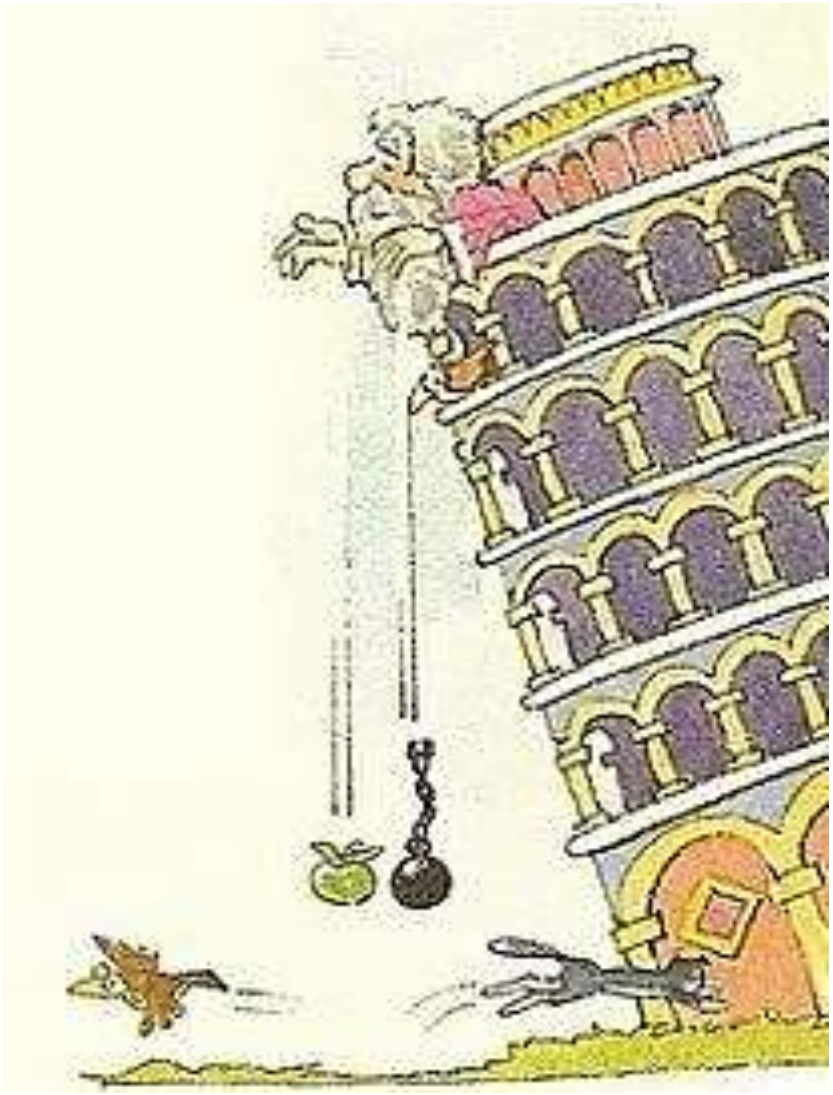
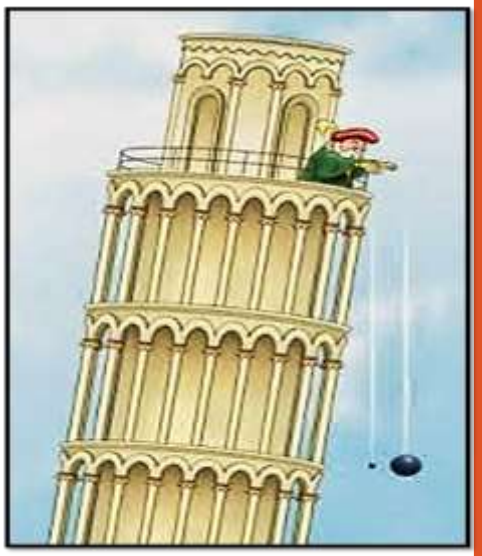
FREE FALL



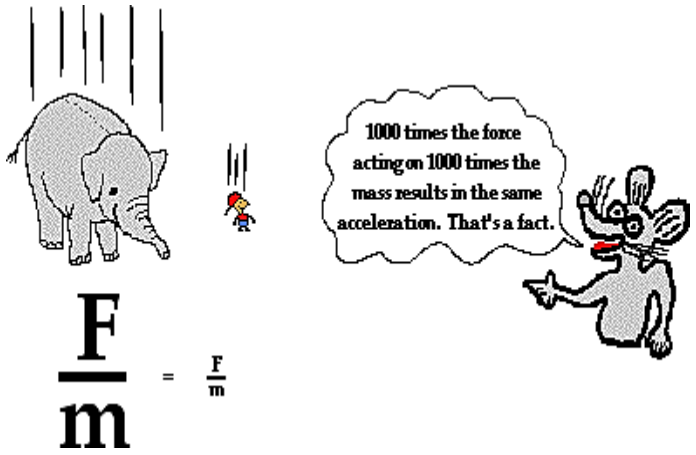
►ACCELERATION CAUSED BY GRAVITY◄

Galileo dropped two heavy metal balls together from the same height (leaning tower) at the same time and inititial velocity is zero (picture 1). Although one weighed much more than the other, they reached the ground almost at the same time. Experiment repeated many times. Galileo demonstated that g is the same for all objects, regardless of their mass! This was confirmed by the Apollo astronauts on the moon, where there is no air resistance.

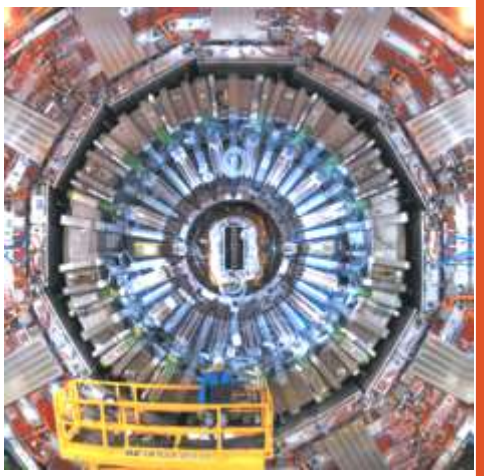
The acceleration caused by the pull of the Earth` s gravity is called **acceleration due to gravity or free fall acceleration**. This quantity is given with symbol **g** and its value is **10** $\frac{m}{s^2}$ close to the surface of the Earth. Acceleration due to gravity is directed downward .



Picture 1

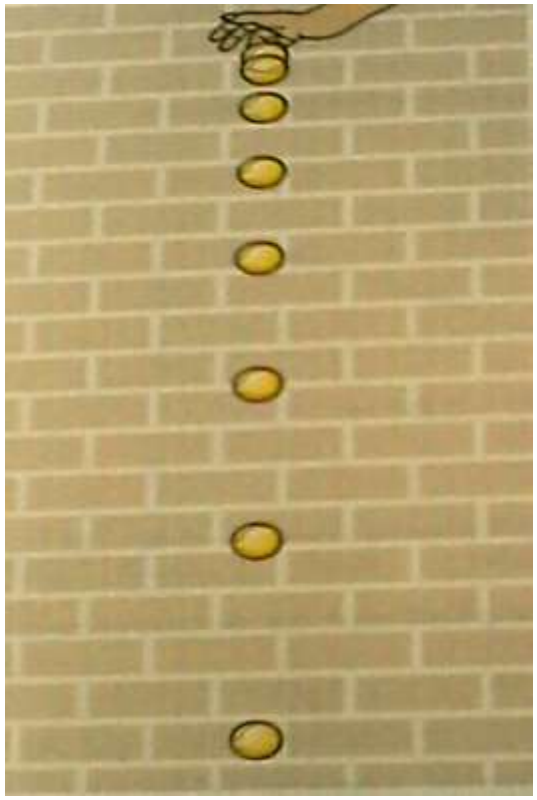


Two research laboratories.(picture 1) According to legend, Galileo investigated fallin bodies by dropping them from the Leaning Tower in Pisa, Italy (picture 2).The Large Hadron Collider (LHC) in Geneva, Switzerland, the world's largest particle accelerator, is used to explore the smallest and most fundamental constituents of matter.

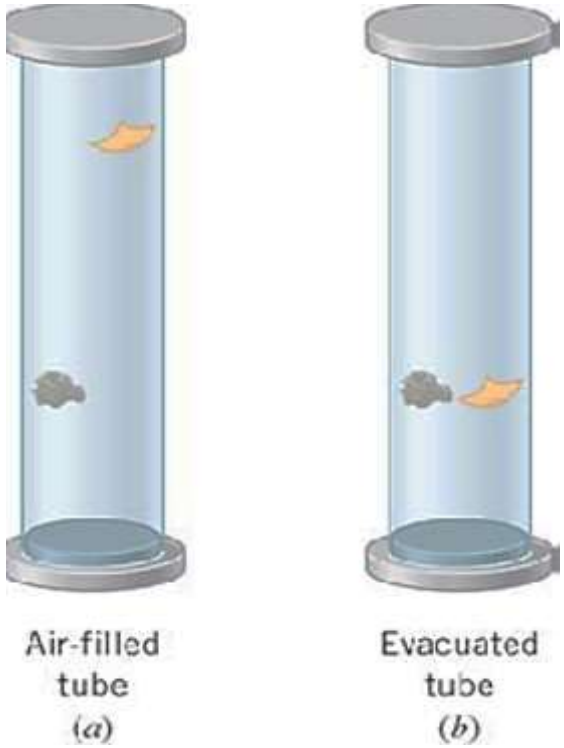


Picture 2

If we drop a ball or stone, it falls to ground. Picture 3 shows the ball at equal interval of time. We can see that the ball's velocity increase as it falls because the spaces between the images of the ball increase steadily. The ball is accelerating.



Picture 3: This picture of a falling ball, based on multiflash photo, clearly shows that the ball velocity increases as it falls.



Picture 4:
In air fiiled tube: stone falls faster then a feather, because the stone is heavier than a feather (picture a)
In evacuated tube (there is no air around them) a stone and feather will fall at the same time (picture b)

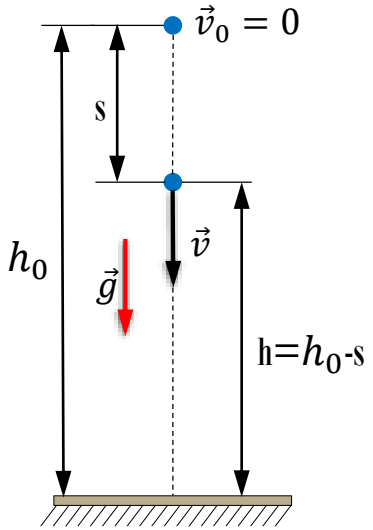
►VERTICAL SHOT◄

Vertical motion is a form of motion in which an object is thrown near the earth`s surface,and it moves along straight trajectory under the action of gravity only. The effect of air resistance is neglected. There are three cases of vertical shots: free fall, vertical shot upward, vertical shot downward.

►FREE FALL◄

Free fall is motion of an object dropped from a heigh h_0 without initial velocity (picture 5).
A dropped object have the acceleration g downward, and it started with zero velocity in the downward direction. It covers more and more distance each second. So we use equations for uniformly accelerated motion (without initial velocity) just substitute a=g.

Here is the the situation where the ball is dropped from a heigh h_0, velocity, distance and position can be predicted after time of t seconds.



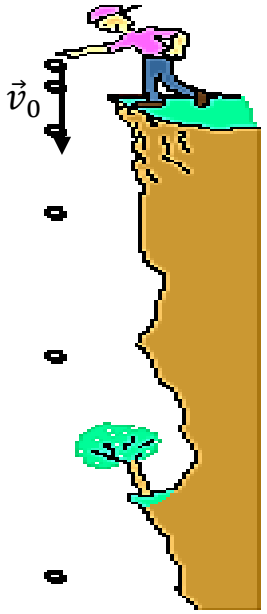
Picture 5:

Velocity of a falling object after a time of t seconds	• $v = g \cdot t$
Distance of a falling object after a time of t seconds	• $s = \frac{1}{2} g \cdot t^2$
Instantaneous height of the object	• h= $h_0 - \frac{g \cdot t^2}{2}$
Velocity of a falling object as a function of distance	• $v = \sqrt{2gs}$

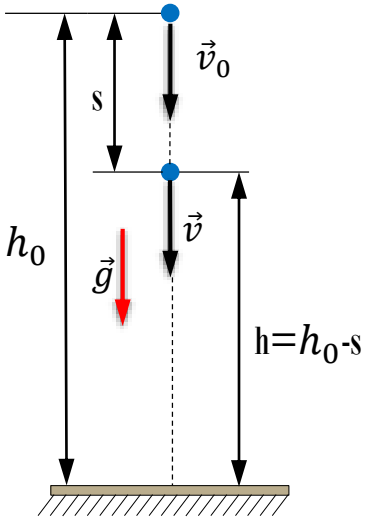
►VERTICAL SHOT DOWNWARD◄

Vertical motion downward is motion of an object thrown from a heigh h_0 with an initial velocity directed vertically downward (picture 6). A dropped object have the acceleration g downward, and it started with initial velocity. It covers more and more distance each second. Vertical motion downward is an example of uniformly accelerated motion (with initial velocity). So we use equations for uniformly accelerated motion (with initial velocity) just substitute a=g.

Here is the the situation (picture 7) where the ball is thrown from a heigh h_0, velocity, distance and position can be predicted after time of t seconds.



Picture 6

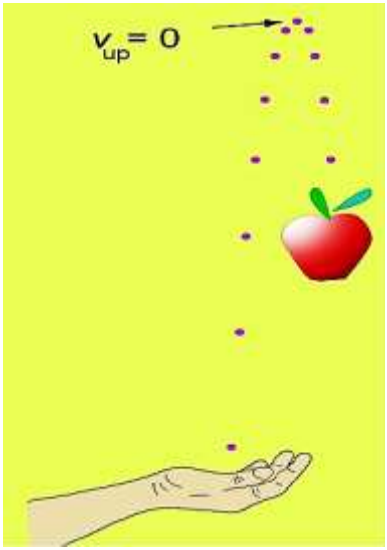


picture 7

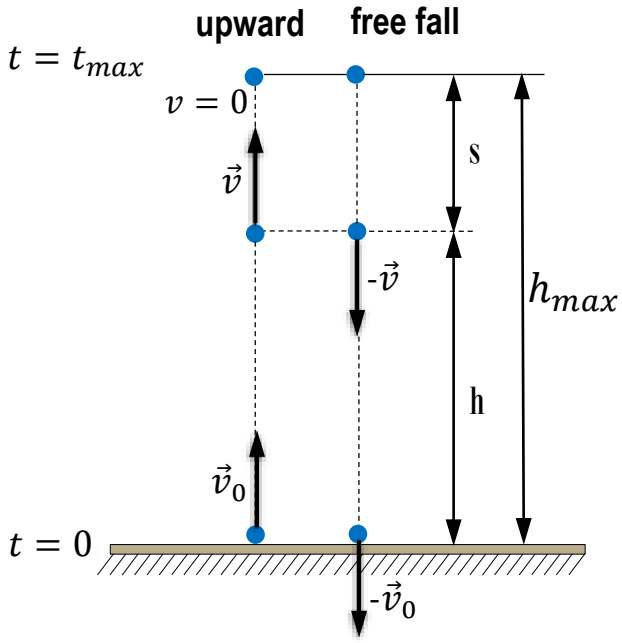
Velocity of a falling object after a time of t seconds	• $v = v_0 + g \cdot t$
Distance of a falling object after a time of t seconds	• $s = v_0 t + \frac{1}{2} g \cdot t^2$
Instantaneous height of the object	• h= $h_0 - v_o t - \frac{g \cdot t^2}{2}$
Velocity of a falling object as a function of distance	• $v = \sqrt{v_0^2 + 2gs}$

►VERTICAL SHOT UPWARD◄

Vertical shot upward is the motion of an object thrown with some initial velocity directed vertically upward from heigh h, or from Earth.
When we throw an object up in the air, it will continue to move upward for some time (it rises to a certain height), stop momentarily at the peak (picture 8), and then change direction and begin to fall. Actually objects thrown into the air have a downward acceleration. Objects moving upward slow down until their direction is reversed, and then they accelerate downward.. At the top of their path the upward speed is zero (only instantaneously). When going up, velocity is positive and acceleration is negative (-9.8 m/s2) - the object is slowing down. When falling down, velocity is negative and acceleration is negative (-9.8 m/s2) - the object is speeding up.



picture 8



picture 9

In the initial moment t= 0 an object is thrown vertically upwards from ground (picture 9) with velocity v_0 and object will slow down as it rises upward so that at a certain moment t_{max} when the object reaches its maximum height then the instantaneous velocity has the value 0 m/s. According to equation $v = v_0 - gt$ (with $v = 0$ and $t = t_{max}$) this occurs at time $t_{max} = \frac{v_0}{g}$

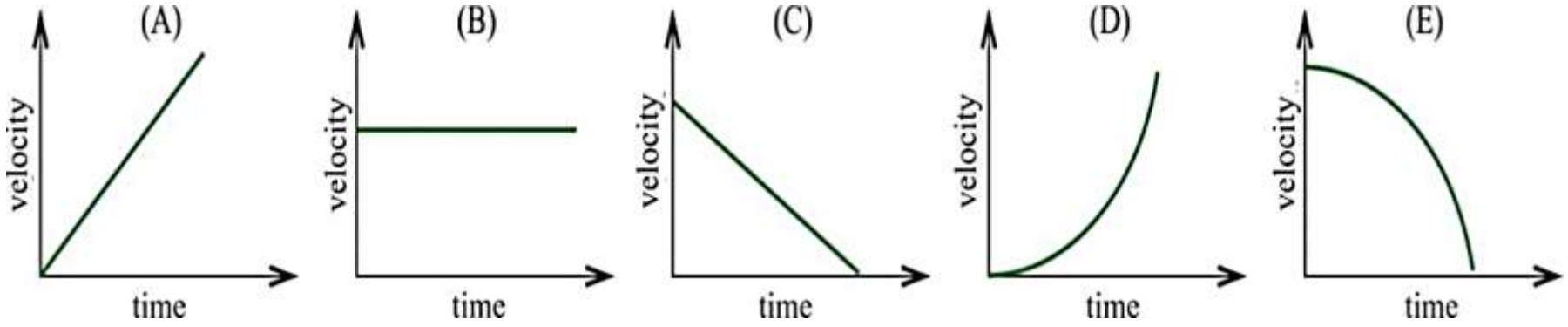
It follows from equation ($v = \sqrt{v_0^2 - 2gs}$) (with $v = 0$ and $s = h_{max}$)

that the maximum height of the ball is given by $h_{max} = \frac{v_0^2}{2g}$

Because we have the same acceleration to the object on the way up (slowing it down) as on the way down (speeding it up), the initial velocity of the object on the way up will equal the velocity of the object at the instant it reaches the point from which it was thrown on the way down. Put another way, the time to go up is equal to the time to go down, and the initial velocity up is equal to the final velocity down (assuming the object begins and ends at the same height above ground).

CAUTION A free-fall misconception It's a common misconception that at the highest point of free-fall motion, where the velocity is zero, the acceleration is also zero. If this were so, once the ball reached the highest point it would hang there suspended in midair! **Remember** that acceleration is the rate of change of velocity, and the ball's velocity is continuously changing. At every point, including the highest point, and at any velocity, including zero, the acceleration in free fall is always the same.

Example :Boris wrote a message on a tennis ball and tossed it up in a vertical direction. Sofia, who was standing on a balcony on the second floor, caught the ball. Which of the following graphs shows how the velocity of the ball was changing during its flight (picture 10)?



picture 10

PROBLEMS

1. A stone dropped from a bridge strikes the water in 5 seconds.

a) What is the velocity of the stone when it strikes the water?

b) What is the height of the bridge?

c)What is the distance travelled in the last second of motion?

2. A stone is thrown upward from the ground with initial velocity of $30\,\frac{m}{s}$.

a) How much time will it take to reach maximum height?

b) How much time will it take to reach ground?

c) With what velocity will it strike the ground?

3. A ball is thrown upward from the edge of a cliff 50m from the ground with initial velocity of $8\,\frac{m}{s}$.

a) What is maximum height ahived by ball?

b) When does the ball reach the ground?

c) With what velocity does the ball hit the ground?

4. One body falls freely from the edge of cliff 10 meters from the ground, while another body is thrown upward with initial velocity from the ground. What should be initial velocity v_0 of the second body, so that body meet at height 2,8m from the ground?

5. A body thrown vertically upwards passes twice by a point. A at a height of 10 m (from the ground) over a time interval of 4 s. Find the initial velocity of the body.