

If A does work on B energy is transferred from $A \to B$

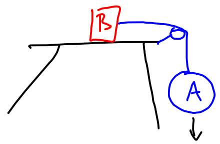
Body A must have energy if it is to push B.

There are two ways that A can have energy.

① Because its moving



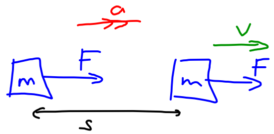
Kinetic Energy



Potential Energy

– Energy due to Position

KE



$F = ma$

$WD = Fs = KE$

$= mas$

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

$v^2 = 2as$

$as = \frac{1}{2}v^2$

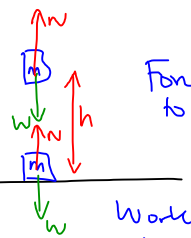
$$\boxed{KE = \frac{1}{2}mv^2}$$

Note we have assumed energy is conserved. If this isn't true then we can't solve any problems.

Law of Conservation of Energy

Energy can not be created or destroyed.

PE



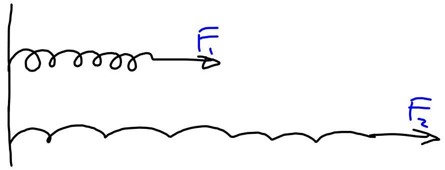
$N = W$

Force required to lift body $= mg$

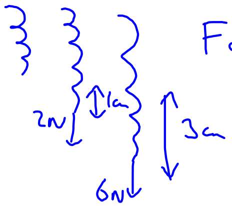
Work done $= mgh$

$\therefore$ Increase in PE $= mgh$

This isn't the only form of PE

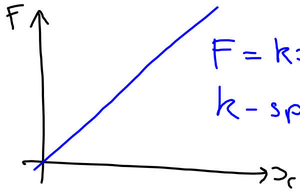


when a string is stretched
the force required gets bigger
for a simple spring $F \propto x$



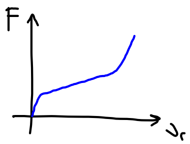
$F \propto$ extension

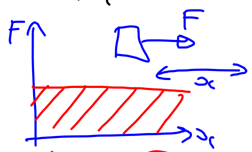
$F = kx$



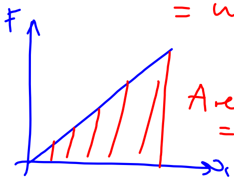
$F = kx$

k - spring const.





Area = Fx
= work



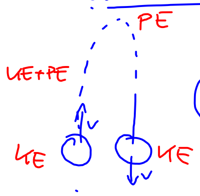
Area = $\frac{1}{2}Fx$
= work

$F = kx$

$W = \frac{1}{2}kx^2$

Elastic PE

Conservation of Energy.



$$\Delta KE = \Delta PE$$

$$\left(\tfrac{1}{2}mv^2 - 0\right) = mgh - 0$$

$$\tfrac{1}{2}\cancel{m}v^2 = \cancel{m}gh$$

$$\tfrac{1}{2}v^2 = gh$$

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

$$0 = v^2 - 2gh$$

Power

Work done per unit time

unit – Watt (W)
scalar

High power ⇒ can do work in a short time

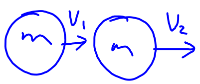
Car ⇒ Fuel → KE ($\tfrac{1}{2}mv^2$)
powerful car will accelerate fast.

Elastic + Inelastic collisions

Elastic collision

KE and momentum are conserved

Cons. of mom^t



$$mu = mv_1 + mv_2$$

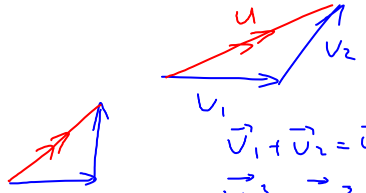
$$u = v_1 + v_2$$

cons. of KE

$$\tfrac{1}{2}mu^2 = \tfrac{1}{2}mv_1^2 + \tfrac{1}{2}mv_2^2$$

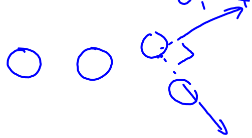
$$u^2 = v_1^2 + v_2^2$$

⇒ either $v_1 = 0$ or $v_2 = 0$



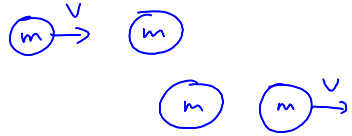
$\vec{v}_1+\vec{v}_2=\vec{u}$

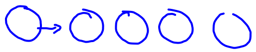
$\vec{v}_1^{\,2}+\vec{v}_2^{\,2}=\vec{u}^{\,2}$



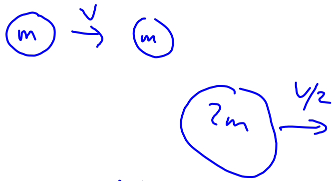
The simplest case

elastic



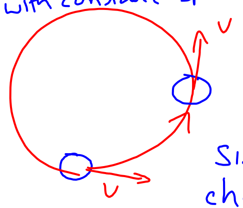


Completely inelastic



Motion in a circle

Consider a body moving in a circle with constant speed.

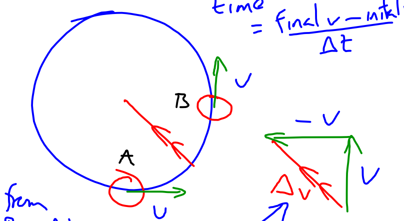


we can see that velocity is not constant since direction is changing

Newt 1 ⇒ unbalanced force

Direction of force - same as direction of acceleration

$a = \frac{\text{change in velocity}}{\text{time}}$
$= \frac{\text{final } v - \text{initial } v}{\Delta t}$



time from $A \to B = \Delta t$

change in velocity from $A \to B$

$a = \frac{\Delta v}{\Delta t}$

The direction of a is towards the centre

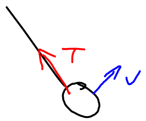
Magnitude of accel.

$$\boxed{a = \frac{v^2}{r}}$$

centripetal acceleration
$\Rightarrow$ centripetal Force $= ma$
$= \frac{mv^2}{r}$

Example

Mass on a string

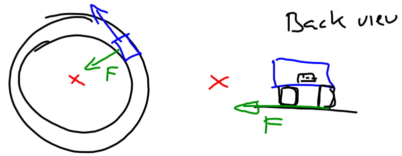


centripetal F is Tension
$T = \frac{mv^2}{r}$

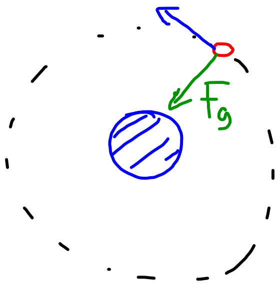
Note Newt 3 $\Rightarrow$ person holding other end of rope will experience an opposite Force

Example 2

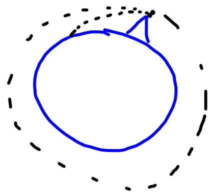
Car on a circular track



Satellite

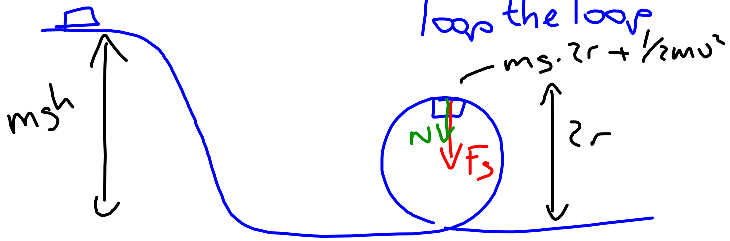


$$F_g = \frac{mv^2}{r}$$



Fairground

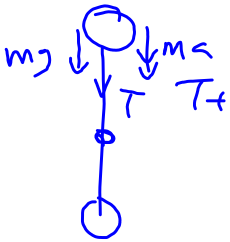
loop the loop



$$F_g + N = \frac{mv^2}{r}$$

If $N = 0$ $\quad F_g = \frac{mv^2}{r}$

$\longrightarrow$ minimum speed



$T + mg = ma$