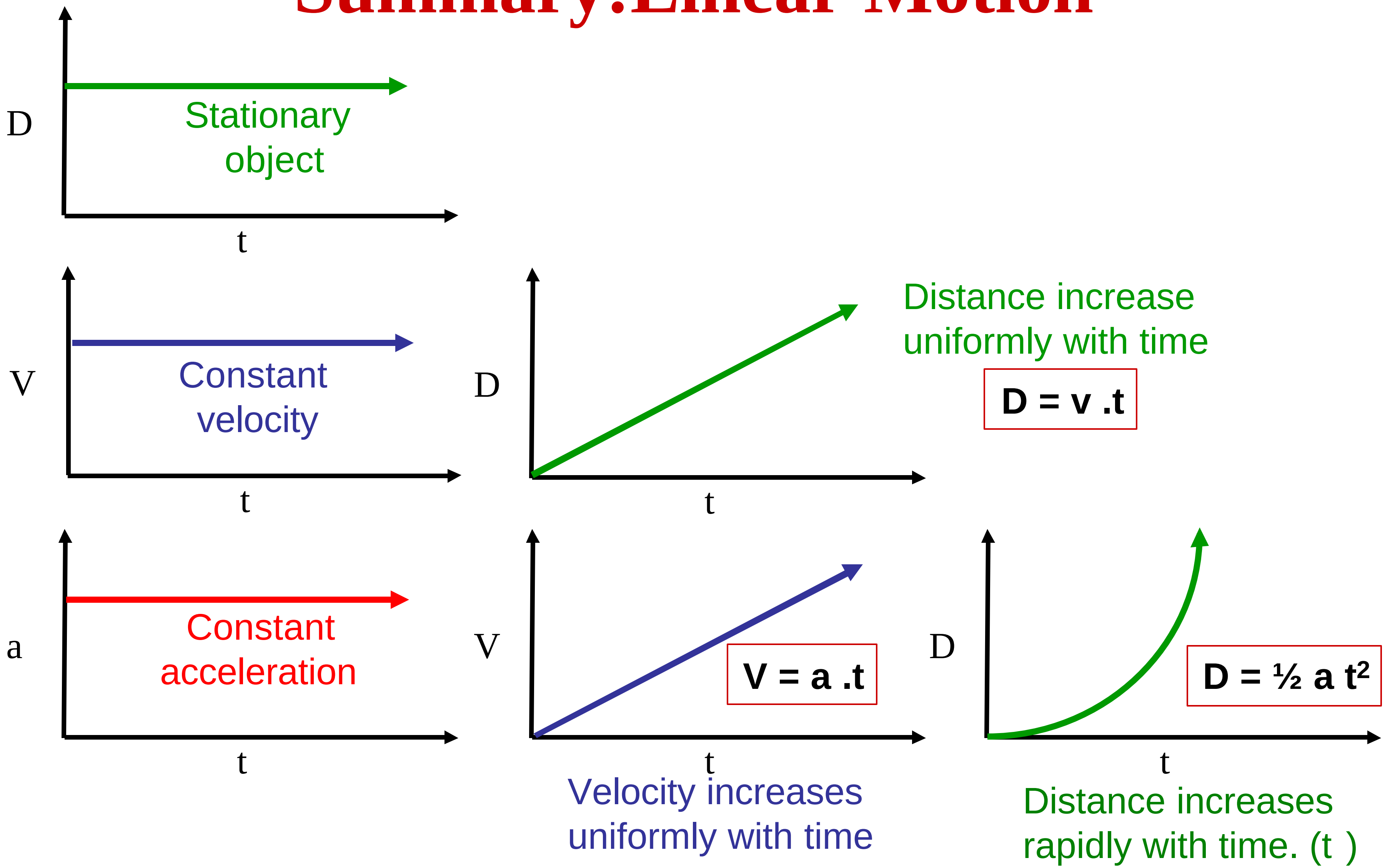
Summary:Linear Motion



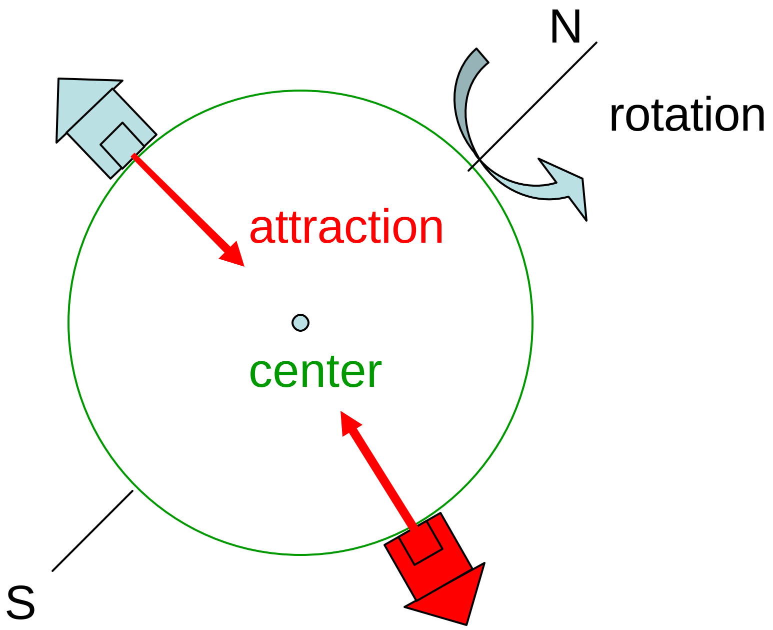
Constant acceleration “a” occurs in nature whenever the **force is constant** e.g. gravity.

Falling Objects and Gravity

- Do you ever question why things fall?
- We take it for granted but some of our **every day ideas** may need **revising**.

GRAVITY:

Gravity is a **force of attraction** between two (or more) bodies that we now know is dependent on the **mass** of the bodies and on their **separation** (Chapter 5).



The Earth is very massive (M = 6x10 kg) and the gravitational attraction between the earth and our bodies (and everything around us) keeps us firmly planted on the ground.

- The **Moon** also has **gravity** but as it is **less massive** the **force** is much **less**, about 1/6 of earth gravity.
- Gravitational attraction between the Sun and the planets keeps them in orbit.
- All bodies (large and small) exhibit gravitational attraction!

- Gravity is an **everpresent force** that produces a **constant downward acceleration**.

ACCELERATION DUE TO GRAVITY : "g"

Basic questions:

What happens to a lead ball when it is let go from an outstretched hand?

1. Does it float or drop to the ground?
2. Does it fall at a constant velocity?
3. Does its velocity increase in time as it fall? (i.e. Is it being accelerated?

Experiment: lead ball demo!

- Difficult to see what is happening as the ball hits the ground in less than 0.5 sec.

NO PROBLEM!

- Let's repeat the experiment using a lighter (i.e. less massive) ball.
(after all its common knowledge that heavier things fall faster.)

- Use wooden ball as much lighter….

Result – Still looked pretty quick!

Critical Experiment:

Drop **both simultaneously** and listen for the different "thuds" as they hit the floor.

AMAZING RESULT!

It seems that **regardless of the mass** (i.e. weight) each object **impacted** the floor at the same **same time**.

❖ This suggests that the **GRAVITATIONAL ACCELERATION** does **NOT** depend on the **MASS** of the object after all!

- We have just performed a classic experiment based on experiments of Galileo in the early 1600’s (i.e., over 350 years ago) that proved Aristotle wrong!

- Aristotle thought (as we often do) that heavier objects fall faster to the ground.

His error: He neglected **AIR RESISTANCE** which slows down lighter and larger area objects.

Exp: - Try sheet of paper…

RESULT:

In the absence of air (e. g. on the moon) a **feather** and a **brick** will arrive at the surface at the same time. (ie they will fall at the same rate).

NOTE: due to Moon’s lower gravity they will take **longer to fall** the same distance than on Earth.

Galileo’s insight that gravitational attraction is the **SAME FOR ALL OBJECTS** on the earth **regardless of their mass or volume** continues to an “**EYE OPENER**”!

How to Measure Gravitational Acceleration

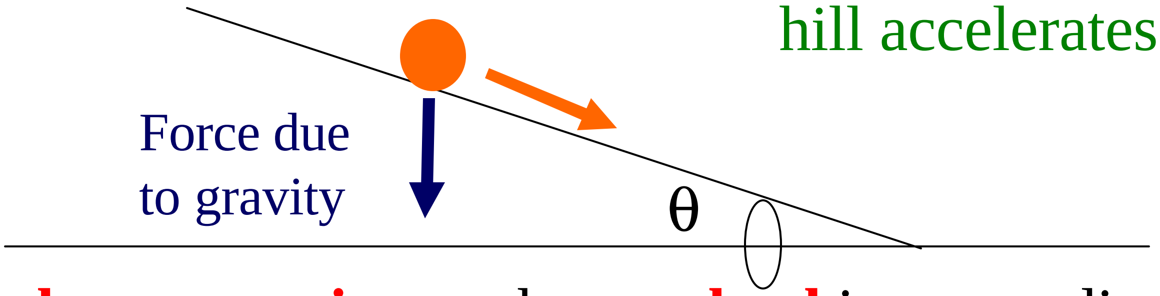
(to see if its really constant!)

- Dropping balls is difficult as the experiment happens so fast (less than 0.5 sec)

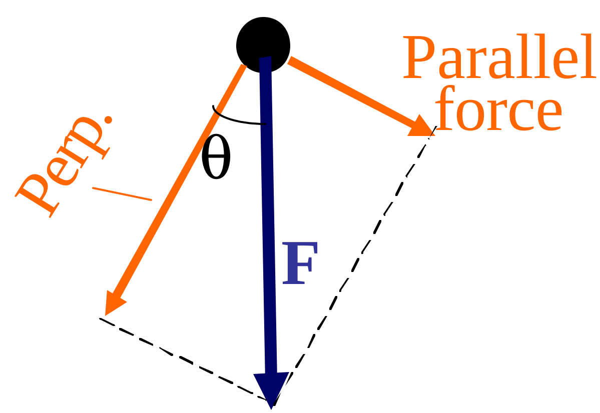
Galileo used a simple (clever) technique to slow the action down…

INCLINED PLANE:

Ball rolling down the hill accelerates less



The **force due to gravity** can be **resolved** into two directions: one **parallel** to the slope which provides a **reduced gravitational acceleration** down the slope, and one **perpendicular** to the slope (which will have **no effect** on ball's motion).

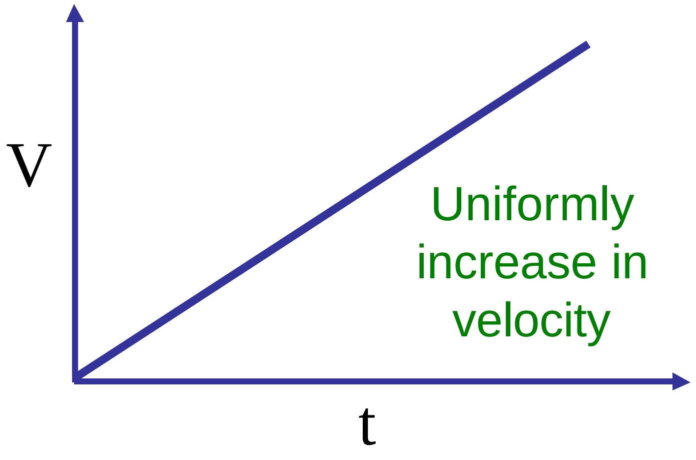


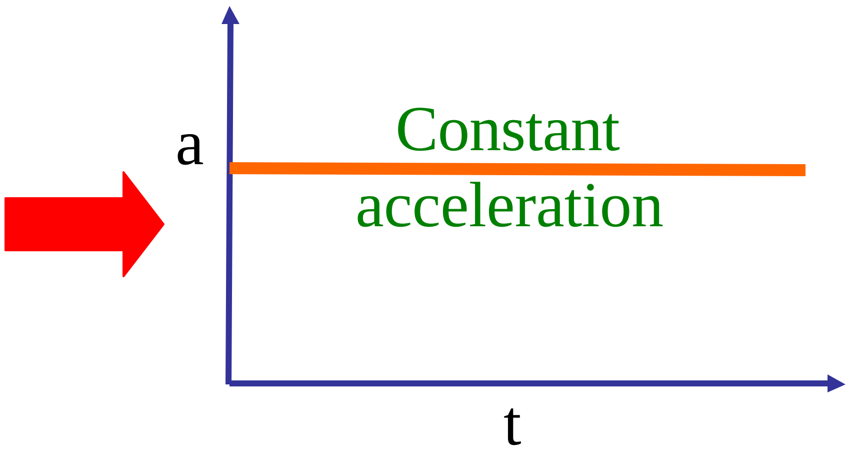
OSERVATION:

- Parallel force is less than the vertical gravitational force.
- Depending on the angle θ the parallel force can be varied (as the parallel force = F. *sinq*).
- Steeper the slope the larger the component of force acting (this is why steep ski slopes are dangerous!).
- Galileo simply rolled balls down the slope and timed them.

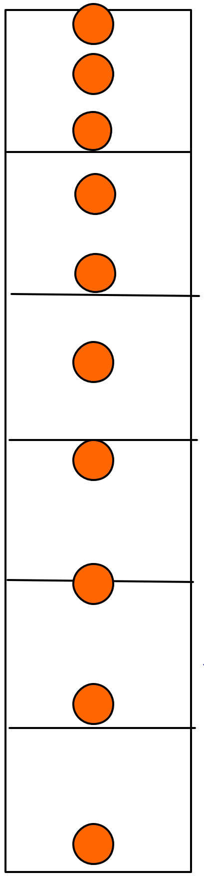
RESULT:

1. As the ball rolled down the slope it gradually **picked up speed** (i.e it accelerated).
2. The **speed** was found to **increase uniformly** with time.





Ex: Falling ball



1/20 s between ball positions

Separation increases rapidly with time

Table 3.1 Distance and Velocity Values for a Falling Ball

Time	Distance	Velocity
0	0	
		24 cm/s
0.05 s	1.2 cm	
		72 cm/s
0.10 s	4.8 cm	
		124 cm/s
0.15 s	11.0 cm	
		174 cm/s
0.20 s	19.7 cm	
		218 cm/s
0.25 s	30.6 cm	
		268 cm/s
0.30 s	44.0 cm	
		320 cm/s
0.35 s	60.0 cm	
		368 cm/s
0.40 s	78.4 cm	
		416 cm/s
0.45 s	99.2 cm	
		464 cm/s
0.50 s	122.4 cm	

Av. vel increases uniformly with time

- Compute **average velocity** for each time interval:

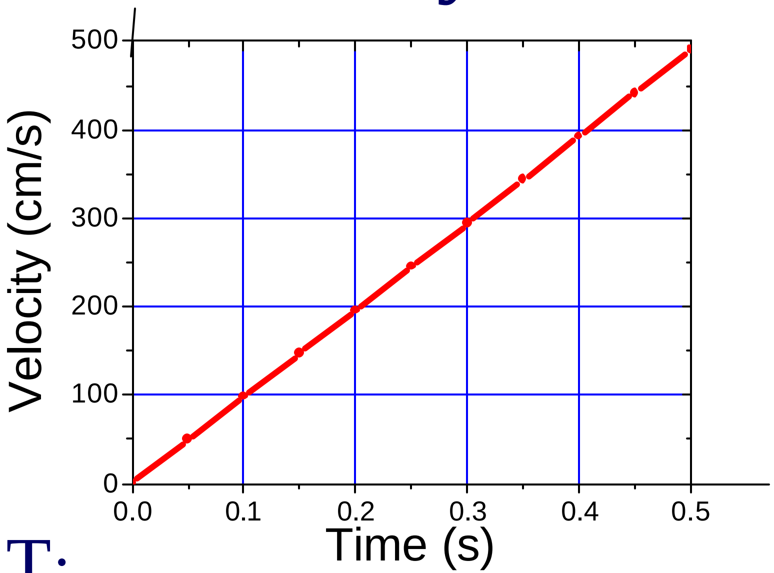
Example:

$$V = \frac{D_2 - D_1}{t} = \frac{19.7 - 11.0}{0.05} = 174 \text{ cm/s} \; (1.74 \text{ m/s})$$

RESULT:

Velocity does **INCREASES** with time to impact.

Plot of Velocity for Each Time Interval



Velocity plotted against time for the falling ball. The velocity values are those shown in previous table.

RESULT:

- Velocity **increases uniformly** with time indicating the acceleration due to gravity (g) is a **CONSTANT VALUE**.
- **Magnitude** of the **acceleration** is given by **slope** of the line.

$$a = \frac{\Delta V}{t} = 9.81 \text{ m/s}^2$$ (called "g")

NOTE: g = 9.81 m/s^2 is often approximated to 10 m/s^2 to help estimate answers.

What does this mean: g ~ 10m/s ?

The velocity of a "**free falling**" object will **increase uniformly** by approx 10 m/s for **every second** it falls.

EXAMPLE:

- If object falls for 1 sec its velocity = 10 m/s
- If object falls for 5 sec its velocity = 50 m/s

Mathematically: **v = g .t** (units: m/s)

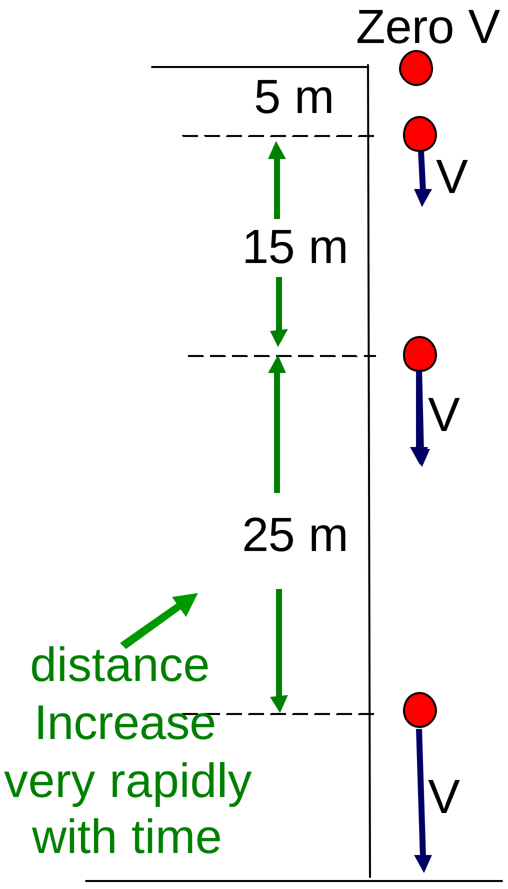
The value of g = 9.81 m/s applies to **all falling objects near the Earth's surface.**

- g **decreases** as we increase in **altitude**.
- g **increases** as we go **down mines** or to **bottom of ocean**.
- g also **varies** with the **shape** of the earth (not spherical).

QUESTION:

What value would "g" have at the center of the earth?

Lets consider effect of **g** on falling object:



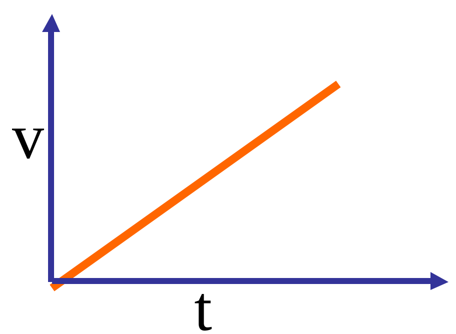
T	D	V	km/hr	MPH
1s	5 m	10 m/s	36	23
2s	20 m	20 m/s	72	45
3s	45 m	30 m/s	108	68

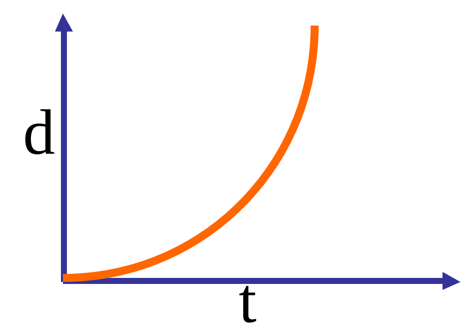
V increases **uniformly** with time

At any instant in time:

$$V = g \times t \qquad d = \frac{1}{2} g t^2$$

(for **zero** initial velocity)





EXAMPLE:

Throw a ball vertically downwards at a velocity of 20 m/s. What will its velocity be after 3 sec and how far will it fall in this time?

Vel: we have so far assumed initial velocity = 0 m/s. However, all we have to do is **ADD** in the initial velocity to our equation:

$$V = V_0 + gt$$

V0 = initial velocity (20 m/s)

V = 20 +10 x3 m/s

V = 50 m/s (or 180 km/hr, 112 MPH!)

(assuming no air resistance)

Distance: to determine distance we need to **ADD** in the effect of the initial velocity:

$$d = V_0 t + \frac{1}{2} g t^2$$

Total distance

Distance if moving at speed V^0 in time

Distance Moved due To gravity acceleration

d = 20 x3 +0.5 x10x3^2 = 105 m

Note: this is **much larger** than 45 m due to g alone!

Summary

1. Acceleration due to gravity "g" near the earth's surface is **CONSTANT** (i.e., **NOT** varying with **TIME**) and has a value of 9.8 m/s .

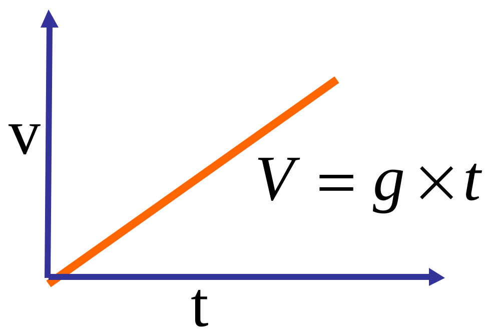
2. An object in free fall will **INCREASE** its **VELOCITY UNIFORMLY** with time. (v = g t)

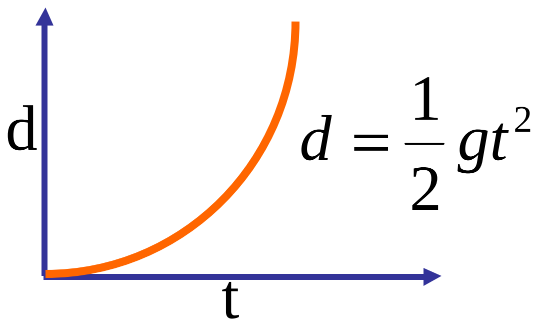
3. The distance fallen in a unit of time will **INCREASE RAPIDLY** with time as the object drops. (d =1/2gt)

4. The **ACCELERATION** due to gravity is **NOT** dependent on the **MASS** or **SIZE** of the object!

5. "g" is **NOT** a "fundamental" constant!

    - But it does **NOT** vary much near the Earth's surface.





Accn. "g" = constant!