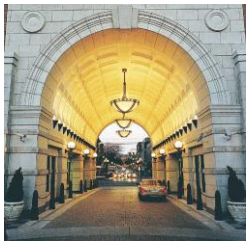
Note on Posted Slides

- These are the slides that I intended to show in class on Mon. Feb. 4, 2013.
- They contain important ideas and questions from your reading.
- Due to time constraints, I was probably not able to show all the slides during class.
- They are all posted here for completeness.

Image from http://www.toronto.ca/audia/elements_hon_man_arch_2001.htm

PHY205H1S
Physics of Everyday Life
Class 8: **Solids**



- Atoms, Elements
- Molecules, Compounds
- Crystal Structure
- Density
- Elasticity
- Tension and Compression
- Arches
- Scaling

Image from http://torontopubliclibrary.typepad.com/hrl/2012/11/research-guide-to-the-humber-river-ontario.html

Chapter 12. Pre-Class Reading Question

- According to Hooke's law, if you double the force when stretching a spring, the elongation of the spring is normally

A. no different, the same
B. twice as much
C. half as much
D. four times as much

Chapter 12. Pre-Class Reading Question

- Which has the greater outer surface area?

A. An elephant
B. An ant
C. neither

Chapter 12. Pre-Class Reading Question

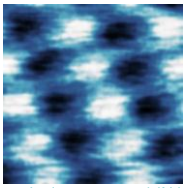
- Which has the greater outer surface area per volume?

A. An elephant
B. An ant
C. neither

Atoms

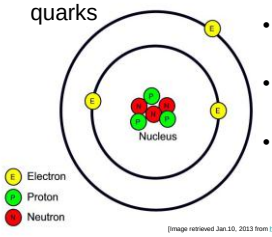
- Atoms are the building blocks of all matter
- They are too small to be seen with visible light
- One gram of water has a volume of 1 cm^3 and contains more than 10^{23} atoms!
- 10^{23} = 100,000,000,000,000,000,000,000

- This is a scanning tunneling microscope image of graphite taken by Igor Fridman, a graduate student in U of T Physics
- The dots are individual carbon atoms



[image from http://www.physics.utoronto.ca/~ifridman/]

- **Atomic structure** is composed of:
  - An atomic **nucleus**, which contains nearly all the mass
  - Orbiting **electrons**
- The nucleus is composed of **protons** and **neutrons**, which are in turn made of smaller quarks



- Protons have electric charge +1
- Electrons have electric charge -1
- All neutral atoms have the same number of protons as electrons

[Image retrieved Jan.10, 2013 from http://www.safetyoffice.uwaterloo.ca/hse/radiation/rad_sealed/matter/atom_structure.htm]

Atoms
Check your neighbour

The nucleus of an electrically neutral iron atom contains 26 protons. How many electrons are in this iron atom?

A. 52
B. 26
C. 24
D. 28
E. zero

The Elements

Atoms
- Refer to particles that make up a substance

Elemental substance
- Composed of only one kind of atom
  – Lightest and most abundant is hydrogen.
- To date, about 115 are known.
  – 90 occur in nature.
  – Others produced in laboratory are unstable.

Words *atom* and *element* can be used interchangeably.

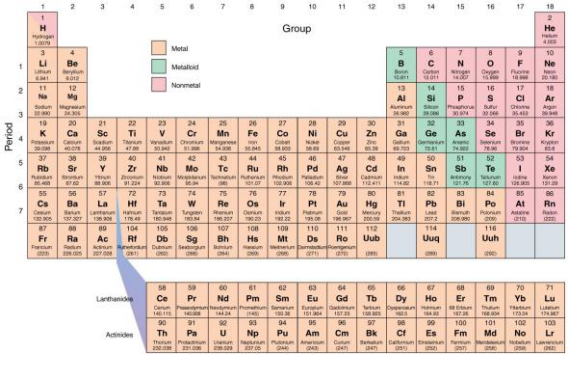
[Image retrieved Feb.4 2013 from http://parisbreakfasts.blogspot.ca/2011/09/financiers.html]

Atoms
Challenge Question: *Do you know it?*

The **atomic number** of an element matches the number of

A. protons in the nucleus of an atom.
B. electrons in a neutral atom.
C. Both of the above.
D. None of the above.

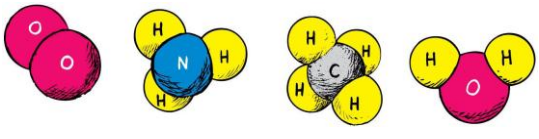
Periodic Table of the Elements



Compounds are made of Molecules

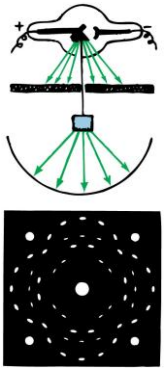
- **Molecules** are two or more atoms bonded together

Example:
- NH_3 (ammonia)
- 3 atoms of hydrogen and 1 atom of nitrogen



Crystal Structure

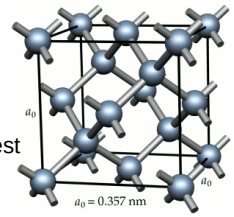
- Atoms in a solid are arranged in a regular array called a crystal.
- If you shine an X-ray beam on a solid and it produces an X-ray diffraction pattern, this is evidence of the crystalline nature of the solid.
- Solids that do not have atoms arranged in a regular array are called amorphous solids.



Crystal Structure

The following kinds of bonds can exist between atoms in a solid:

- Ionic
- Covalent
- Metallic
- Van der Waals—the weakest



The properties of a solid are dependent upon the kind of bonds that exists between the atoms.

[Image retrieved Jan.11 2013 from http://www.e6cvd.com/cvd/page.jsp?pageid=361]

Density

- Amount of mass per unit volume of a material.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

- Unit of density is kg/m^3 or g/cm^3.
- Example:
  Density of water is 1000 kg/m^3, or 1 g/cm^3.

[Image retrieved Jan. 11, 2013 from http://www.amazon.com/Evian-Water-Liter-Pack/dp/B0041HVMU0]

Atoms
Check your neighbour

If the volume of an object were to double, with no change in mass, what would happen to its density?

A. It would remain unchanged.
B. It would double.
C. It would decrease by a factor of two.
D. None of these.

Elasticity

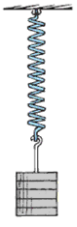
- A solid object subjected to external forces may undergo changes in shape and/or size.
- A body's *elasticity* is a measure of how much it changes when a deforming force is exerted on it and how well it returns to its original shape.
  – Materials that do not return to their original shape are *inelastic.*

[Image retrieved Jan. 11 2013 from http://en.wikipedia.org/wiki/File:Office-pink-erasers.jpg]

Elasticity

Hooke's law: The extension of a spring is directly proportional to the force applied to it.

Force ~ extension or $F \sim \Delta x$



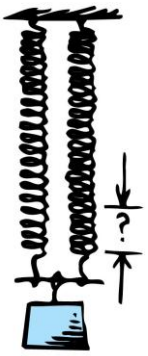
Elasticity
CHECK YOUR NEIGHBOR

A 10-cm-long spring extends to 12 cm when a 1-kg load is suspended from it. What would be its length if a 3-kg load were suspended from it?

A. 14 cm
B. 16 cm
C. 20 cm
D. 24 cm

Hooke's Law: Example 1

- Consider a spring that stretches an amount *d* when a load of mass *m* is suspended from it.
- How much will the spring stretch if two identical springs support the same single mass as shown?



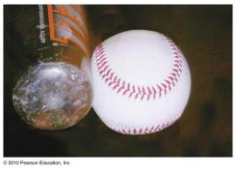
Hooke's Law: Example 2

- Consider a spring that stretches an amount *d* when a load of mass *m* is suspended from it.
- How much will the spring stretch if two identical springs support the same single mass as shown?

Tension and Compression

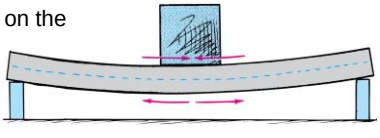
When something is
- pulled it is in **tension.**
- squashed it is in **compression.**

[Image retrieved Jan.11 2013 from http://busstop.typepad.com/blog/2007/07/the-blonde-and-.html]



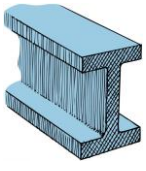
Tension and Compression

When girder is as shown, it is under
- **tension** on the lower side.
- **compression** on the upper side.

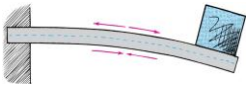


Tension and Compression

Often construction uses an I–beam, i.e., a beam with a cross-section shaped as letter **I**.



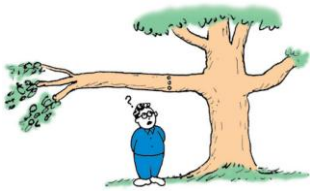
When the beam is used as shown, the shape of the I-beam
- *maximizes* **strength** because the top (under tension) and bottom (under compression) have the most material.
- *minimizes* **weight** because the middle of the beam that is not under stress has the least material.



Tension and Compression
CHECK YOUR NEIGHBOR

Suppose you drill a hole horizontally through a tree branch as shown. Where will the hole weaken the branch the least?

A. Near the top
B. Near the bottom
C. Near the middle
D. It does not matter.



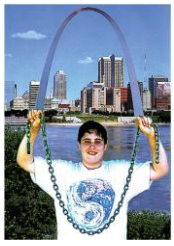
Arches

- Roofs of some older buildings needed many supporting columns.

- But with the discovery of arches, supporting columns were no longer needed.
  - Arches take advantage of the capacity of stone to withstand compression.
  - They use this ability of stone to increase the strength of the structure.

Arches

- If the arch is supporting only its own weight, then the proper shape is a **catenary** (e.g., Arch of St. Louis).



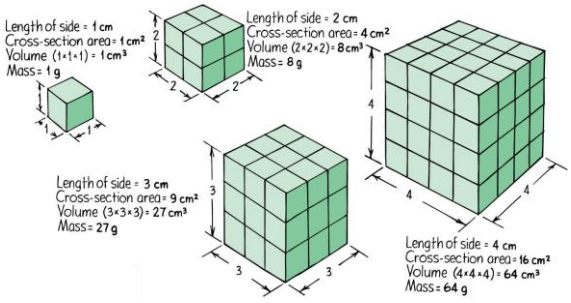
- The catenary is also the natural shape of a chain that hangs between two points.
- An arch rotated around is a dome (e.g., Convocation Hall).

[Image retrieved Jan.11 2013 from http://openbuildings.com/buildings/convocation-hall-profile-7687]

Scaling

- **Scaling** is the study of how the volume and shape (size) of any object affect the relationship of its *strength*, *weight*, and *surface area*.
  - *Strength* is related to the area of the cross section (which is two-dimensional and is measured in *square* centimeters).
  - *Weight* relates to volume (which is 3-dimensional and is measured in *cubic* centimeters).

Scaling

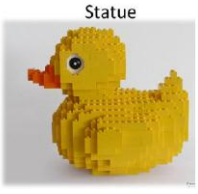


Scaling Example

- A sculptor is making a statue of a duck.
- She first creates a model.
- To make the model requires exactly 2 kg of bronze.
- The final statue will be 5 times the size of the model in all three dimensions.
- How much bronze will she require to cast the final statue?
- (You may find it helpful to think about the model being constructed of Lego blocks, with the final statue made of Lego blocks that are 5 times the size in each dimension as the ones used to make the model.)

Model

Statue



Atoms
Check your neighbour

When you scale up an object to 3 times its linear size, the surface area increases by

A. 3 and the volume by 3.
B. 3 and the volume by 9.
C. 3 and the volume by 27.
D. 9 and the volume by 27.
E. 4 and the volume by 8.

So the surface area to volume ratio is

$$\frac{\text{Surface area}}{\text{Volume}} \sim \frac{\text{size}^2}{\text{size}^3} \sim \frac{1}{\text{size}}$$

Strength to Weight Ratio decreases with increasing size.

[Image is © Jiri Bohdal http://www.naturephoto-cz.com/house-fly-photo-14134.html]

[Image retrieved Jan.11, 2013 from http://en.wikipedia.org/wiki/File:African_Bush_Elephant.jpg]

Scaling

- Air resistance is proportional to surface area.
- Force of gravity is proportional to mass, which is proportional to volume.
- So the ratio of air resistance to weight decreases as size increases.

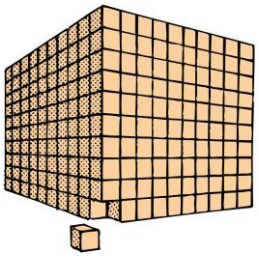
[Image is © Jiri Bohdal http://www.naturephoto-cz.com/house-fly-photo-14134.html]

[Image retrieved Jan.11, 2013 from http://en.wikipedia.org/wiki/File:African_Bush_Elephant.jpg]

Scaling
CHECK YOUR NEIGHBOR

If a 1-cm^3 cube is scaled up to a cube that is 10 cm long on each side, how does the surface area to volume ratio change?

A. 1/100 of original
B. 1/10 of original
C. 10 times original
D. 100 times original



Before Class 9 on Wednesday

- Please read Chapter 13, or at least watch the 10-minute pre-class video for class 9
  - Something to think about:
  - Where is the pressure greater, at the bottom of a large but shallow lake or a small but deep pond?