Chapter 7

Acceleration

Uniform Acceleration

Rate of change of velocity (w.r.t. time)

Change in velocity in unit time

Acceleration = (change in velocity) ÷ time

Symbol: a

Units: $m\ s^{-2}$

Uniform Acceleration

Velocity is a vector

Therefore … a body accelerates if …

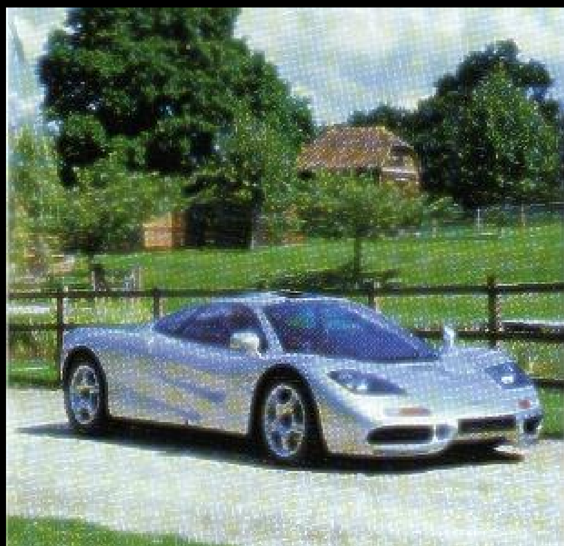
… its velocity changes in *magnitude*

or

… its velocity changes in *direction*

Ferrari

Changing magnitude



4.8 seconds

0 to 100 km h^{-1}

Changing direction

Equations Of Motion

$$v = u + at$$

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

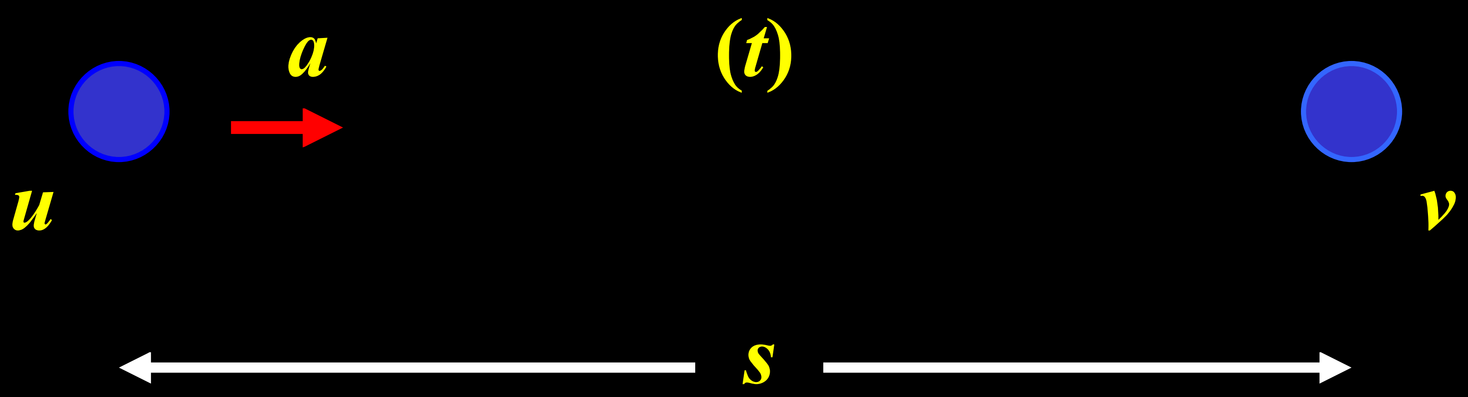
$$v^2 = u^2 + 2as$$

a = acceleration

u = initial velocity

v = final velocity

s = displacement t = time

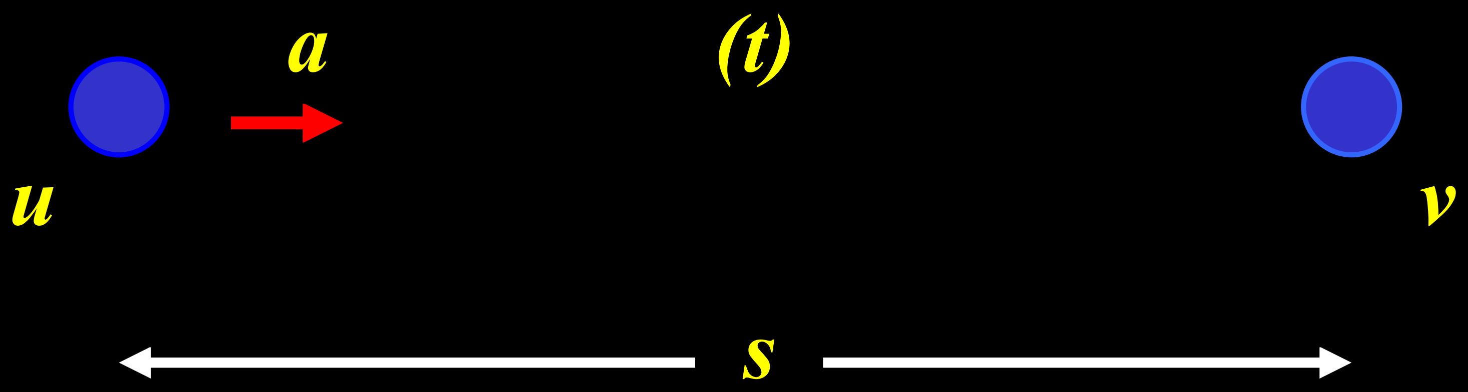


Deriving $v = u + at$

a = change in velocity ÷ time

$a = (v - u) \div t$

$v = u + at$



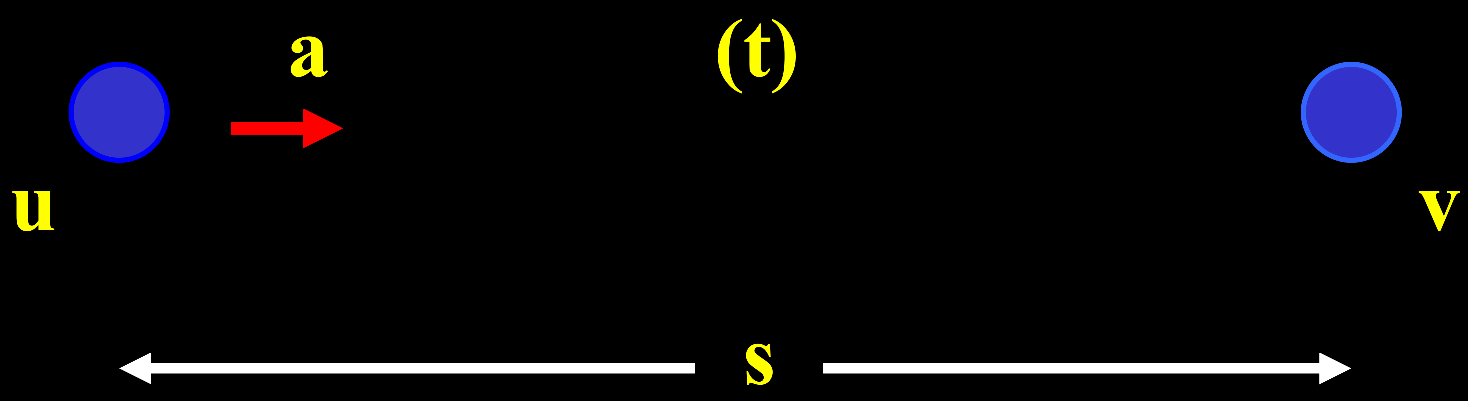
Deriving: $s = ut + \frac{1}{2}at^2$

s = (average velocity) x time

$s = \frac{1}{2}(u + v)\,t$ [average velocity = $\frac{1}{2}(u + v)$]

$s = \frac{1}{2}(u + u + at)\,t$

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



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

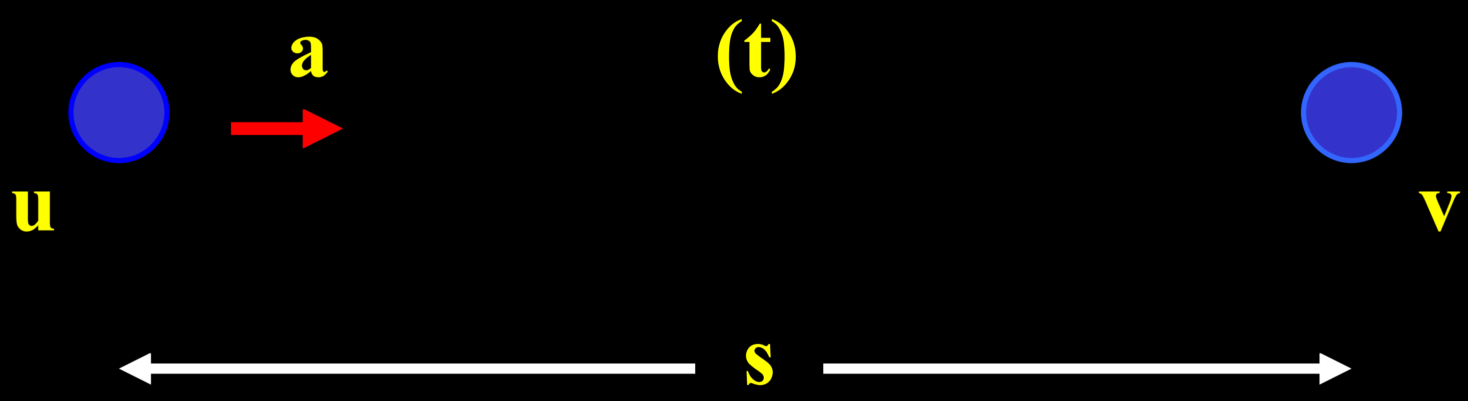
$$v = u + at$$

$$v^2 = (u + at)^2$$

$$v^2 = u^2 + 2.u.at + a^2t^2$$

$$v^2 = u^2 + 2a(ut + \tfrac{1}{2}at^2)$$

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



P1 The velocity of a car increases from 10 m s^{-1} East to 40 m s^{-1} East in 5 seconds.

Calculate the average acceleration of the car.

East = + direction

$$\text{Average acceleration} = \frac{\text{final velocity - initial velocity}}{\text{time taken}}$$

$$\text{Average acceleration} = \frac{(+40) - (+10)}{5}$$

$$= 6\ m\ s^{-2}\ East$$

P2 **The speed of a bicycle moving in a straight line decreases from 15 m s^{-1} North to 3 m s^{-1} North in 6 s. Find its average acceleration.**

North = + direction

$$\text{Average acceleration} = \frac{\text{final velocity - initial velocity}}{\text{time taken}}$$

$$\text{Average acceleration} = \frac{(+3)-(+15)}{6}$$

$$= -2\ m\ s^{-2}$$

$$2\ m\ s^{-2}\quad \text{South}$$

P3 A car starting from rest has an acceleration of 4 m s^{-2}.

Find: (i) its velocity after 8 s,

(ii) the distance it travels in 8 s,

(iii) how long it takes to reach a velocity of 100 m s^{-1}.

(i) Forward = + direction

$u = 0$, $a = +4$, $t = 8$, $v = ??$

$v = u + at$

$v = 0 + (+4)(8)$

$v = +32$ m s^{-1}

P3 A car starting from rest has an acceleration of 4 m s^{-2}.

Find: (i) its velocity after 8 s,

(ii) the distance it travels in 8 s,

(iii) how long it takes to reach a velocity of 100 m s^{-1}.

(ii) Forward = + direction

$u = 0$, $a = +4$, $t = 8$, $s = ??$

$s = ut + ½ at^2$

$s = 0 + ½ (+4)(8)^2$

$s = 128$ m

P3 A car starting from rest has an acceleration of 4 m s^{-2}.

Find: (i) its velocity after 8 s,

(ii) the distance it travels in 8 s,

(iii) how long it takes to reach a velocity of 100 m s^{-1}.

(iii) Forward = + direction

$u = 0$, $a = +4$, $v = +100$, $t = ??$

$v = u + at$

$+100 = 0 + (+4)(t)$

$t = 25$ s

P4 **A car with constant acceleration travels a distance of 100 m while its velocity changes from 10 m s^{-1} to 25 m s^{-1}. Calculate its acceleration.**

Forward = + direction

$u = +10, \quad v = +25, \quad s = +100, \quad a = ??$

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

$(+25)^2 = (+10)^2 + 2a\,(+100)$

$a = 2.63 \text{ m s}^{-2}$

P5 **A car travelling with a speed of 10 m s^{-1} passes a pole on the roadside at a certain instant. It immediately accelerates with an acceleration of 2 m s^{-2}. How far is it from the pole when its velocity is 30 m s^{-1}?**

Forward = + direction

$u = +10, \quad v = +30, \quad a = +2, \quad s = ??$

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

$(+30)^2 = (+10)^2 + 2(+2)s$

$s = +200$ m

P6 **A train which has a constant acceleration travels a distance of 2 km in 50 s. If its initial velocity is 20 m s^{-1}, find its acceleration.**

Forward = + direction

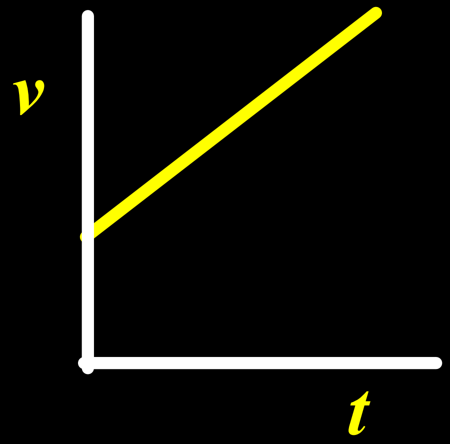
$u = +20, \quad s = +2000, \quad t = +50, \quad a = ??$

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

$2000 = (+20)(+50) + \frac{1}{2}a(50)^2$

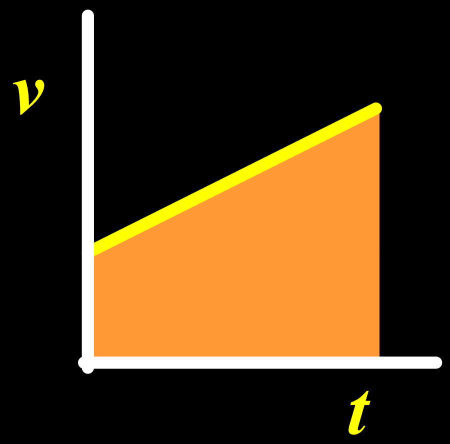
$a = +0.80 \text{ m s}^{-2}$

Velocity - Time Graphs



Slope = ??

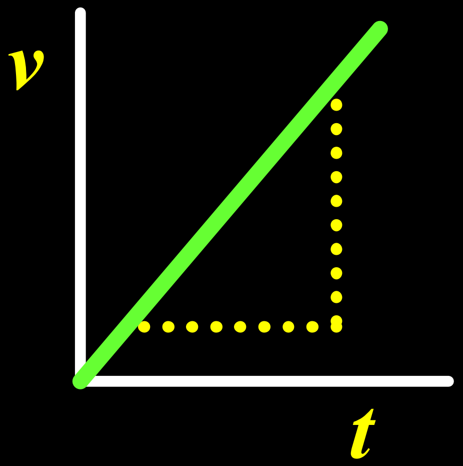
Acceleration

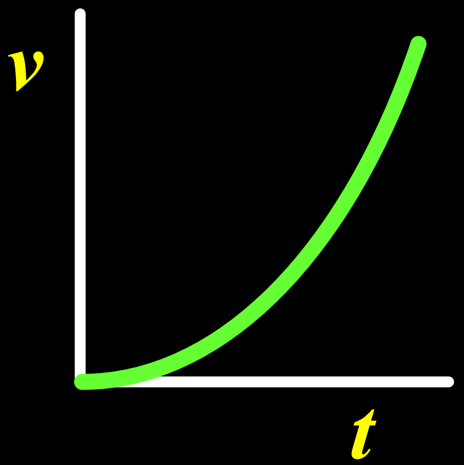


Area under graph = ??

Distance travelled

Velocity - Time Graphs





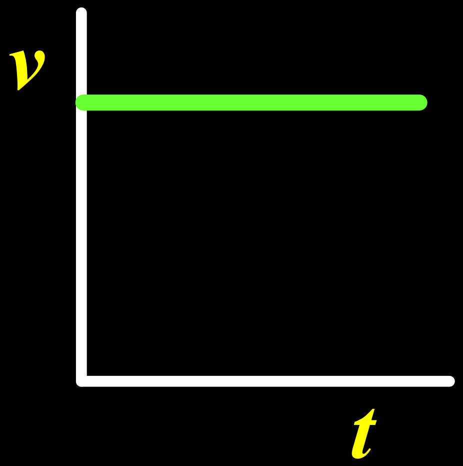
$$Slope = \frac{\Delta v}{\Delta t}$$

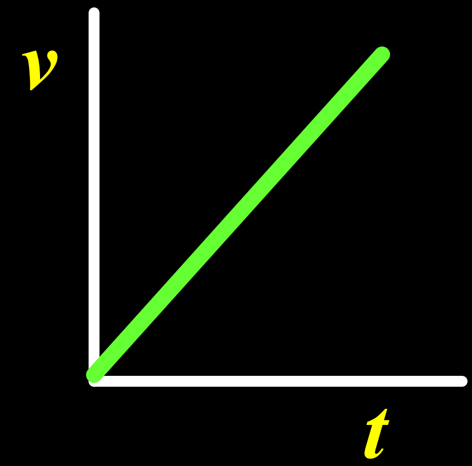
Acceleration increasing

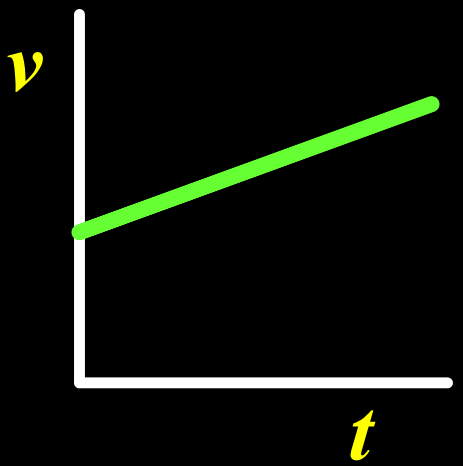
$$Slope = acceleration\ (a)$$

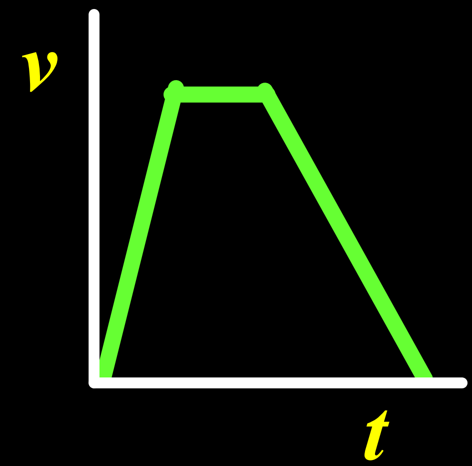
Velocity - Time Graphs

Comment



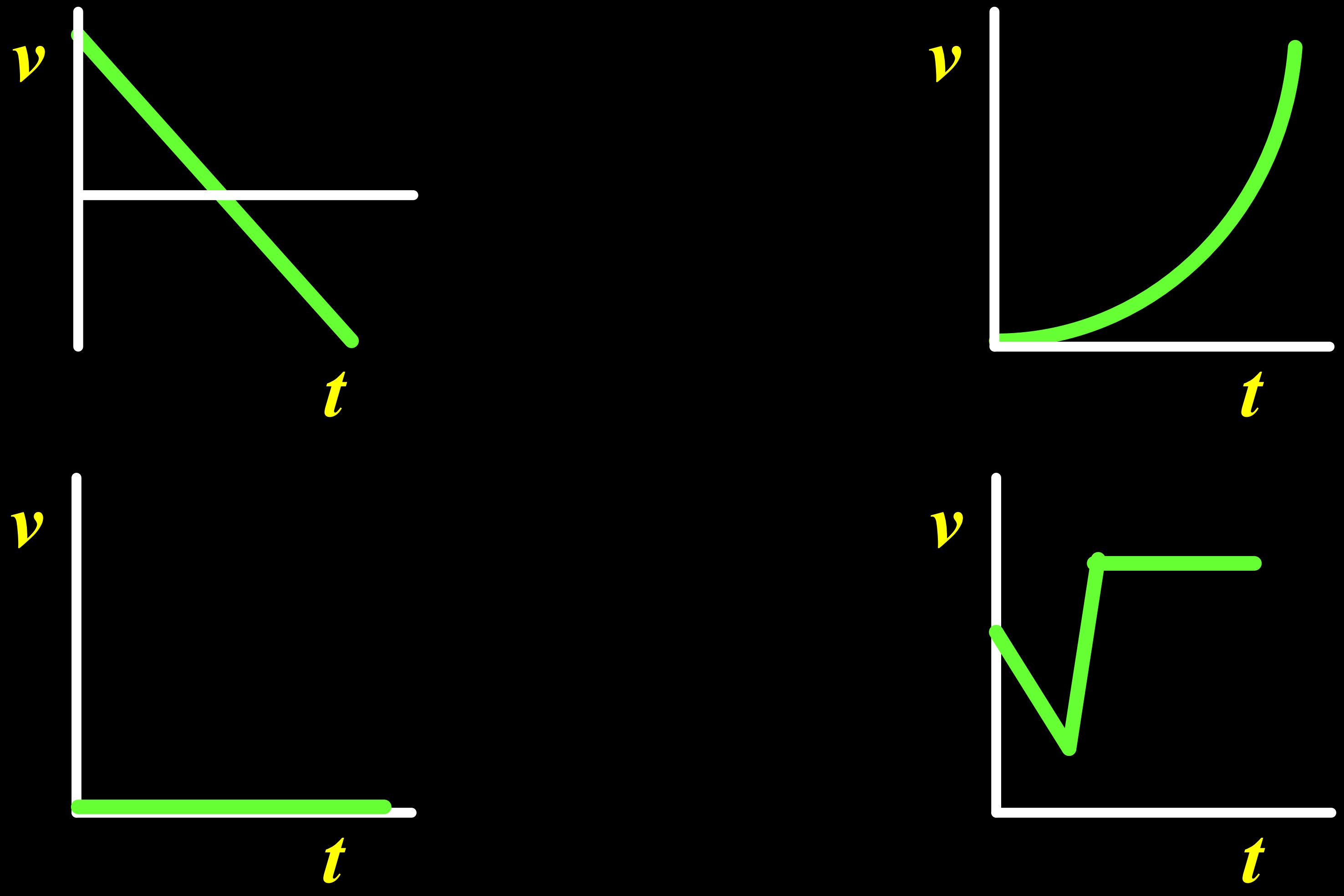






Velocity - Time Graphs

Comment



Measuring Velocity & Acceleration

Powder Track Timer

Air Track Timer

Ticker Tape Timer

Powder Track Timer

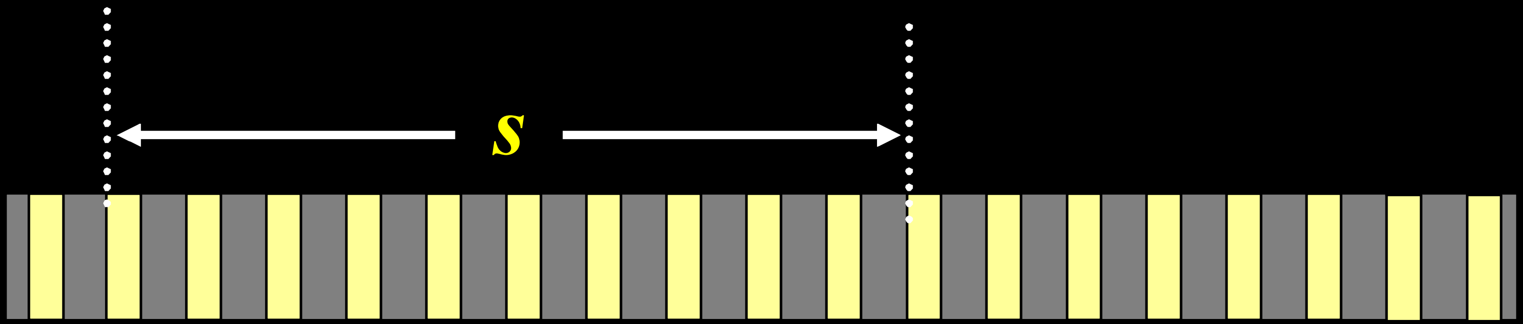
Trolley

A.C. Power Supply

Track

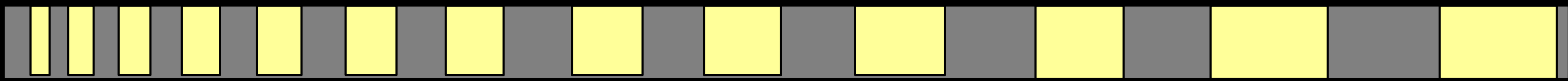
Sulphur Powder

PTT - Measuring Velocity



Velocity = spread of 10 patches ÷ (10 x 0.02)

PTT - Measuring Acceleration



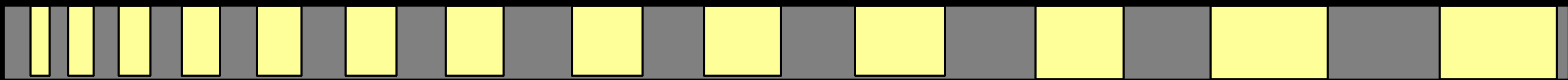
$v = u + at$

u = spread of 5 patches near the start ÷ (5 x 0.02)

v = spread of 5 patches near the end ÷ (5 x 0.02)

t = "n" x 0.02

PTT - Measuring Acceleration



or

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

u **= spread of 5 patches near the start ÷ (5 x 0.02)**

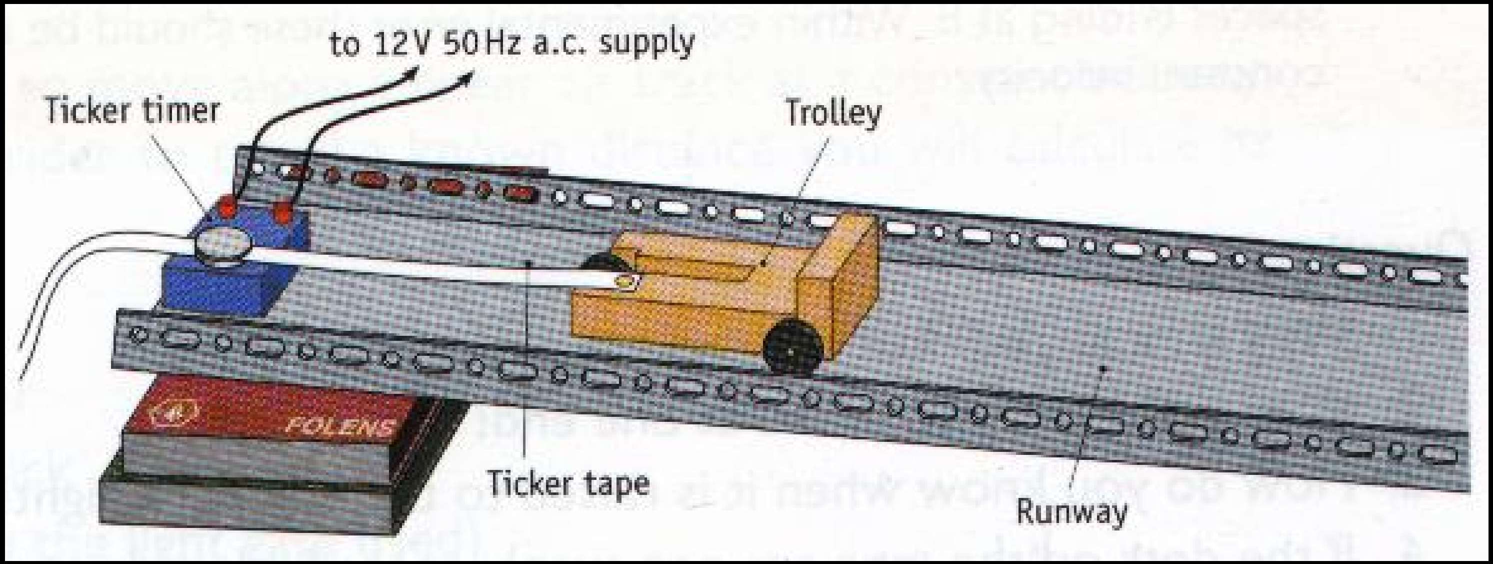
v **= spread of 5 patches near the end ÷ (5 x 0.02)**

s **= distance from middle of *u* patches to middle of *v* patches**

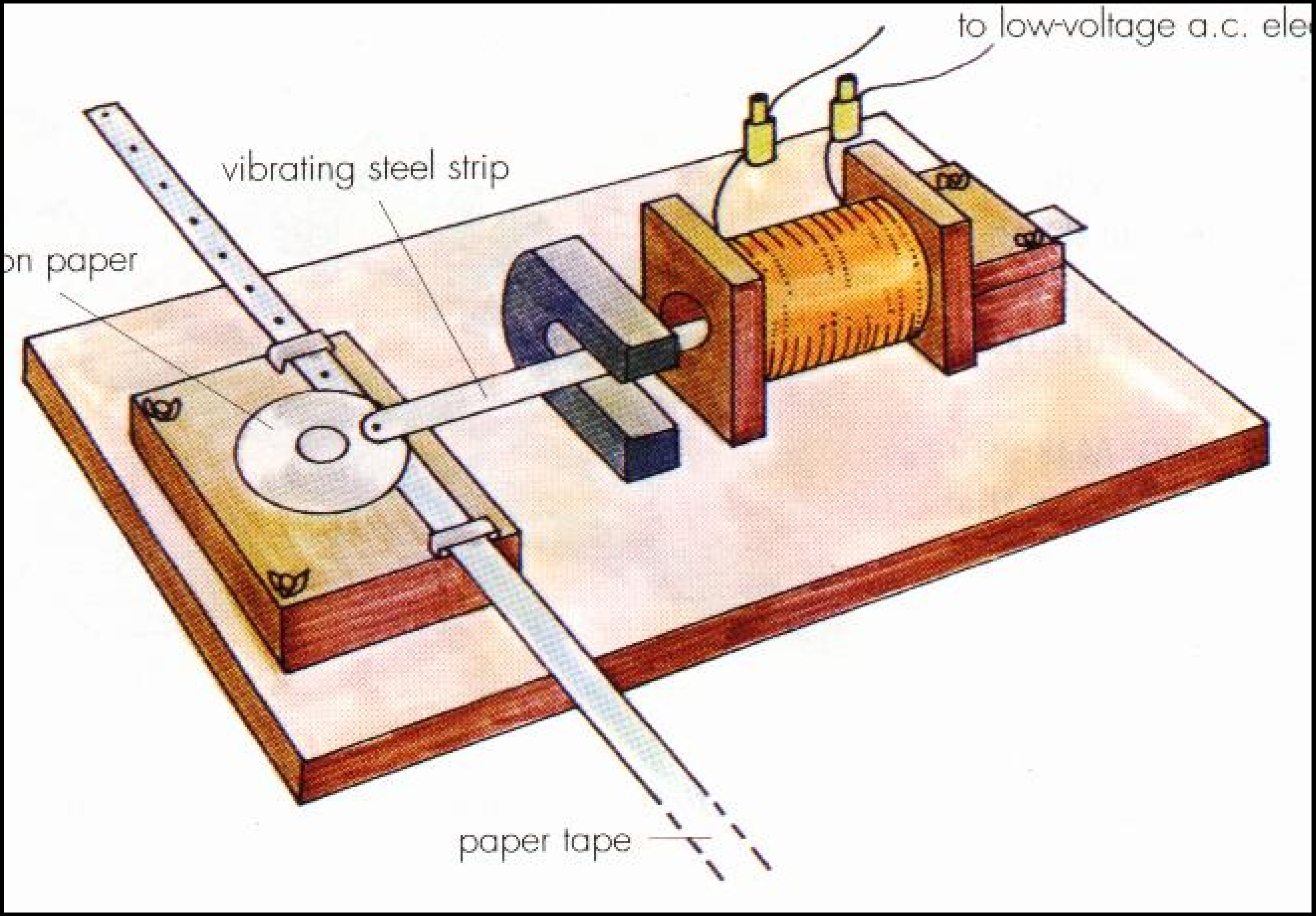
PTT - Precautions

- Wedge … to compensate for ??
- *u* and *v* well apart
- Repeat for other patches ...
- Velocity … use more than 10 patches

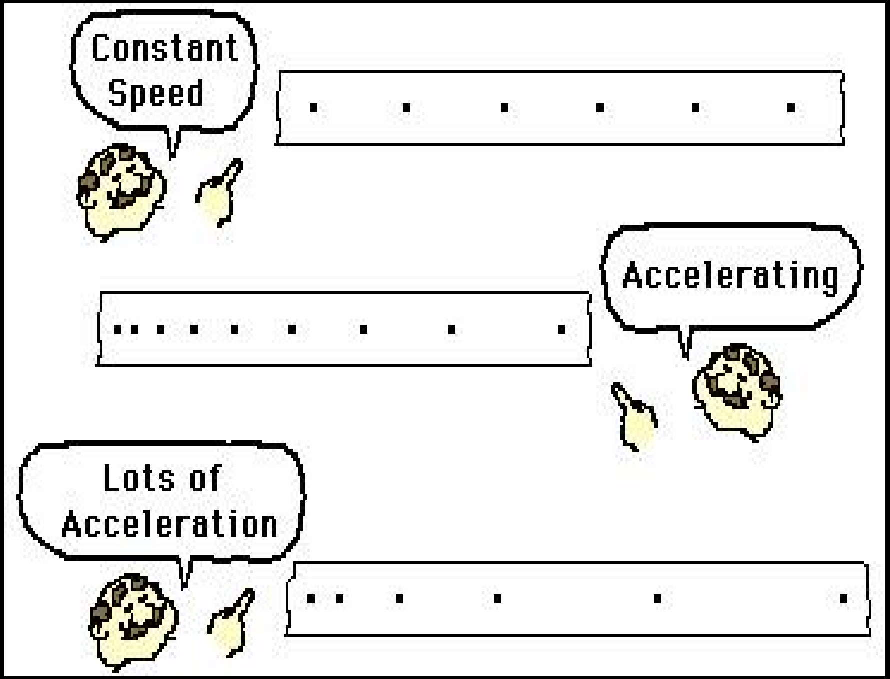
Ticker-Tape Timer



Ticker-Tape Timer

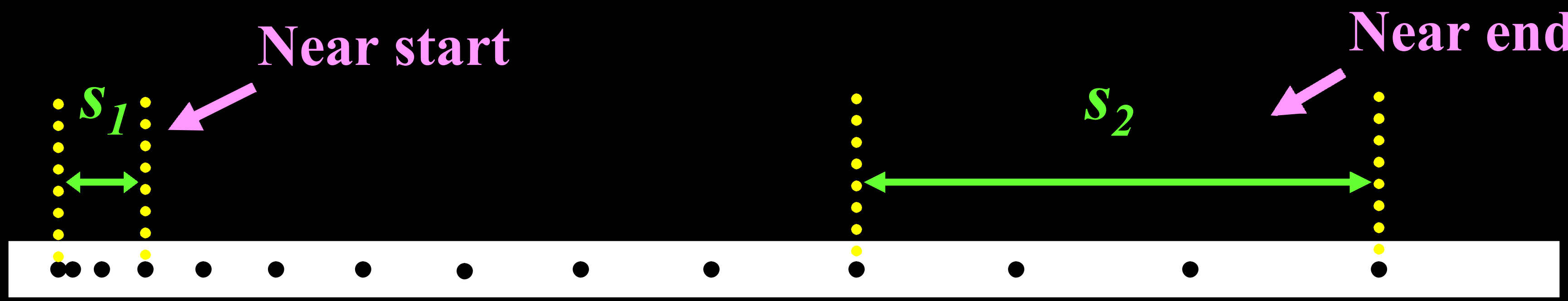


Ticker-Tape Timer



TTT - Measuring Acceleration

$$v = u + at$$



$$u = \frac{s_1}{3 \times 0.02}$$

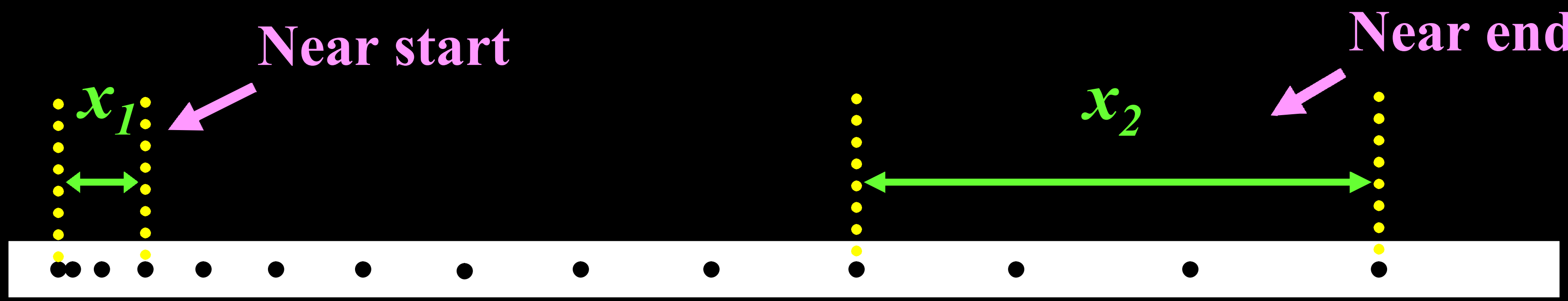
$$t = \text{“}n\text{”} \times 0.02$$

$$v = \frac{s_2}{3 \times 0.02}$$

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

TTT - Measuring Acceleration

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



$$u = \frac{x_1}{3 \times 0.02}$$

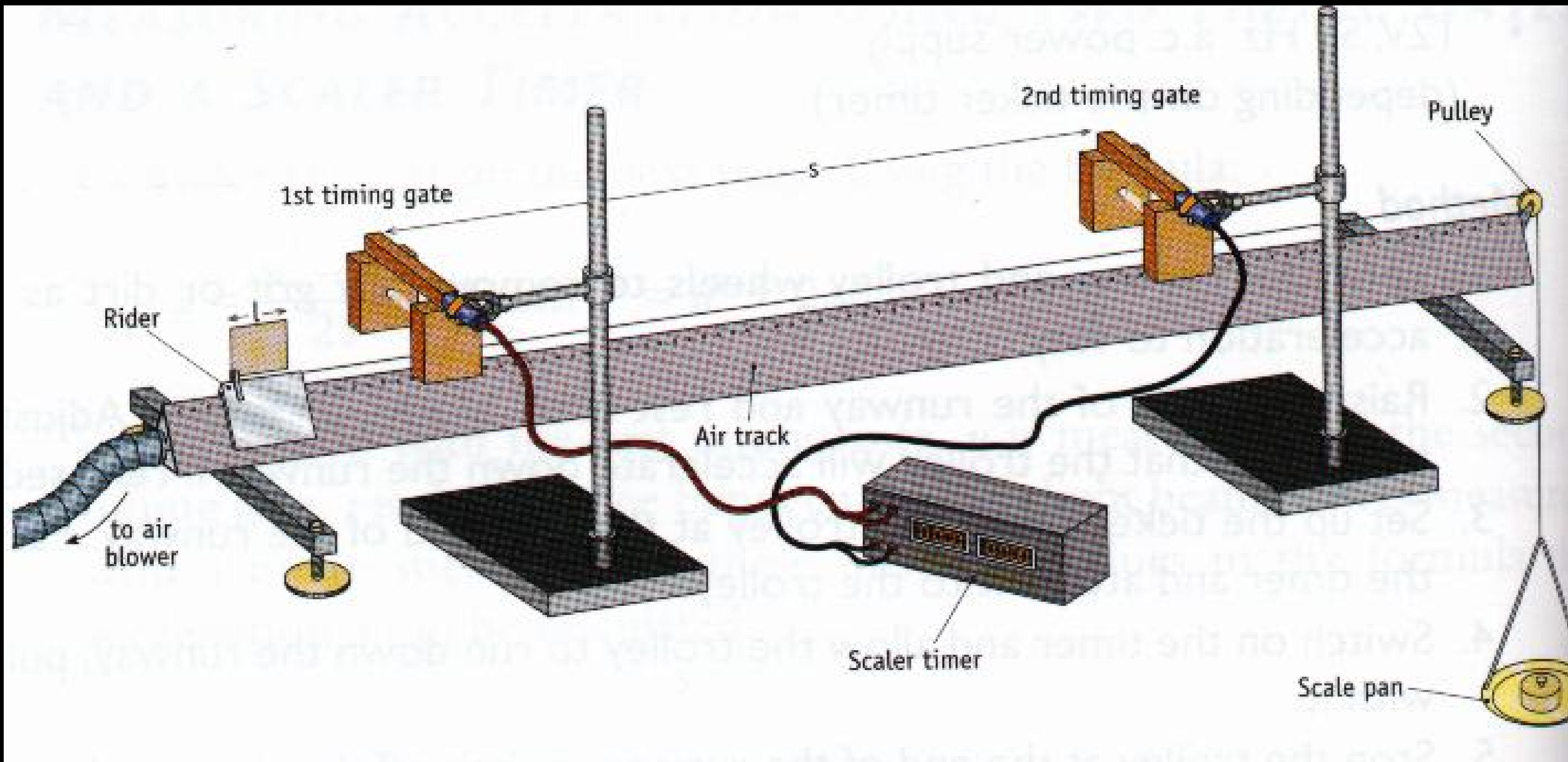
$$v = \frac{x_2}{3 \times 0.02}$$

s = distance from "middle of u" to " middle of v"

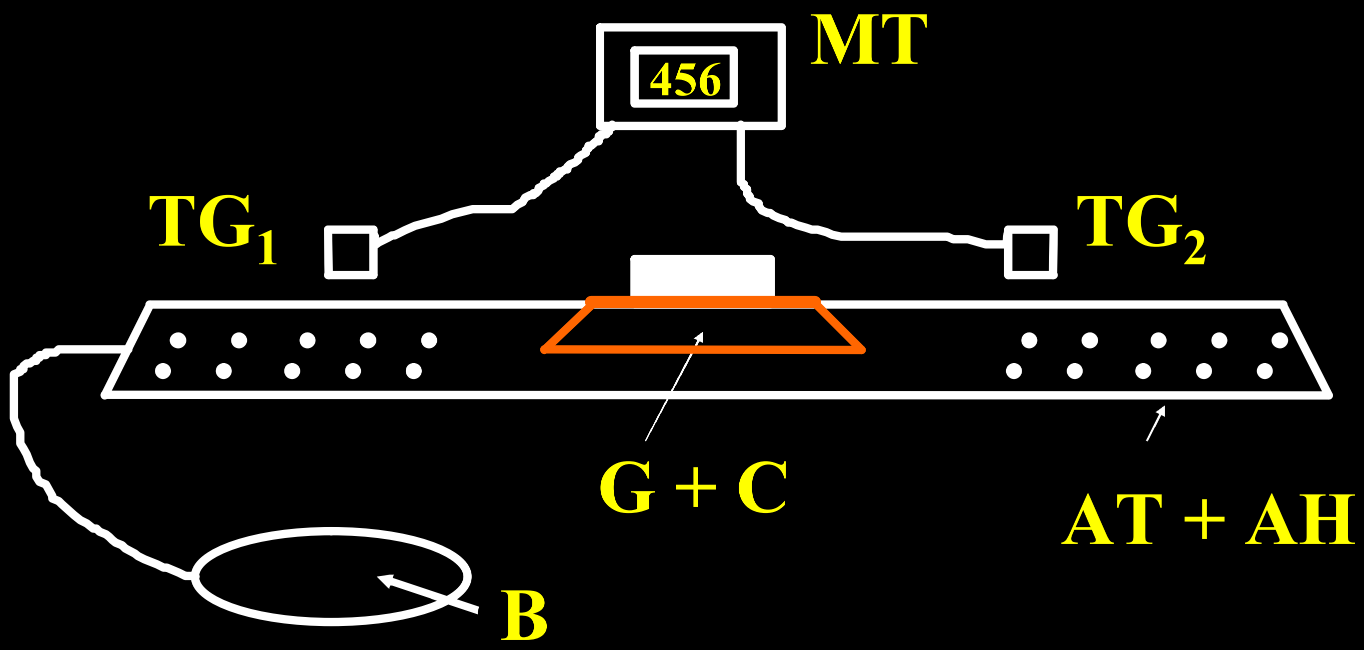
$$a = \frac{v^2 - u^2}{2s}$$

Air Track Timer

Measuring Acceleration



Air Track Timer



Air Track + Air Holes

Timing Gates

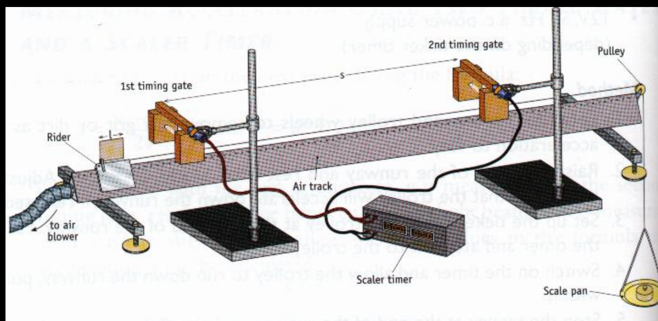
Blower

Glider + Card

Millisecond Timer

Air Track Timer

Measuring Acceleration



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

$$u = \frac{width\ of\ card}{time\ gate\ 1} \qquad v = \frac{width\ of\ card}{time\ gate\ 2}$$

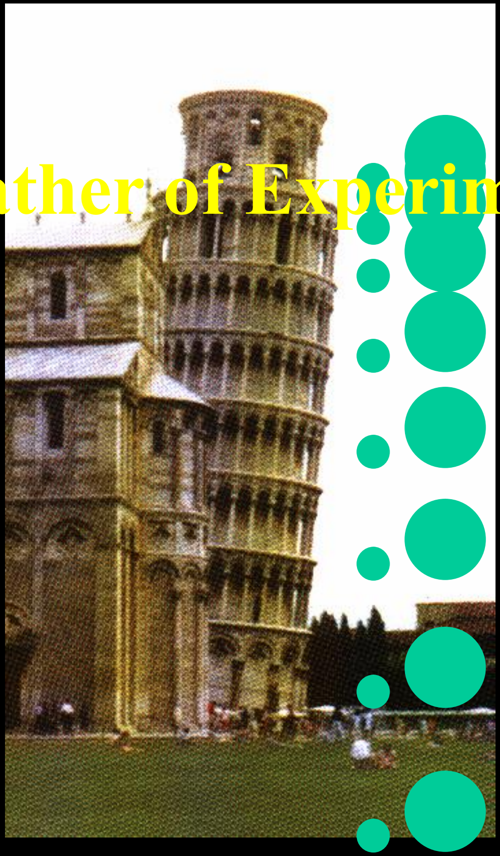
$$s = distance\ from\ gate\ 1\ to\ gate\ 2$$

Precautions

- s large
- strong enough air supply
- repeat other …

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

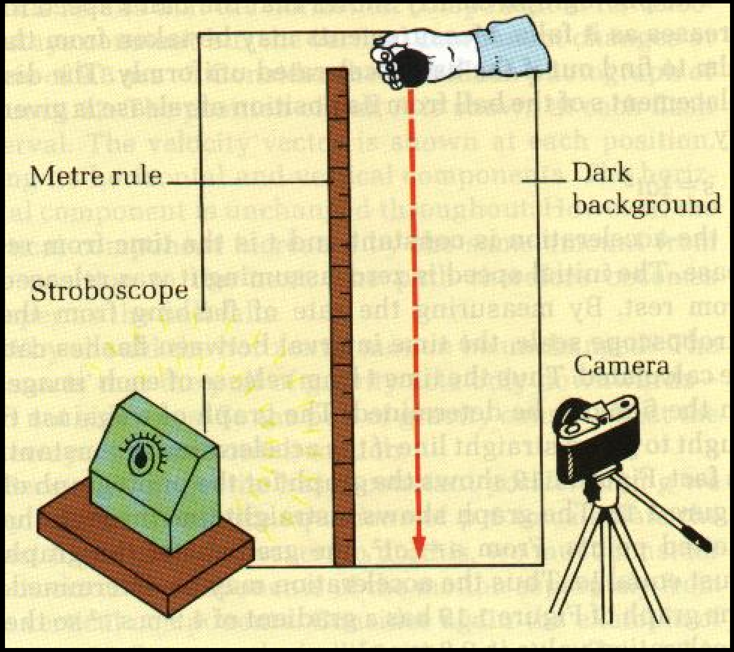
Acceleration Due To Gravity "g"

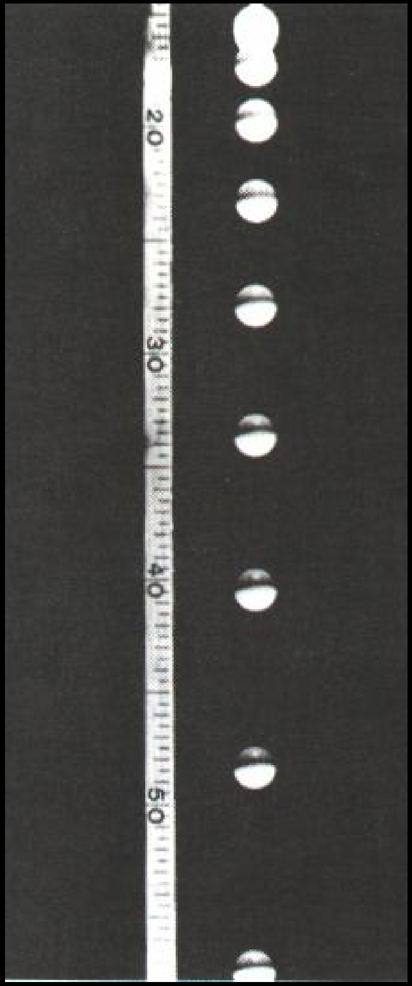


Father of Experimental Science

$g = 9.8 \text{ m s}^{-2}$

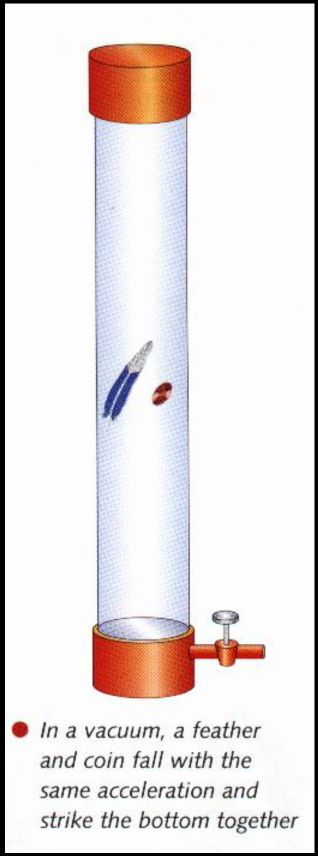
Acceleration Due To Gravity "g"





$g = 9.8 \text{ m s}^{-2}$

Value of 'g'



Cork	9.81
Equator	9.78
North Pole	9.83
Top Mt. Everest	9.77
Moon	1.6

Value of *g* depends on …

- distance from centre of earth
- rotation of the earth
- planet, etc.

P8 **An object is dropped from the top of a building which is 30 m high.**

(i) With what speed does the object hit the ground?

(ii) How long does it take to reach the ground?

(i) **Down = + direction**

$u = 0, \quad s = +30, \quad a = +9.8, \quad v = ??$

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

$v^2 = 0 + 2(+9.8)(+30)$

$v = 24.2 \text{ m s}^{-1}$

P8 **An object is dropped from the top of a building which is 30 m high.**

(i) With what speed does the object hit the ground?

(ii) How long does it take to reach the ground?

(ii) **Down = + direction**

$u = 0$, $a = +9.8$, $v = +24.2$, $t = ??$

$v = u + at$

$24.2 = 0 + (+9.8)\,t$

$t = 2.47$ s

P9 **An object falls from the top of a building and strikes the ground 5 s later.**

Find the height of the building.

Down = + direction

$u = 0$, $a = +9.8$, $t = +5$, $s = ??$

$s = ut + ½ at^2$

$s = 0 + ½ (+9.8)(+5)^2$

$s = 123$ m

P10 **A stone is thrown vertically upwards with an initial velocity of 20 m s^{-1}.**
Find the greatest height reached by the stone.

Up = + direction

$u = +20, \quad a = -9.8, \quad v = 0, \quad s = ??$

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

$0 = (+20)^2 + 2(-9.8)\,s$

$s = 20.4$ m

P11 **A body is thrown vertically upwards with an initial speed *u* from a point P which is 20 m above the ground. After 4 s is is at a point Q and has a velocity of 6 m s^{-1} downwards.**

Find: (i) the value of *u*, (ii) the height of Q above ground.

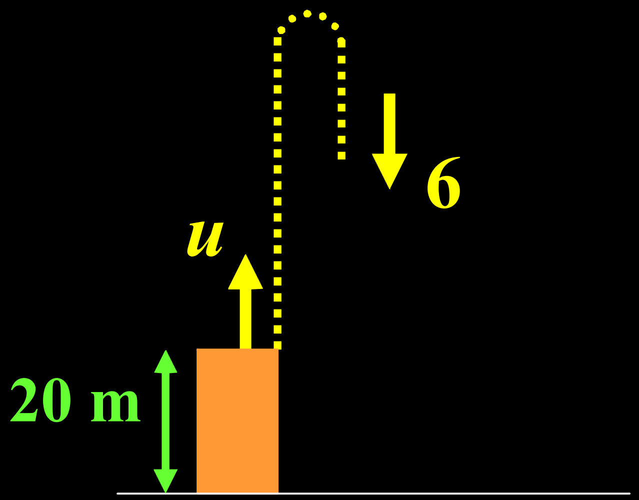
(i) Up = + direction

u = ??, a = - 9.8, t = +4, v = - 6, s = ??

$$v = u + at$$

$$-6 = u + (-9.8)(4)$$

$$u = +33.2 \text{ m s}^{-1}$$

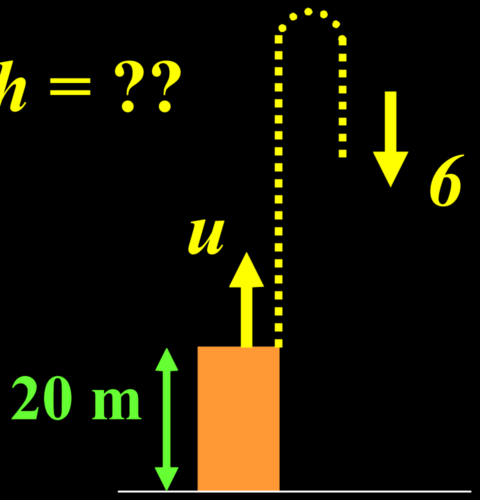


P11 **A body is thrown vertically upwards with an initial speed *u* from a point P which is 20 m above the ground. After 4 s is is at a point Q and has a velocity of 6 m s^{-1} downwards.**

Find: (i) the value of *u*, (ii) the height of Q above ground.

(ii) Up = + direction

$u = +33.2, \quad a = -9.8, \quad t = +4, \quad s/h = ??$



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

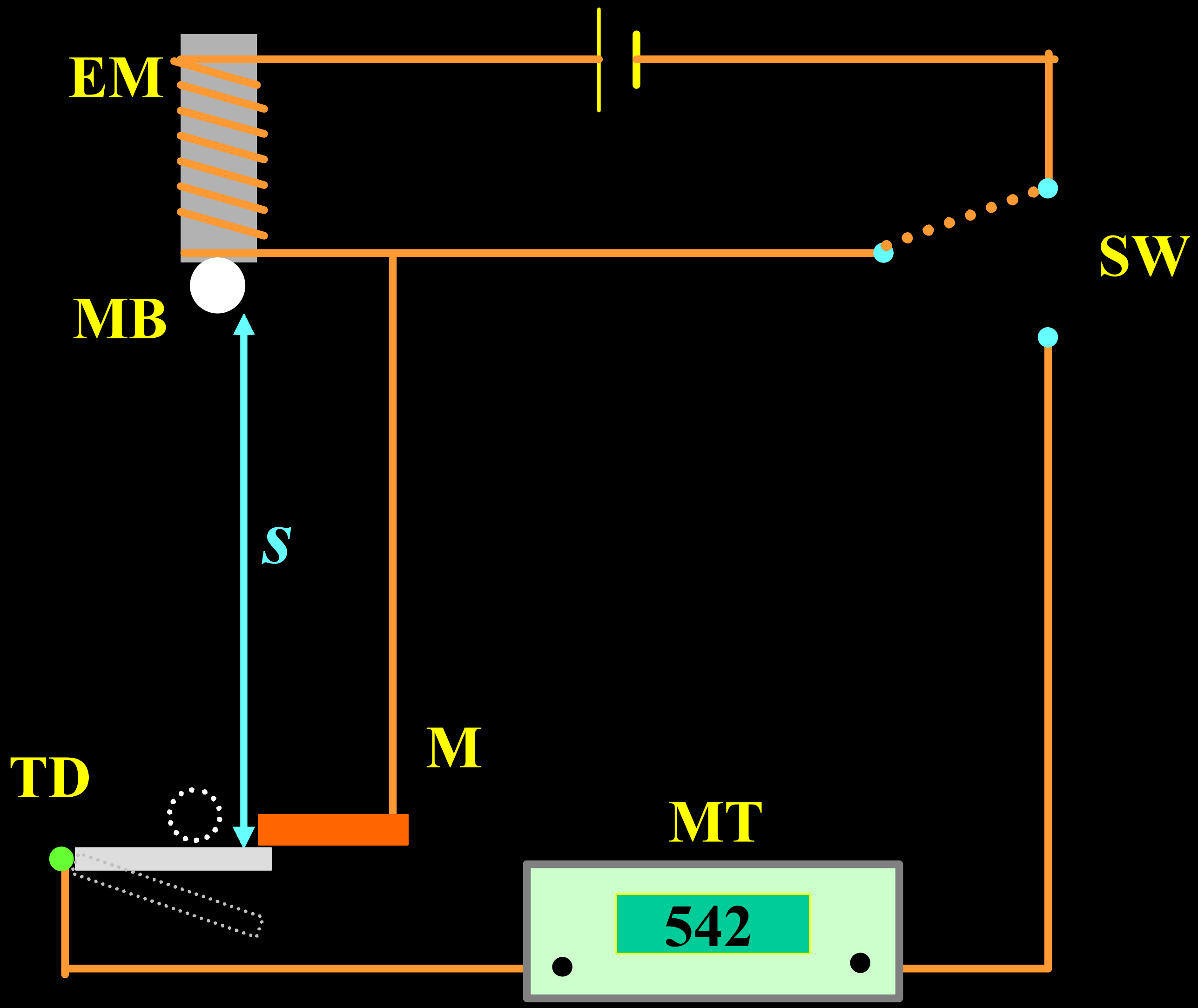
$s = (+33.2)(+4) + \frac{1}{2}(-9.8)(+4)^2$

$s = +54.4$ m

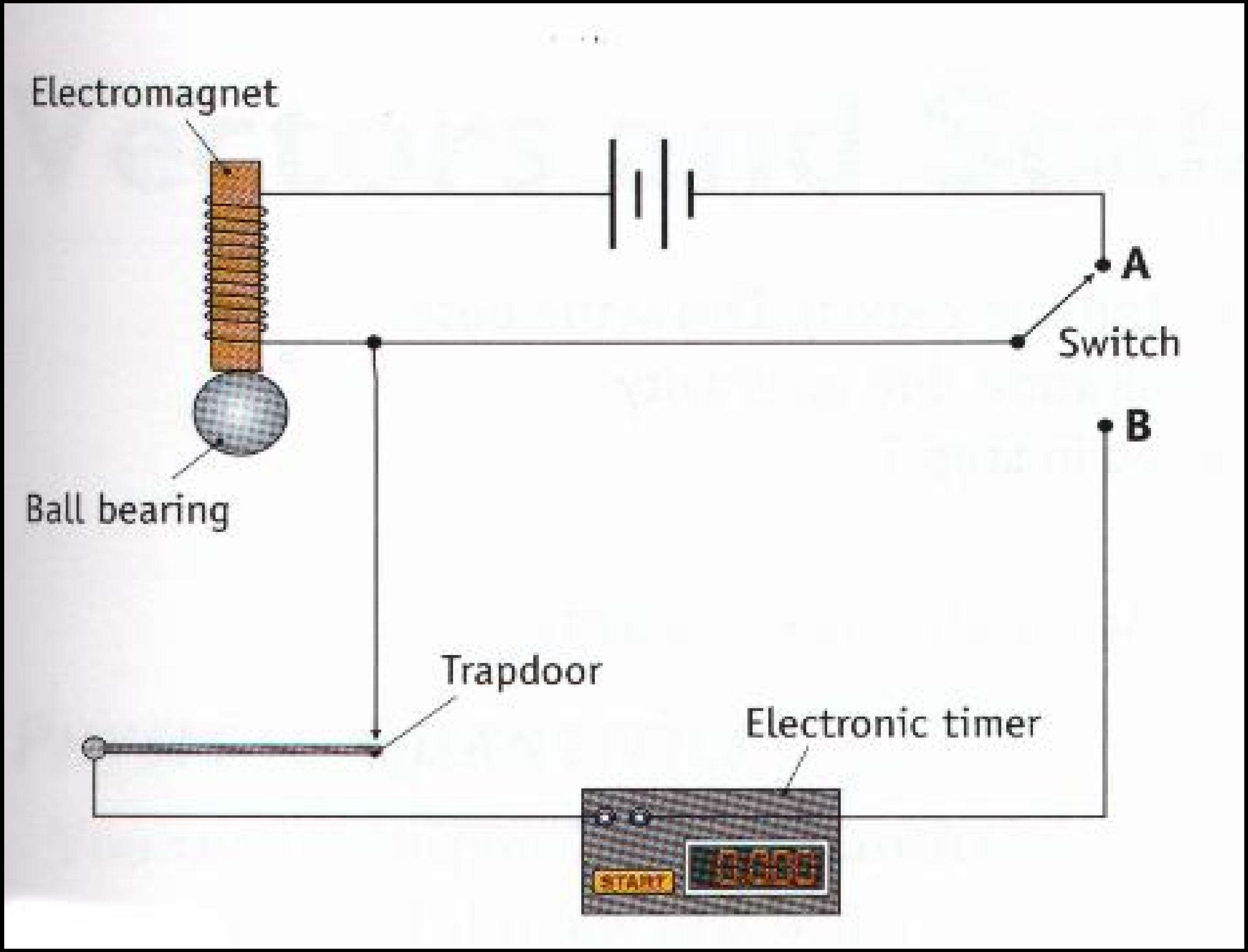
$\Rightarrow$ 54.4 m above P

$\Rightarrow$ Height = 20 + 54.4 = 74.4 m above ground

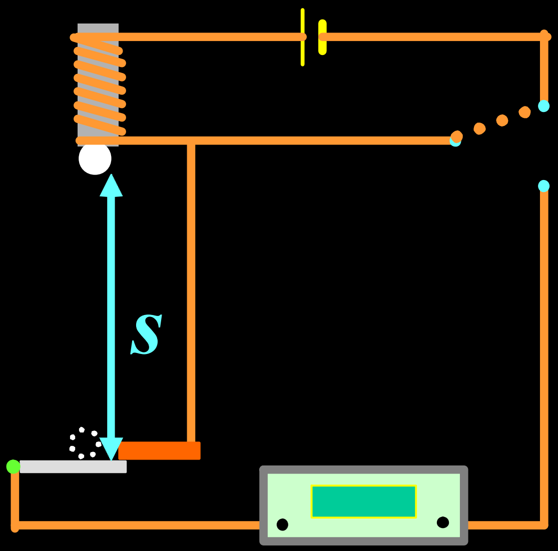
Expt.   Measure g by Free-Fall



Expt. Measure g by Free-Fall



Procedure (Expt. Measure g by Free-Fall)



1. Flick switch.
   Ball falls freely.
   Timer starts & stops auto ...
   Repeat for same height.
2. Measure *s*, *t*.
3. *s* = distance from … to …
   t = smallest time …
4. Repeat … other heights … to average *g* / to graph

Results (Expt. Measure g by Free-Fall)

Distance Fallen	Time For Fall in seconds	Smallest Time	Acceleration Due To Gravity
s / m	t_1, t_2, t_3, t_4	t / s	g / m s^{-2}

$$s = u\,t + \tfrac{1}{2}\,a\,t^2$$
$$s = 0 + \tfrac{1}{2}\,g\,t^2$$

$$\Rightarrow \quad g = \frac{2s}{t^2}$$

Calculate average g

or ...

Results (Expt. Measure g by Free-Fall)

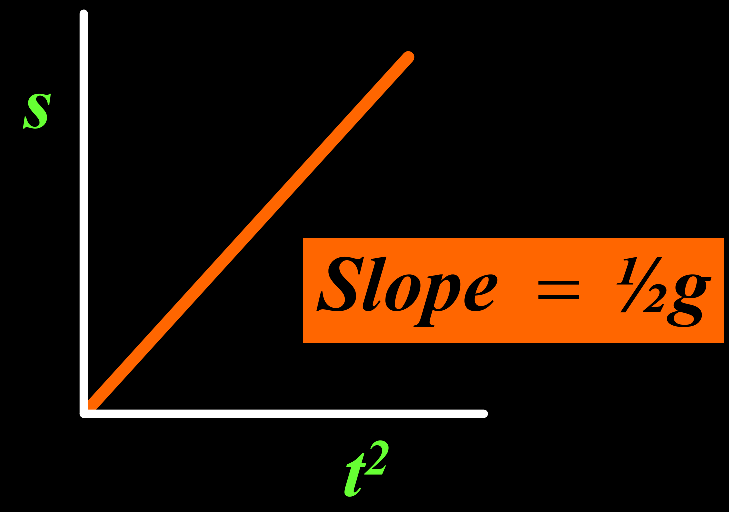
$$s = u\,t + \tfrac{1}{2}\,a\,t^2$$

$$s = 0 + \tfrac{1}{2}\,g\,t^2$$

$$s = (\tfrac{1}{2}\,g)\,t^2$$

| | |

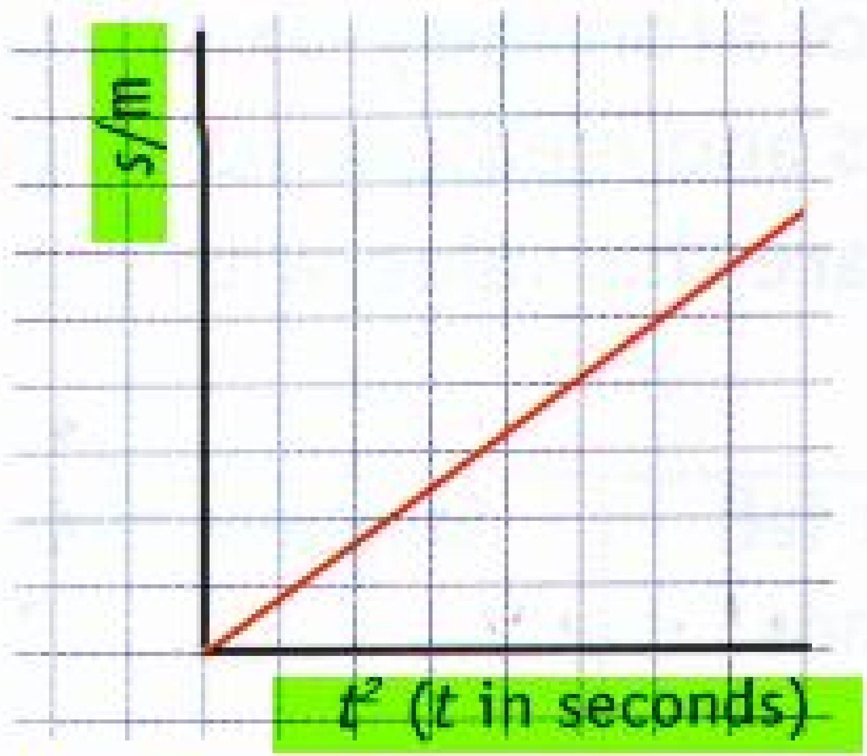
$$y = m\;x$$



$$g = slope \times 2$$

Results

(Expt. Measure g by Free-Fall)



g = 2 x slope of graph

Precautions (Expt. Measure g by Free-Fall)

- Good release method (burn / paper / ruler …)
- Smallest time
- Larger height
- Trapdoor loosely held
- Repeat to get average *g*