Mechanics

Ildikó László, PhD

Dept. Programming Languages and Compilers
Eötvös Loránd University, Budapest, Hungary

Our Place in the Universe

- - in our everyday life we are surrounded by different objects, like houses, mountaines and so on..
- - there are also much bigger objects around us, like the Moon the Sun or stars and galaxies, which form the macrocosmos;
- - but there are also atoms, electrons or bacteria which form the microcosmos;
- - there is a very big difference between the dimensions of these objects or systems;
- - in order to deal with them we are using units;

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Units, Standards and the SI System

- - it is important, to be aware of that, that the measurement of any quantity is made relative to a particular standard or unit, which has to be specified;
- - one cannot say, that the weight of a child is 57;
- - 57 kg., or 57 pounds? - has to be specified;
- - until about 200 years ago, the units of measurement were not standardized, and different nations used different units;
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- - it was said, that one of the reasons for the explosion of a spacecraft was caused by mixing up these two different units;
- - British units of length, *inch, foot, mile,* are defined in *SI* units, which comes from the French word Systeme International ;
- - **SI units**

quantity	**unit**	**abbrev.**
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Time	second	s
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Important metric (SI) prefixes and multipliers

- - **SI units**

Prefix	**Abbrev.**	**Value**
Tera	T	10^{12}
Giga	G	10^{9}
Mega	M	10^{6}
Kilo	k	10^{3}
Hecto	h	10^{2}
Deka	da	10^{1}
Deci	d	10^{-1}
Centi	c	10^{-2}
Mili	m	10^{-3}
Nano	n	10^{-9}
Pico	p	10^{-12}
Femto	f	10^{-15}

Displacement and Average Velocity

- - Kinematics is that part of mechanics, which gives the description of how objects move;
- - although motion has been studied from ancient ages the modern understanding of motion was established only in the sixteenth and seventeenth centuries;
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- - what each of them means?
- - **speed** is used to express the magnitude of how fast an object is moving;
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- - a person is walking through a path *s* in a forest from point *a*. to point *b*.;
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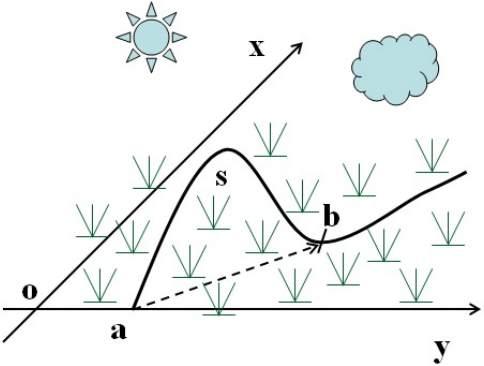

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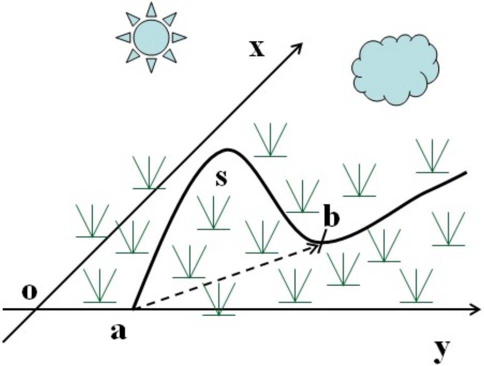

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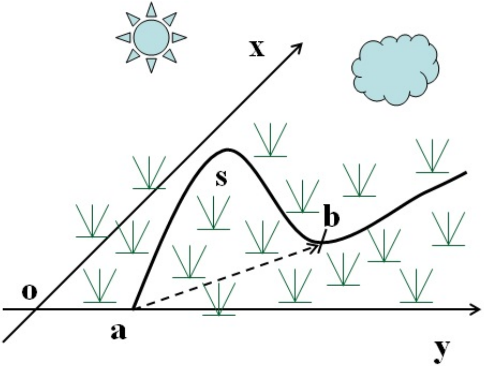

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- - for simplicity lets consider a rectilinear trajectory;

- - at an initial time t_1 an object starts from point x_1 and arrives at x_2 in moment t_2, then
- - the **average velocity** defined as the *the displacement divided by the elapsed time* is:

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- - when the magnitude of the acceleration is constant and the motion is rectilinear, the acceleration can be given by:

$$a = \frac{v_2 - v_1}{t_2 - t_1}; \quad (4)$$

- - let us consider the initial time $t_1 = 0, \; x_1 = x_0$ and denote t_2 by t and $x_2 = x$;
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- - we discussed *uniform* and *uniformly accelerated* motion without asking, what causes an object at rest, let's say, to start to move;
- - it is said, that Aristotle $(a.C.384 - a.C.322)$ believed that a force was required to keep an object moving along a horizontal plane;
- - after almost 2000 years later Galileo Galilei $(1564 - 1642)$ was able to imagine an idealized case, where there is no friction;
- - this let him to conclude, that it is just as natural for an object to be at rest as it is to be in a horizontal motion;

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- - Galileo finally came to the conclusion that an object will continue moving with constant velocity if no force acts on it;
- - based on this foundation, Isaac Newton (1643 – 1727) summarized his famous laws of motion in his great work: **Principia**;
- - **Newton's First Law states that:**
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- \- what happens, if a net force is acting on a body?
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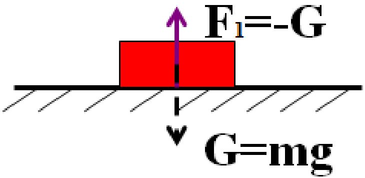
- - which can be expressed by a vector equation:

$$\vec{F} = m\vec{a}; \tag{10}$$

Newton's Third Law

- - a force applied to any object it is always applied by another object;
- - **Newton's Third Law states that:**
- - **- whenever an object exerts a force on another object, the second exerts an equal and opposite force on the first one; ;**
- - it is important to emphasize, that the **action-** and the **reaction** forces are acting on different objects;



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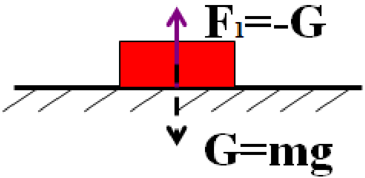

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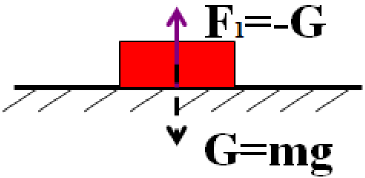

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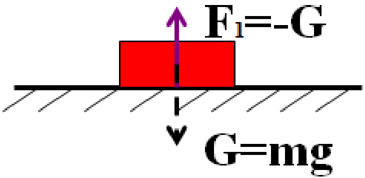

The Force of Gravity

- - as you could see at the discussion of Newton's third law at any object acts a force;
- - Galileo came up with the idea that objects drop near the surface of the earth because the earth exerts a force on them;
- - Galileo stated that their acceleration is the same g;
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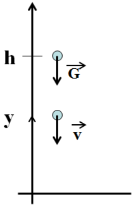
The Force of Gravity - Free fall

- - if an object, near to the surface of the earth it is allowed to fall vertically, due to the gravitational force, this will be a uniformly accelerated motion;
- - let us assume, that the object is falling from a hight h where its initial velocity is zero;
- - its acceleration due to gravity will be g and its position and velocity at a certain moment t will be given by:

$$y = h - \frac{1}{2}gt^2; \text{ and } v = gt; \quad (12)$$



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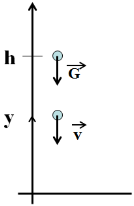

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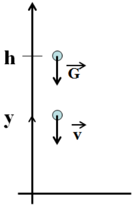
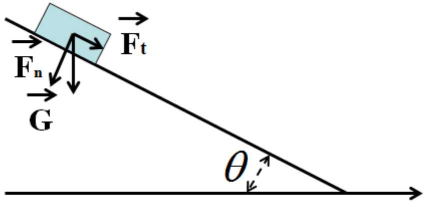


The Motion of an object on an Incline

- \- let's take an object of mass m on an incline, which makes an angle θ with the horizontal plane;
- \- the earth exerts a force $\vec{G}$ on it;
- \- the normal component of this force $\vec{F_n}$ is acting on the incline; (- which exerts an equal and opposite force on the object of mass m not on the figure;)



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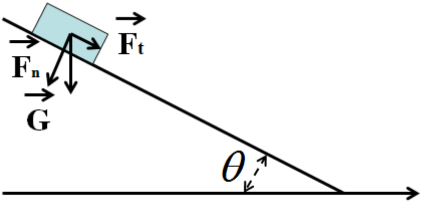

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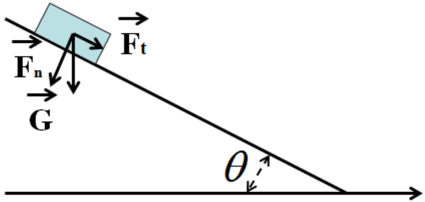

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- - the magnitude of the normal component acting on the incline is $F_n = mgcos\theta$ and the component paralell with the plane of the incline is $F_t = mgsin\theta$;
- - conform Newton's second law, the object, if no other force acts on it, will have a uniformly accelerated motion, with an acceleration given by

$$ma_t = mgsin\theta; \; that\ is : a_t = gsin\theta; \qquad (13)$$

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- - whenever an object is placed on another object, or is moving on it, between them appears a **friction**;
- - theis is caused by the roughness of the two surfaces;
- - the friction which acts on an object sliding on another one, is called *kinetic friction*;
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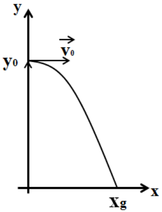
Horizontal Projection

- - if an object is thrown horizontally with an initial velocity v_0, from a height y_0 then
- - the horizontal motion is a uniform motion;
- - and the vertical motion is a uniformly accelerated motion, with an acceleration $-g$;



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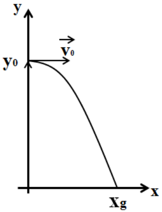

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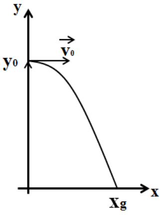

Horizontal Projection

- - the equations of the horizontal motion are:

$$v_y = gt; \tag{15}$$

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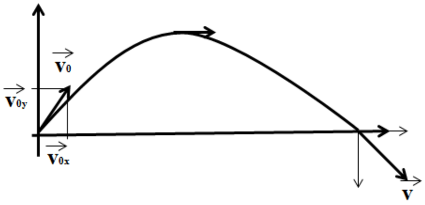
Projectile Motion

- - it is called projectile motion that motion of an object, which is projected into the air with an initial velocity v_0 under an angle α with the horizontal plane;



Projectile Motion

- - let the motion be in the *xy* plane as in the figure;
- - then, the components of the acceleration are:

$$a_x = 0 \; and \; a_y = -g; \tag{18}$$

- - the components of the initial velocity v_0 will be:

$$v_{x0} = v_0 cos\alpha \; and \; v_{y0} = v_0 sin\alpha; \tag{19}$$

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Projectile Motion

- - since $a_x = 0$, the horizontal motion is a uniform motion with a constant speed v_{x0}, that is:

$$x = v_{x0}t = v_0 t sin\alpha; \tag{20}$$

- - in the vertical plane the object has an acceleration $a_y = -g$ that is, the motion is a uniformly accelerated motion:

$$y = v_{y0}t - \frac{1}{2}gt^2 = v_0 t sin\alpha - \frac{1}{2}gt^2; \tag{21}$$

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The de Broglie Hypothesis

- - de Broglie suggested that
  - the electron wave must be a circular standing wave that closes in itself;
- - that is:
  $2\pi r_n = n\lambda$;
- - then, for an electron orbiting on a circle
  - of radius r_n this follows:
  $mvr_n = \frac{nh}{2\pi}$;

$$\frac{e}{m} = \frac{E}{rB^2}; \quad (23)$$

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