## Review for Test #3 Nov 19

Topics:
- Static Electricity, charges, voltage
- Electric currents, Ohm's Law
- Magnetism, inductance, motors and generators
- Sound and waves, Doppler effect, speed of waves
- Electromagnetic radiation, properties of light, black holes

Methods
- Conceptual Review and Practice Problems Chapters 10 - 14
- Review lectures (on-line) and know answers to clicker questions and homeworks.
- Go over practice test. Attend SI sessions.
- Bring:
- Banner ID and Two Number 2 pencils
- Simple calculator (no electronic notes)

Reminder: There are NO make-up tests for this class

## Test #3 Review

How to take a multiple choice test
1) Before the Test:
- Study hard
- Get plenty of rest the night before

2) During the Test:
- Draw simple sketches to help visualize problems
- Solve numerical problems in the margin
- Come up with your answer first, then look for it in the choices
- If you can't find the answer, try process of elimination
- If you don't know the answer, Go on to the next problem and come back to this one later
- TAKE YOUR TIME, don't hurry
- If you don't understand something, ask me. This is not meant to be a vocabulary test.

## Test #3 Useful Equations

Schwarschild radius: $R = \frac{2GM}{c^2}$

Escape Velocity: $v_{esc} = \sqrt{\frac{2GM}{R}}$

$P = I V$ Power = Current * Voltage
$V = I R$ Voltage = Current * Resistance

$F = \frac{k q_1 q_2}{r^2}$ Coulomb's Law for electric force

$B = \frac{L}{4\pi d^2}$ Brightness falls off with the square of distance

$T = 1/f$

$v = f\lambda$ velocity of a wave = freq * wavelength
$c = f\lambda$ velocity of a light = freq * wavelength = 300,000 km/s

## The Electrical Force

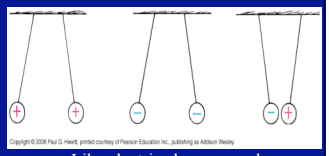
- Coulomb's Law

$F = k \frac{q_1 q_2}{r^2}$

- Compare to Gravity

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

  - $k = 9$ Trillion $N \cdot m^2/C^2$
  - $G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$
    $k/G \sim 10^{20}$

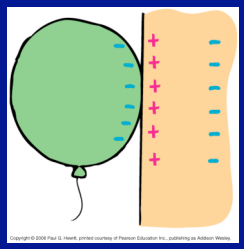


Like electric charges repel and opposites attract.

DEMO - charged spheres

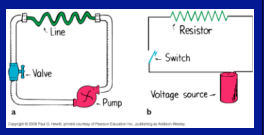
## Static Electricity and Conservation of Charge

- Electrons in your clothes are loosely bound => dislodged
  - Charge is conserved
    - Balloon – net negative charge
  - But wall is electrically neutral, so why does balloon stick?
    - Balloon polarizes surface molecules in wall
      - Opposites attracted, likes repelled
      - Net charge of wall is still zero



## Circuits

- Charged particles flow through an electric circuit
  - In a metal, the free conduction electrons flow
  - In fluids, it is often the positive ions that flow
- Charge carriers flow *through* a circuit due to an applied voltage *across* the circuit




Water flows through a pipe as long as there is a difference in pressure between its ends. Only the water flows, not the pressure.

## Ohm's Law

- Does the current in a circuit increase or decrease as
  - the applied voltage is increased? Increase
  - the resistance of the circuit is increased? Decrease
- *The current in a circuit is directly proportional to the voltage across the circuit and inversely proportional to the resistance.*

$$\text{Current} = \frac{\text{voltage}}{\text{resistance}} \qquad \text{Amperes} = \frac{\text{volts}}{\text{ohms}}$$

## Clicker Question:

The electric power of a lamp that carries 2 A at 120 V is:

A: 2 watts

B: 20 watts

C: 240 watts

D: 60 watts

## Clicker Question:

Say you have a battery in a circuit with a total resistance of 1000 ohms. If you lower the resistance to 100 ohms, what happens to the amount of current flowing through the circuit?

A: Goes down by a factor 10

B: Stays the same

C: Goes up by a factor of 10

D: Goes up by a factor of 100

## Clicker Question:

Magnetism is the motion of electrons as they:

A: move around the nucleus

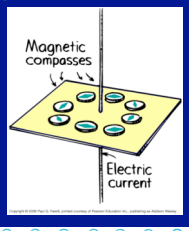
B: spin on their axis

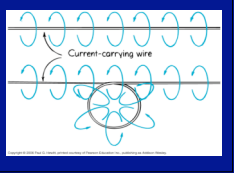
C: both A and B are correct

D: none of the above

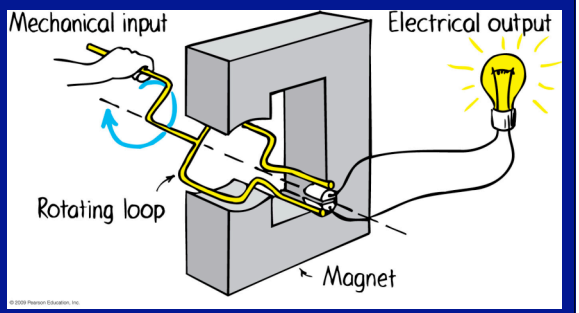
## Electric Currents and Magnetic Fields

- Moving charge creates a magnetic field => so will a current in a wire
  - First detected by the deflection of compasses
    - Pattern of concentric circles
  - What happens if the direction of the current is reversed?




## The Electric Generator



## Clicker Question:

When a bar magnet is broken in two pieces, each half is:

A: no longer magnetic.

B: stronger than the original magnet.

C: the same strength at the original magnet

D: half as strong as the original magnet

## Clicker Question:

Which force field can increase an electon's speed?

A: only an electric field

B: only a magnetic field

C: either an electric field or a magnetic field

D: none of these

## Clicker Question:

When a bar magnet is thrust inside a copper coil, the coil tends to:

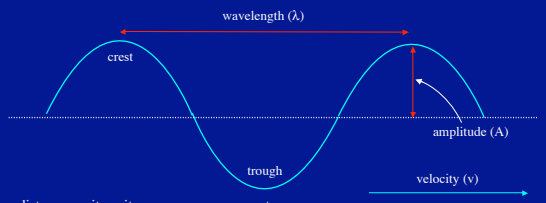
A: repel the magnet

B: attract the magnet

C: have no effect

Radiation travels as waves.
Waves carry information and energy.

Properties of a wave




λ is a distance, so its units are m, cm, or mm, etc.

Period (T): time between crest (or trough) passages

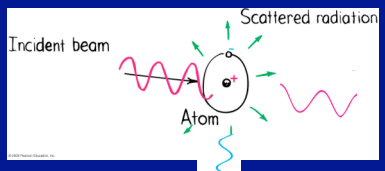
Frequency (ν): rate of passage of crests (or troughs), $\nu = \frac{1}{T}$
(units: Hertz or cycles/sec)

Also, $v = \lambda \nu$

$E = h\nu$

## Why is the Sky Blue?

Light from the Sun at short wavelengths scatters to larger angles off dust grains and other particles in the atmosphere than do long wavelengths




Blue light is scattered more than red light

## Why is the Sky Blue?

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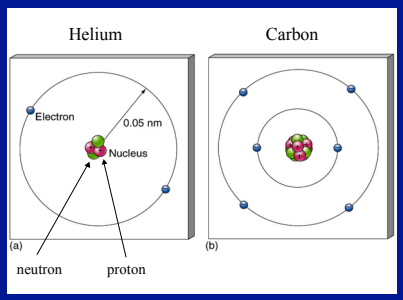
Blue light more th

The Green Flash

## Elements



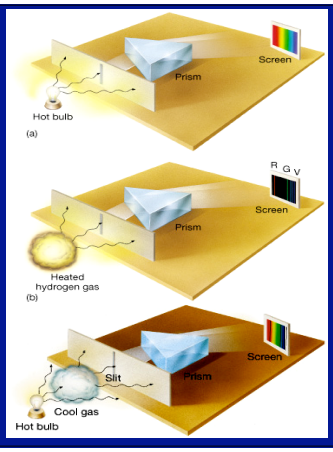

Atoms have equal positive and negative charge. Each element has its own allowed energy levels and thus its own spectrum.

## Kirchhoff's Laws

1. A hot, opaque solid, liquid or dense gas produces a continuous spectrum.

2. A transparent hot gas produces an emission line spectrum.

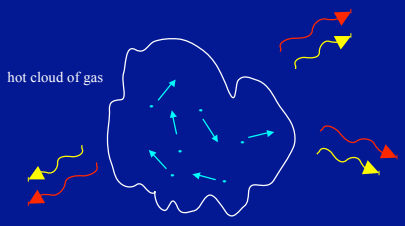
3. A transparent, cool gas absorbs wavelengths from a continuous spectrum, producing an absorption line spectrum.




## So why absorption lines?


The green photons (say) get absorbed by the atoms. They are emitted again in random directions. Photons of other wavelengths go through. Get dark absorption line at green part of spectrum.

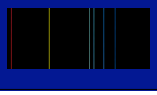
## Why emission lines?




- Collisions excite atoms: an electron moves into a higher energy level

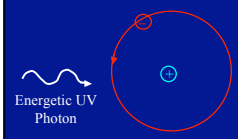
- Then electron drops back to lower level

- Photons at specific frequencies emitted.

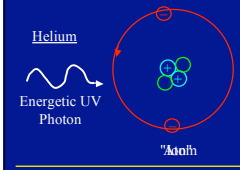


## Ionization

Hydrogen

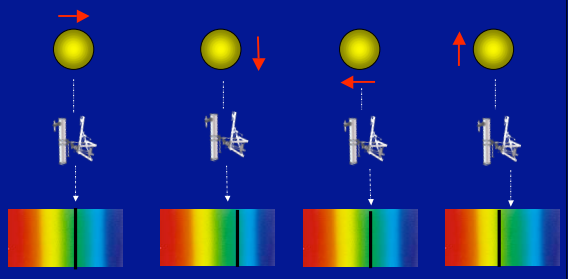



Helium



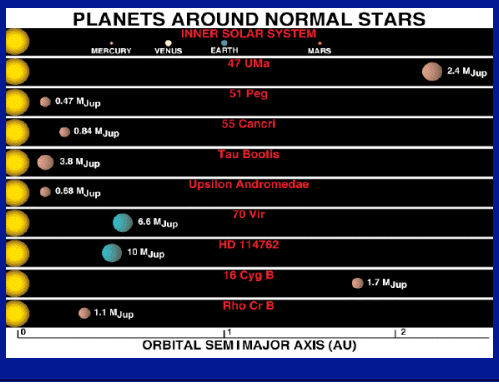

Two atoms colliding can also lead to ionization.

Star wobbling due to gravity of planet causes small Doppler shift of its absorption lines.



Amount of shift depends on velocity of wobble. Also know period of wobble. This is enough to constrain the mass and orbit of the planet.

Over 300 extrasolar planets known. Here are the first few discovered.




## Clicker Question:

A star much colder than the sun would appear:

A: red

B: yellow

C: blue

D: smaller

E: larger

## Clicker Question:

In AM radio information (music, news, etc.) is sent out:

A: using sound waves.

B: by modulating the amplitudes of the radio waves.

C: by modulating the frequencies of the radio waves.

D: by modulating the periods of the radio waves.

## Clicker Question:

Compared to the average speed in air, the speed of a beam of light in glass is:

A: faster

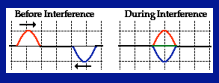
B: slower

C: the same

D: backwards

4. Interference

Waves can interfere with each other

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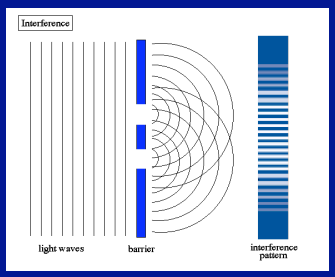
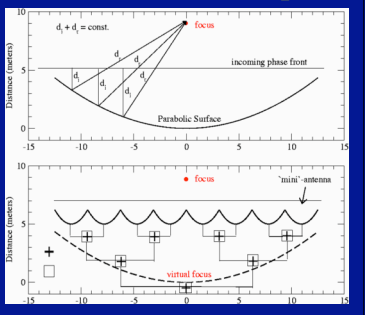



## Aperture Synthesis – Basic Concept

If the source emission is unchanging, there is no need to collect all of the incoming rays at one time.

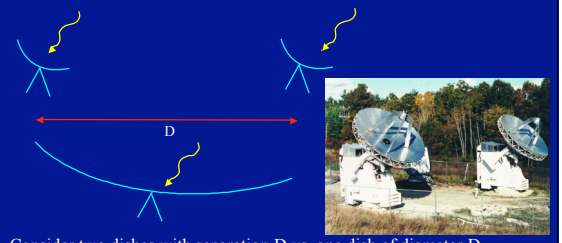
One could imagine sequentially combining pairs of signals. If we break the aperture into N sub-apertures, there will be N(N–1)/2 pairs to combine.

This approach is the basis of aperture synthesis.



## Interferometry

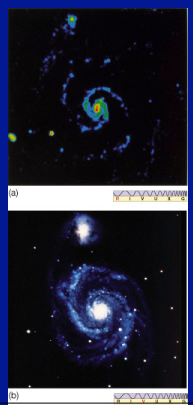
A technique to get improved angular resolution using an array of telescopes. Most common in radio, but also limited optical interferometry.




Consider two dishes with separation D vs. one dish of diameter D. By combining the radio waves from the two dishes, the achieved angular resolution is the same as the large dish.

Example: wavelength = 5 cm, separation = 2 km, resolution = 5"

Very Large Array (NM). Maximum separation of dishes: 30 km



VLA and optical images of M51

## General Antenna Types

Wavelength > 1 m (approx) — Wire Antennas



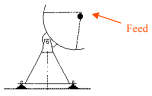
Dipole

Yagi

Helix

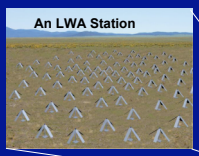
or arrays of these

Wavelength < 1 m (approx)




Reflector antennas

## The Long Wavelength Array (LWA)





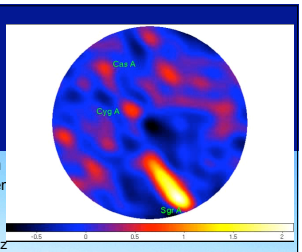
20-80 MHz tuning range (at least)

Baselines up to 400 km for resolution [8,2]" @ [20,80] MHz

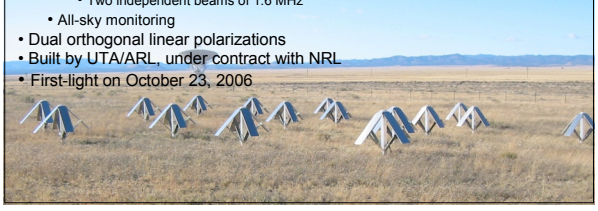
53 "stations" - mJy-class sensitivity

Important astrophysical & ionospheric science

First Stage in Development:
Long Wavelength Development Array



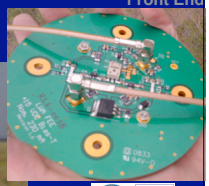

- 60-80 MHz, internal baseline of 20 m
  - Expanded with addition of outlier elements
- Capabilities
  - Digital delay beamforming
    - Two independent beams of 1.6 MHz
  - All-sky monitoring
- Dual orthogonal linear polarizations
- Built by UTA/ARL, under contract with NRL
- First-light on October 23, 2006



## Antennas & Front Ends

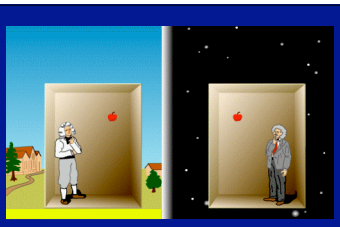
Antenna

Front End



NRL/NRAO "Gen2"
T = 120 K
G = 32 dB
$P_{1dB}$ = -14 dBm (in)

Galactic Noise-Dominated $T_{sys}$

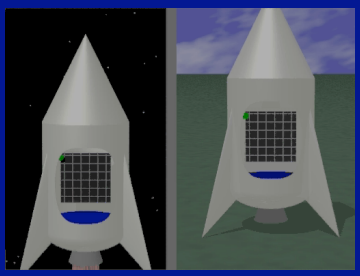


4. Gravity and acceleration are equivalent. An apple falling in Earth's gravity is the same as one falling in an elevator accelerating upwards, in free space.

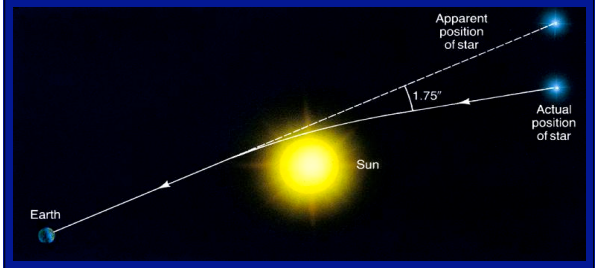
5. All effects you would observe by being in an accelerated frame of reference you would also observe when under the influence of gravity.

Examples:

1) Bending of light. If light travels in straight lines in free space, then gravity causes light to follow curved paths.



Observed! In 1919 eclipse.




## Clicker Question:

What is the escape velocity at the Event Horizon of a 100 solar mass black hole?

A: 300,000 km/s

B: 3,000,000 km/s

C: 30,000,000 km/s

D: 300,000,000 km/s