Studying for the challenge exam

- Read the book
- Learn the models, like
  - Electrical model of matter
  - Molecular model of matter
  - Big bang model of the universe
  - The different models of the atom
  - The nebular model of star formation
- Focus on new concepts
  - Cosmology
  - Plate tectonics
  - The geologic column
- Answer all the questions at the end of each chapter

Reminders

- Please be respectful of others in the class by resisting the urge to talk when someone else has the floor.
- We will cover what we can in class and will attempt to answer questions as they arise. However, if we fail to cover every section of a chapter, that does not excuse you from knowing that information.
- For additional help read the book, ask the TAs, get in a study group, come to my office hours, etc.
A freely falling body in the absence of air resistance

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>Acceleration (ft/s²)</th>
<th>Distance (feet)</th>
<th>Velocity (ft/sec)</th>
<th>Velocity (mph)</th>
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<td>32</td>
<td>1600</td>
<td>320</td>
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</table>

Note that 32 ft/s² is the same as 22 mph per sec
Take home lesson(s) (so far) on gravity:

- Acceleration due to gravity (near the surface of the earth) is the same (constant, unchanging, etc).
- The position and velocity of our falling object do change, but its acceleration (due to gravity) does not.
- Recall Newton’s second law: $F=ma$.
  - If there is acceleration, there must be an unbalanced force.
  - For a given mass, the force due to gravity (near the surface of the earth) or weight is also constant!
Famous “Pisa” experiment
The acceleration caused by gravity is constant regardless of the direction of motion. The rate a cannonball slows while traveling upward is the same rate it speeds up when coming down.
Consider “sideways” motion

- The green ball is thrown to the right at the same time the blue ball is dropped.
- Both will hit the ground at the same time because the acceleration of all falling bodies is the same regardless of their initial velocities.
Be honest …

Our naïve impulse is to think that heavy things fall faster (Aristotle)

BUT THEY DON’T!!!

This tells us something about gravity. Indeed, to Newton, this needed an explanation.
So Chicken Little was almost right: The moon is falling!

- Newton concluded that the centripetal acceleration of the moon in its (almost) circular orbit is the same thing as the acceleration due to the force of gravity.
- **BUT**: the (centripetal) acceleration of the moon is not the same as the acceleration due to gravity at the surface of the earth.
- Newton concluded further that the force of gravity depends on distance. It gets weaker according to the square of the distance.
What do we know so far?

The force of gravity:
- results in all objects falling at the same rate (near the surface of the earth)
- depends on the mass which is being attracted
- depends on distance

Anything else?

Recall Newton’s third law. The force of gravity also depends on the other mass in the pair.
A very little math...

- **Newton’s law of gravity**
  
  \[ F = G \frac{Mm}{d^2} \]
  
  describes the gravitational force on any object of mass “m” exerted by a body of mass “M”.

- **Newton’s second law of motion,** \( F = ma \), describes the acceleration experienced by an object that feels a force “F”.

  \[ F = ma = G \frac{Mm}{d^2} \]
More massive objects feel a greater force of gravity but resist accelerating by the same amount. Since the mass of the earth is constant, and the distance from the center of the earth only changes by a tiny fraction, gravitational acceleration of any body is independent of its mass! Heavy and light things all fall at the same rate.
Quiz:

Two objects of masses \(m\) and \(M\) (the moon and the earth, say) are attracted gravitationally. What would happen if the distance between them were to double?

1. The force is halved
2. The force decreases by 4
3. The force doubles
4. The force increases by 4
Quiz:
Two objects of masses $m$ and $M$ (the moon and the earth, say) are attracted gravitationally. What would happen if one of the masses were to double?

1. The force is halved
2. The force decreases by 4
3. The force doubles
4. The force increases by 4
Weightlessness in a plane:
“The Vomit Comet”
Eating on the vomit comet
“Curved spacetime”

- The “vomit comet” is an example that one cannot tell the difference between constant acceleration resulting from motion and the acceleration due to gravity as felt on the surface of the earth.
- Einstein called this idea the equivalence principle.
- With 10 years and lots of math, he developed the “general theory of relativity.”
  - It is a new “model” of gravity.
The Newtonian model of gravity

- There is a force of attraction between massive objects. If one knows these gravitational forces, one can find/predict the paths (orbits) of those objects.
- The force of gravity acts instantaneously between widely separated masses. (action-at-a-distance)

The Einsteinian model of gravity

- There is no force of gravity per se. Instead, there is space and time which can be curved. The paths (orbits) of masses in that curved space-time are the shortest paths traced out on that curved 4-dim “surface.”
- The influence of gravity (the changing curvature of space-time) is not instantaneous, but travels at the speed of light.
- Mass tells space(-time) how to curve and (curved) space(-time) tells mass how to move.
Based on Occam’s razor, Einstein’s idea is far too complicated to be believed

*unless* …

… it makes additional, testable, and true predictions that Newton’s model does not.

It does!
Einstein triumphant

- Bending of starlight by the sun (or other masses, i.e. stars, galaxies, etc.)
  - “Gravitational lensing”
- Black holes
  - Gravity is so strong, nothing can escape
  - Probably at the center of most galaxies
- An expanding universe
- Measurable light from the earliest era of the universe
A star on a little stroll …
So, is Newton wrong?

or

the power of models

That depends …

Are you speaking of really, really, really strong gravity (black holes) or of really, really, really big distances (cosmology)?

Then yes, Newtonian gravity is wrong.

If not, then Newtonian gravity is really, really, really good at describing what we observe.
Unregistered clickers as of last Friday: 

- 11207041
- 112D724E
- 139C901F
- 15C5B060
- 16051102
- 164F2E77
- 17799FF1
- 179466E5

http://ps100.byu.edu/grade_form.aspx
The Electromagnetic Interaction

- Electrification happens all the time.
QUIZ:
Did you read Chapter 4 before coming to class?

A. Yes, the whole chapter.
B. I started it, but didn’t finish.
C. No, but I will repent.
D. Augh! It’s only a week into the semester and it feels like I’m already two weeks behind.
The electric force

- There is a thing called charge
- There are two types
  - Positive (+)
  - Negative (-)
- Opposite types exhibit an attractive force
- Similar types exhibit a repulsive force
The Electrical Model of Matter

- At first electricity was thought to be a fluid, like water.

- Experiments done by J. J. Thompson showed this “fluid” to be a stream of charged particles.
  - He broke atoms into positive and negative parts.
The Electrical Model of Matter

- Positive charged “ions” behave individually like atoms.
- Negative charges are always the same regardless of where they come from.
  - The charge of individual electrons was first measured in the Millikan/Fletcher oil-drop experiment.
### Electrical force law
- It is different from Gravity, but looks the same.
- \[ F_{\text{gravity}} = \frac{G m M}{d^2} \]
- \[ F_{\text{electrical}} = \frac{k q Q}{d^2} \]
- It can be attractive and repulsive
- Electrical force between two electrons is \(10^{42}\) times stronger than gravitational force
- ALL CONTACT FORCES ARE ELECTRICAL

### Electrical model of matter
- Matter contains positive and negative charges.
- Protons (+) are fixed
- Electrons (-) move
- Positively charged objects are missing electrons
- Negatively charged objects have extra electrons
- Electrically neutral objects have equal numbers of protons and electrons
1. electrons are sprayed onto the belt

2. electrons are carried to the top

3. electrons are taken off the belt and spread out on the metal sphere.
QUIZ:
Why do the little rice puffs fly away from the top of the Van de Graaff accelerator?

a) Newton’s first law applied to electric forces.
b) They all have too many electrons

c) Protons move onto the rice puffs and repel the electrons on the sphere.
d) Dissimilar charges attract
Magnetism

- We use the fancy word magnetic “field” as a replacement for the idea of a magnetic force.
- Magnetic fields are generated by moving electric charges.
- At a microscopic level, some atoms act like tiny little magnets.
- In some materials, these little magnets line up the same way.
- High temperatures make the atoms move and make magnets non-magnetic.
Demo/Quiz:
Which statement(s) is(are) true?

A. Flowing electricity can create magnetism
B. Moving magnets can create electricity
C. Both A and B
D. Neither A nor B
E. Can you do the demo again?
QUIZ:

Two charges are moved twice as close to each other. How can one charge be changed in order to keep the electric force between them the same?

A. Make the charge one fourth as large
B. Halve the charge
C. Double the charge
D. Quadruple the charge
E. No change in the charge is needed. The electric force will remain the same.
Insulators and Conductors

- Conductors are materials that electricity flows through easily.
- Insulators are materials that electricity does not flow through easily.
- There is much more on the behavior of electrons in materials in following chapters. We will find that the behavior of electrons explains much of the nature of the world around us.
Contact Force

- This is air friction, sliding friction, cutting, touching, pushing, resting on something, connected by a rope, etc.
- It only exists when things touch.