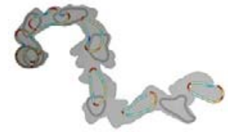
Physics 131- Fundamentals of Physics for Biologists I



Professor: Wolfgang Losert wlosert@umd.edu

11/09/2012

- Review Materials for Midterm 2

Foothold ideas: Viscosity

- Viscosity is a resistive force that an object feels when it moves through a fluid as a result of the fluid sticking to the object's surface. This layer of fluid tries to slide over the next layer of fluid and the friction between the speeds that layer up and so on.
- The result is a force proportional to the velocity of the object.

$$\vec{F}^{viscous}_{fluid\to object} = -6\pi\mu R_{object}\vec{v}$$

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Foothold ideas: inertial Drag force

- The drag (inertial force) is a resistive force felt by an object moving through a fluid. It arises because the object is pushing fluid with it, bringing it up to the same speed it's going.
- The result is a force proportional to the density of the fluid, the area of the object, and the square of the object's velocity.

$$F^{drag}_{fluid \to object} = Cd_{fluid} A_{object} v^2$$

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Reynolds' Number

- Generally, for an object moving in a fluid both drag and viscosity are present. However, often, one is much more important.
- The ratio of the two forces (inertial force / viscosity) is called the Reynolds' Number (leaving out a few dimensionless constants)

$$\mathrm{Re} = \frac{dvR}{\mu}$$

  - For small objects (v, R small) the resistive forces are generally dominated by viscosity;
  - For larger objects (v, R large) tend to be dominated by inertial forces (drag).

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Foothold Ideas: Gravity

- Every object (near the surface of the earth) feels a downward pull proportional to its mass:

$$\vec{W}_{E \to m} = m\vec{g}$$

where $\vec{g}$ is referred to as *the gravitational field.*

- This is a pForce even though nothing touching the object is responsible for it.
- The gravitational field has the same magnitude for all objects irrespective of their motion and at all points.
- The gravitational field always points down.
- It is measured to be $g \approx 9.8$ N/kg

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Model: Charge
A hidden property of matter

- Matter is made up of two kinds of electrical matter (positive and negative) that have equal magnitude and that cancel when they are together and hide matter's electrical nature.
- Matter with an equal balance is called neutral.
- Like charges repel, unlike charges attract.
- The algebraic sum of postive and negative charges is a constant (i.e, $N_+ - N_-$ = const.)

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Conductors and Insulators

- Insulators
  - In some matter, the charges they contain are bound and cannot move around freely.
  - Excess charge put onto this kind of matter tends to just sit there.
- Conductors
  - In some matter, charges in it can move around throughout the object.
  - Excess charge put onto this kind of matter redistributes itself or flows off (if there is a conducting path to ground).
- Unbalanced charges attract neutral matter (polarization)

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Making Sense of Coulomb's Law

- Changing the test charge
- **Changing the source charge**
- **Changing the distance**
- **Specifying the direction**
- **Use Subscripts!**

$$\vec{F}_{Q\to q} = \frac{k_C qQ}{R^2}\hat{r}_{Q\to q}$$

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Foothold idea: Electric Forces and Fields

When we focus our attention on the electric force on a particular object with charge q_0 (a "test charge") we see the force it feels depends on q_0.

Define quantity that does not depend on charge of test object "test" charge -> **Electric Field E**

$$\vec{F}_{q_0}^{E\,net} = \frac{k_C q_0 q_1}{r_{01}^2}\hat{r}_{1\to 0} + \frac{k_C q_0 q_2}{r_{02}^2}\hat{r}_{2\to 0} + \frac{k_C q_0 q_3}{r_{03}^2}\hat{r}_{3\to 0} + \ldots \frac{k_C q_0 q_N}{r_{0N}^2}\hat{r}_{N\to 0}$$

$$\vec{F}_{q_0}^{E\,net} = q_0 \vec{E}(\vec{r}_0)$$

$$\vec{E}(\vec{r}_0) = \frac{k_C q_1}{r_{01}^2}\hat{r}_{1\to 0} + \frac{k_C q_2}{r_{02}^2}\hat{r}_{2\to 0} + \frac{k_C q_3}{r_{03}^2}\hat{r}_{3\to 0} + \ldots \frac{k_C q_N}{r_{0N}^2}\hat{r}_{N\to 0}$$

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Foothold ideas: Fields

- A *field* is a concept we use to describe anything that exists at all points in space, even if no object is present.
- A *field* can have a different in magnitude at different points in space. (and if it's a vector field, direction). Examples: temperature, wind speed, wind direction
- A *gravitational*, *electric, or magnetic field* is a force field. Fields allow us to predicts the force that a test object would experience. The field does not depend on what test object is used.

$$\vec{g}(\vec{r}) = \frac{\vec{F}_{\text{acting on } m}(\vec{r})}{m} \qquad \vec{E}(\vec{r}) = \frac{\vec{F}_{\text{acting on } q}(\vec{r})}{q}$$

Field is the value at a position in space " r " assuming that the force is measured by placing the object at r .

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Momentum: Definition

- We define <u>momentum</u>:

$$\vec{p} = m\vec{v}$$

- This is a way of defining "the amount of motion" an object has.
- Our "delta" form of N2 becomes

which we can rewrite as
$$\vec{F}^{net} = m\frac{\Delta\vec{v}}{\Delta t} = m\vec{a}$$
$$\vec{F}^{net} = \frac{\Delta(m\vec{v})}{\Delta t} = \frac{\Delta\vec{p}}{\Delta t}$$

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The Impulse-Momentum Theorem

- Newton 2 $\vec{a} = \vec{F}^{net}/m$
- Put in definition of *a* $\frac{d\vec{v}}{dt} = \frac{\vec{F}^{net}}{m}$
- Multiply up by Δt $m\Delta\vec{v} = \vec{F}^{net}\Delta t$
- Define Impulse $\vec{\mathscr{I}}^{\,net} = \vec{F}^{net}\Delta t$
- Combine to get Impulse-Momentum Theorem $\Delta\vec{p} = \vec{\mathscr{I}}^{\,net}$

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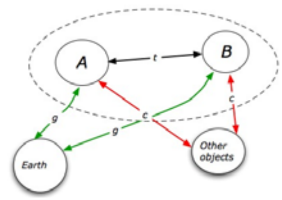
Momentum Conservation: 1

- If two objects, A and B, interact with each other and with other ("external") objects,

$$m_A \,\Delta\vec{v}_A = (\vec{F}_A^{ext} + \vec{F}_{B\to A})\Delta t$$
$$m_B \,\Delta\vec{v}_B = (\vec{F}_B^{ext} + \vec{F}_{A\to B})\Delta t$$

- Adding:

$$m_A \,\Delta\vec{v}_A + m_B \,\Delta\vec{v}_B = \left[\vec{F}_A^{ext} + \vec{F}_B^{ext} + \left(\vec{F}_{A\to B} + \vec{F}_{B\to A}\right)\right]\Delta t$$
$$\Delta\left(m_A\vec{v}_A + m_B\vec{v}_B\right) = \vec{F}_{AB}^{ext}\Delta t$$



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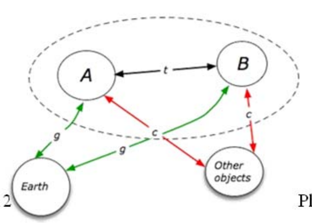
Momentum Conservation: 2

- If the <u>external</u> forces on the "system of interest" cancel, then momentum is conserved.

$$\Delta\left(m_A\vec{v}_A + m_B\vec{v}_B\right) = 0$$
$$m_A\vec{v}_A^{\,i} + m_B\vec{v}_B^{\,i} = m_A\vec{v}_A^{\,f} + m_B\vec{v}_B^{\,f}$$



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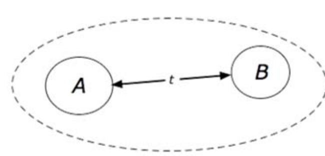

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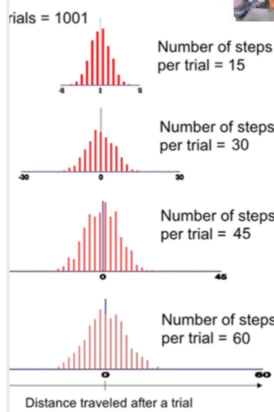
Foothold ideas: Random walk in 1D

- As a result of random motion, an initially localized distribution will spread out, getting wider and wider. This phenomenon is called *diffusion*
- The square of the average distance traveled during random motion will grow with time:
- $$\left\langle \left(\Delta x\right)^2 \right\rangle = 2D\Delta t$$
- *D* is called *the diffusion constant* and has dimensionality [*D*] = L^2/T



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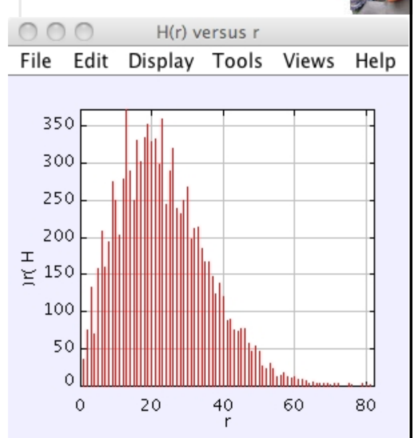
Foothold ideas: Random walk in 2D

- The density of walkers decreases uniformly as you get farther from the source.
- The total number within a given radius peaks – since the area within a radius r decreases to 0 as r gets small.
- The average squared displacement grows with time :

$$\left\langle \left(\Delta r\right)^2 \right\rangle = 4D\Delta t$$



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Foothold ideas: Kinetic Theory of a Gas

- We model the gas as lots of tiny little hard spheres far apart (compared to their size) and moving very fast.
- The motions are in all directions and change directions very rapidly. A model saying that on the average the total momentum is 0 (and stays 0 by momentum conservation) is a good one.
- Because there are some many particles and the collisions so sensitive to initial conditions, we can't predict the motion of individual particles for long.

Fick's law

- 1D result

$$J = -D\frac{dn}{dx} \quad D = \tfrac{1}{2}\lambda v_0$$

Does not yield the trajectory of molecules, but tells us, how a collection of molecules is distributed

The Ideal Gas Law

Chemist's form

$$pV = n_{moles}RT$$

$n_{moles} = \frac{N}{N_A}$

$R = k_B N_A$

Physicist's form

$$pV = Nk_BT$$

$p = nmv_x^2$

$\frac{3}{2}k_BT = \frac{1}{2}mv^2$

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Foothold ideas: Pressure

- A constrained fluid has an internal pressure –like an internal force at every point in all directions. (Pressure has no direction.)
- At a boundary or wall, the pressure creates a force perpendicular to the wall. $\vec{F} = p\vec{A}$
- The pressure in a fluid increases with depth. (Why?)

$$p = p_0 + \rho gd$$

- When immersed in a fluid, an object feels an (upward) BF equal to the weight of the displaced fluid. (Archimedes' Principle)

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