Physics 121.
Tuesday, February 12, 2008.

Frank L. H. Wolfs
Department of Physics and Astronomy, University of Rochester

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- Topics:
  - A quick lesson on statistics.
  - Course announcements.
  - Friction:
    - A quick review
    - Drag forces
  - Gravitation:
    - The force of gravity
    - Motion of satellites

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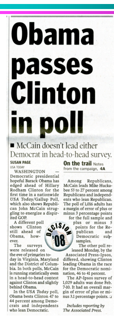
Use and abuse of statistics.

- On 1/17 we discussed the 1998 presidential election as an example of the significance of sampling errors.
- Today's news paper headline is clearly inconsistent with a proper treatment of the data:
  - Obama: 47%
  - Clinton: 44%
  - Sampling error: 5%
- If the quoted error correspond to 1 σ, then a difference of more than 1 σ between the two candidates has a 32% probability of being due to counting statistics.
- Do you agree with the headline?



Obama passes Clinton in poll

■ McCain doesn't lead either Democrat in head-to-head survey.

SUSAN PAGE
USA TODAY

On the trail Notes from the campaign, **4A**

WASHINGTON — Democratic presidential hopeful Barack Obama has edged ahead of Hillary Rodham Clinton for the first time in a nationwide *USA Today*/Gallup Poll, which also shows Republican John McCain struggling to energize a dispirited GOP.

A different poll shows Clinton still ahead of Obama, however.

The surveys were released on the eve of primaries today in Virginia, Maryland and the District of Columbia. In both polls, McCain is running statistically even in a head-to-head contest against Clinton and slightly behind Obama.

In the *USA Today* poll, Obama bests Clinton 47 to 44 percent among Democrats and independents who lean Democratic.

Among Republicans, McCain leads Mike Huckabee 53 to 27 percent among Republicans and independents who lean Republican. The poll of 1,016 adults has a margin of error of plus or minus 3 percentage points for the full sample and plus or minus 5 points for the Republican and Democratic subsamples.

The other poll released Monday, by the Associated Press-Ipsos, differed, showing Clinton leading Obama in the race for the Democratic nomination, 46 to 41 percent.

The AP-Ipsos survey of 1,029 adults was done Feb. 7-10. It had an overall margin of error of plus or minus 3.1 percentage points.

Includes reporting by The Associated Press.

D&C
2/12/08

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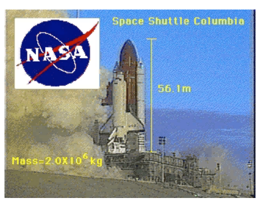
Physics 121.
Course announcements.

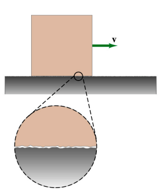
- The solutions of homework set # 2 are now available on the web.
- Homework set # 3 is now available on the web and is due on Saturday morning, February 16, at 8.30 am.
- The most effective way to work on the assignment is to tackle 1 or 2 problems a day.
- If you run into problems, please attend our office hours and/or ask questions during workshop. Do not wait until the last moment to try to resolve homework related issues.

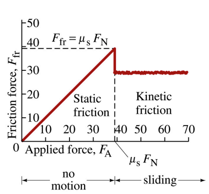
Preview of homework set # 4.

- On set # 4 you will be asked to carry out our first video analysis.
- You will study the launch of the space shuttle. The main question are:
  - what is the acceleration of the space shuttle?
  - what is the force generated by the engines?
- You will need to use loggerPro for this analysis. You can download the software from the Physics 121 website.



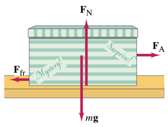
Friction.
Slowing us down!

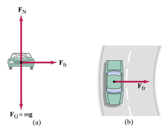


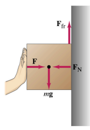


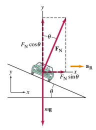
Key problem: evaluating the normal force.

Friction.
Slowing us down!









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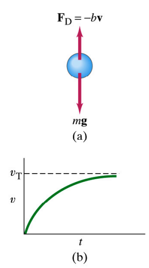
Air "friction" or drag.

- Objects that move through the air also experience a "friction" type force.
- The drag force has the following properties:
  - It is proportional to the cross sectional area of the object.
  - It is proportional to the velocity of the object.
  - It is directed in a direction opposite to the direction of motion.
- The drag force is responsible for the object reaching a terminal velocity (when the drag force balances the gravitational force).



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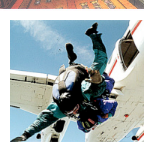
Air "friction" or drag.

- The science of falling cats is called feline pesematology.
- This area of science uses the data from falling cats in Manhattan to study the correlation between injuries and height.
- The data show that the survival rate is doubling as the height increases (effects of terminal velocity). E.g. only 5% of the cats who fell seven to thirty-two stories died, while 10% of the cats died who fell from two to six stories.



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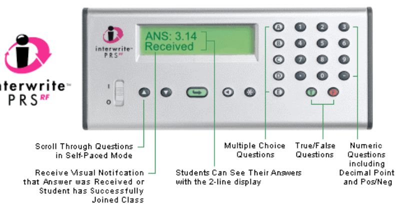
Friction.

- Let’s test our understanding of the friction force by looking at the following concept questions:
  - Q7.1
  - Q7.2

interwrite PRS



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The gravitational force. It keeps us together.

- The motion of the planets of our solar system is completely governed by the gravitational force between the components of the solar system.
- The law of universal gravitation was developed by Newton based on simple observations of the motion of the moon around the earth.

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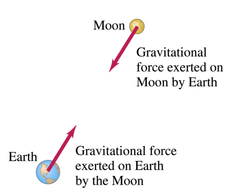
The gravitational force.

- The force of gravity is the weakest force we know …… but it is the main force responsible for the motion of the components of our solar system and beyond.
- This is a consequence of the fact that the gravitational force is always attractive. The other forces can be attractive, repulsive, or zero.



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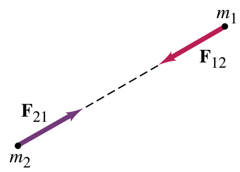
The gravitational force.

- The gravitational force has the following properties:
  - It is always attractive.
  - It is proportional to the product of the masses between which it acts (proportional to $m_1 m_2$).
  - It is inversely proportional to the square of the distance between the masses (proportional to $1/r_{12}^2$).
  - It is directed along the line connecting the two masses.

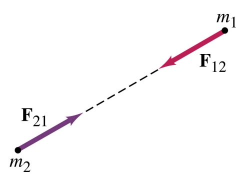


The gravitational force.

- The magnitude of the gravitational force is given by the following relation:

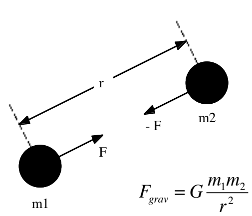
$$F_{grav} = G\frac{m_1 m_2}{r^2}$$

- The constant G is the gravitational constant which is equal to 6.67 x 10^{-11} N m^2/kg^2.



The gravitational force. The shell theorem (Appendix D).

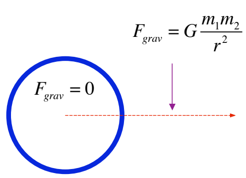
- The gravitational force law is only valid if the masses involved are point masses (mass located at a single point).
- In reality we always are dealing with objects that are not point-like object, but have their mass distributed over a non-zero volume.
- Using the principle of superposition you can show that the gravitational force exerted by or on a uniform sphere acts as if all the mass of the sphere is concentrated at its center.



$$F_{grav} = G\frac{m_1 m_2}{r^2}$$

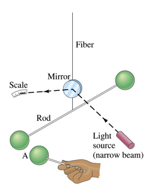
The gravitational force.
The shell theorem (Appendix D).

- Consider a shell of material of mass m_1 and radius R.
- In the region outside the shell, the gravitational force will be identical to what it would have been if all the mass of the shell was located at its center.
- In the region inside the shell, the gravitational force on a point mass m_2 is equal to 0 N.



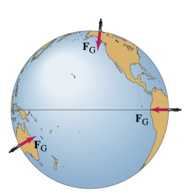
The gravitational force.
Measuring G.

- The gravitational constant G can be measured using the Cavendish apparatus.
- The Cavendish apparatus relies on the attraction between small mass mounted on a rod and larger masses located nearby.
- Let's have a look at this experiment ……..



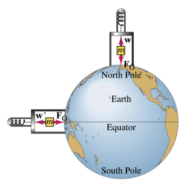
The gravitational force.
The mass of the Earth.

- Using Newton's gravitational law and the measured gravitational acceleration on the surface of the earth, we can determine the mass of the earth:
  - $F_{grav} = GmM_{earth}/R_{earth}^2$
  - $F_{grav} = mg$
  - By combining these two expressions for the gravitational force we find that
    $M_{earth} = gR_{earth}^2/G$
    or
    $M_{earth} = 5.98 \times 10^{24}$ kg



The gravitational force. Variations in the gravitational force.

- The gravitational force on the surface of the earth is not uniform for a number of different reasons:
  - The effect of the rotation of the earth.
  - The earth is not a perfect sphere.
  - The mass is not distributed uniformly, and significant variations in density can be found (in fact using variations in the gravitational force is one way to discover oil fields).



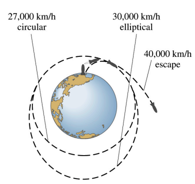
Orbital motion.

- Consider an object of mass m moving in a circular orbit of radius r around the earth.
- In order for this motion to be possible, a net force must be acting on this object with a magnitude of mv^2/r, directed towards the center of the earth.
- The only force that acts in this direction is the gravitational force and we must thus require that

$$GmM_{earth}/r^2 = mv^2/r$$

or

$$v^2 = GM_{earth}/r$$



Orbital motion.

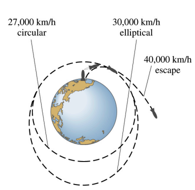
- The orbital velocity is related to the period of motion:

$$v = 2\pi r/T$$

and the relation between v and r can be rewritten as a relation between T and r:

$$r^3 = GM_{earth}T^2/4\pi^2$$

- This relation shows that based on the orbital properties of the moon we can determine the mass of the earth.



Orbital motion.

- The relation between orbit size and period can also be applied to our solar system and be used to determine the mass of the sun:

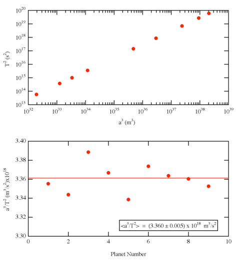
$$r^3 = GM_{sun}T^2/4\pi^2$$

- Using the orbital information of the planets in our solar system we find that

$$GM_{sun}/4\pi^2 = (3.360 \pm 0.005)\text{x}10^{18}\text{m}^3/\text{s}^2$$

or

$$M_{sun} = (1.989 \pm 0.003)\text{x}10^{30}\text{ kg}$$

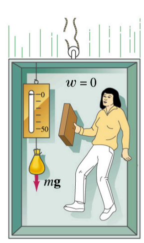


Orbital motion and weightlessness.

- One of the most confusing aspects of orbital motion is the concept of weightlessness.
- Frequently people interpret this as implying the absence of the gravitational force.
- Certainly this can not be the case since the gravitational force scales as $1/r^2$ and is thus not that different from the force we feel on the surface on the earth.

Orbital motion and weightlessness.

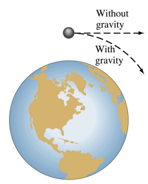
- We experience apparent weightlessness anytime we fall with the same acceleration as our surroundings.
- Consider a falling elevator. Every object in the elevator will fall with the same acceleration, and the elevator will not need to exert any additional forces, such as the normal force, on those inside it.
- It appears as if the objects in the elevator are weightless (in reality they of course are not).



a = g(down)

Orbital motion and weightlessness.

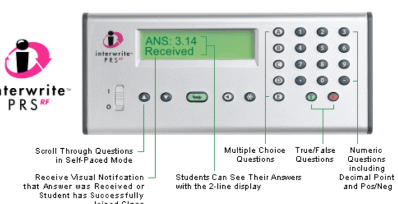
- Weightlessness in space is based on the same principle:
  - Both astronaut and spaceship "fall" with the same acceleration towards the earth.
  - Since both of them fall in the same way (gravitational acceleration only depends on the mass of the earth, not on the mass of the spaceship or the astronaut) the astronaut appears to be weightless.



Orbital motion.

- Let's test our understanding of orbital motion by looking at the following concept questions:
  - Q7.3
  - Q7.4

interwrite PRS



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That's all!
More gravity on Thursday!

Opportunity's Horizon Credit: Mars Exploration Rover Mission, JPL, **NASA**

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