LECTURE 8
CHAPTER 8,9

PHY 100. BLACK BODY, PHOTOEL. EFFECT, QUANTA

MIDTERM 1 : WEDNESDAY 17th HOYT 2 pm

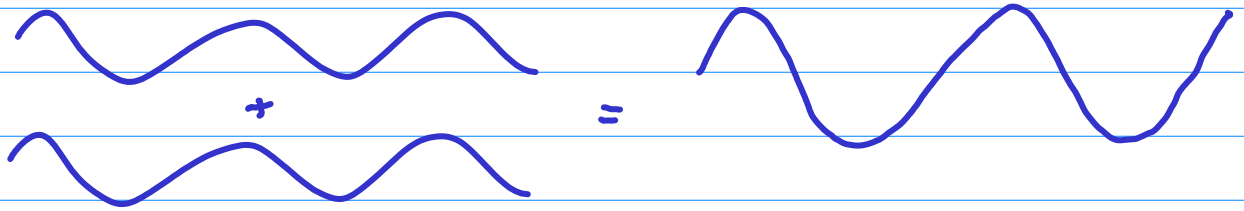
- BRING A CALCULATOR
- I WILL PROVIDE A FORMULA SHEET
- MATERIAL COVERED :
  - LECTURES 1-7
  - RECITATIONS 1-3
  - PROBLEMS 1-4

RECAP: MAXWELL'S EQNS. TELL US THAT LIGHT IS A WAVE

SIMILAR TO OTHER TYPES OF WAVES: WATER WAVES, PULSES ON A STRING, SOUND WAVES, EARTHQUAKE WAVES

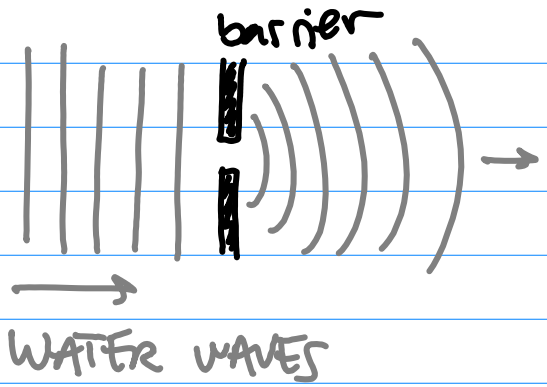
LIGHT EXHIBITS TYPICAL WAVE CHARACTERISTICS:

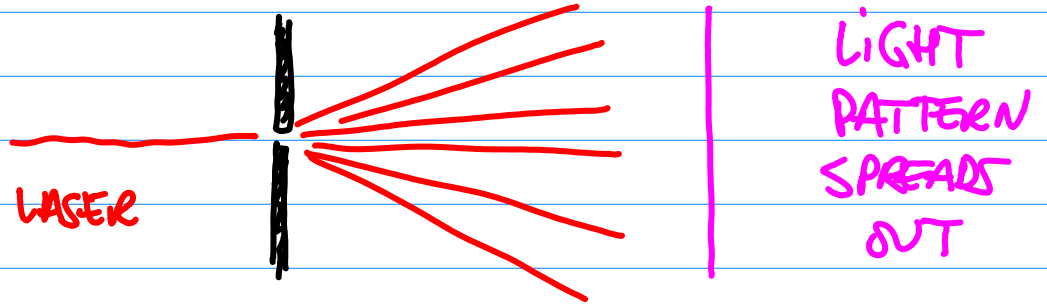
1) INTERFERENCE



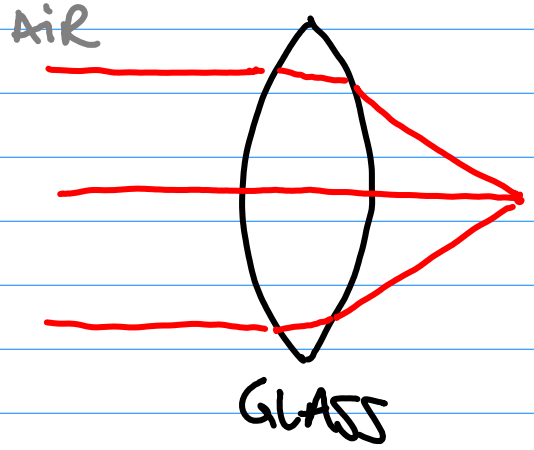
WAVE AMPLITUDES ADD TOGETHER

2) DIFFRACTION





3) REFRACTION: WAVES BEND AT THE INTEFACE BETWEEN MEDIA (SLOW → FAST, etc...)
THE AMOUNT OF BENDING DEPENDS ON THE WAVE'S FREQ.



PRISM: WHITE LIGHT IS THE COMBINATION OF MANY WAVELENGTHS IN THE VISIBLE SPECTRUM.

So WE KNOW LIGHT IS A WAVE

LET'S USE LIGHT TO UNDERSTAND MATTER...
LOOK AT LIGHT EMITTED BY MATTER.

THREE CASES:
- GLASS: LIGHT GOES THROUGH IT
- METAL: LIGHT IS REFLECTED
- SOOT: LIGHT IS ABSORBED (AND IT IS TRANSFORMED INTO HEAT)

NOW REVERSE THIS PICTURE AND HEAT A PIECE OF SOOT:
IT WILL RADIATE LIGHT.

→ A GOOD ABSORBER IS A GOOD EMITTER

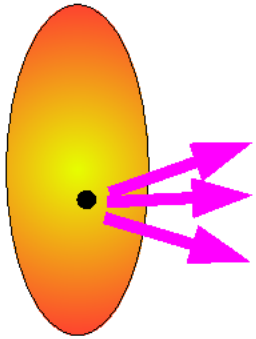
"PERFECT ABSORBER": A LITTLE HOLE IN AN OVEN

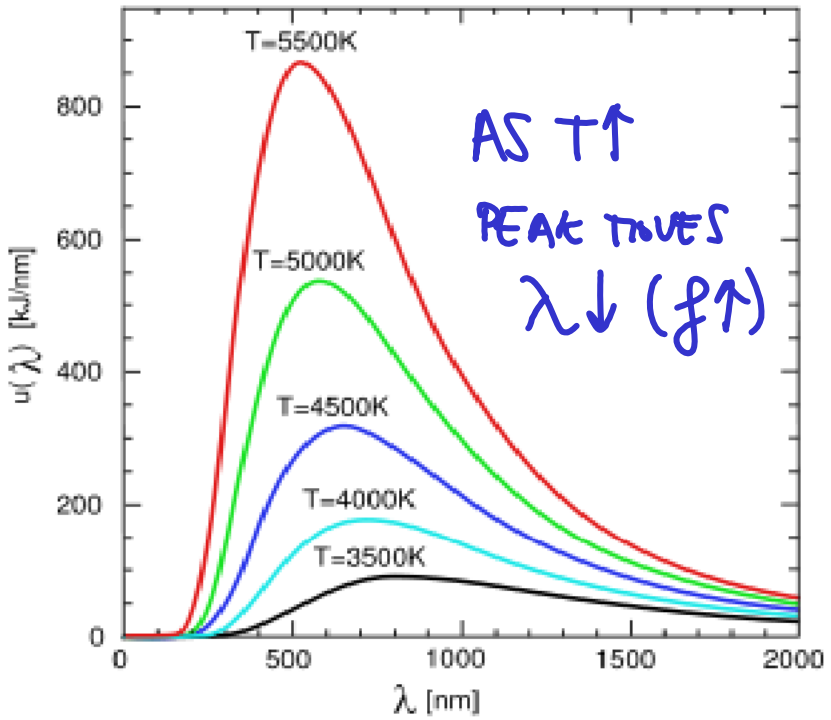
ANY LIGHT THAT COMES IN IS VERY UNLIKELY TO COME OUT AGAIN AS IT WILL BE ABSORBED IN THE WALLS INSIDE.

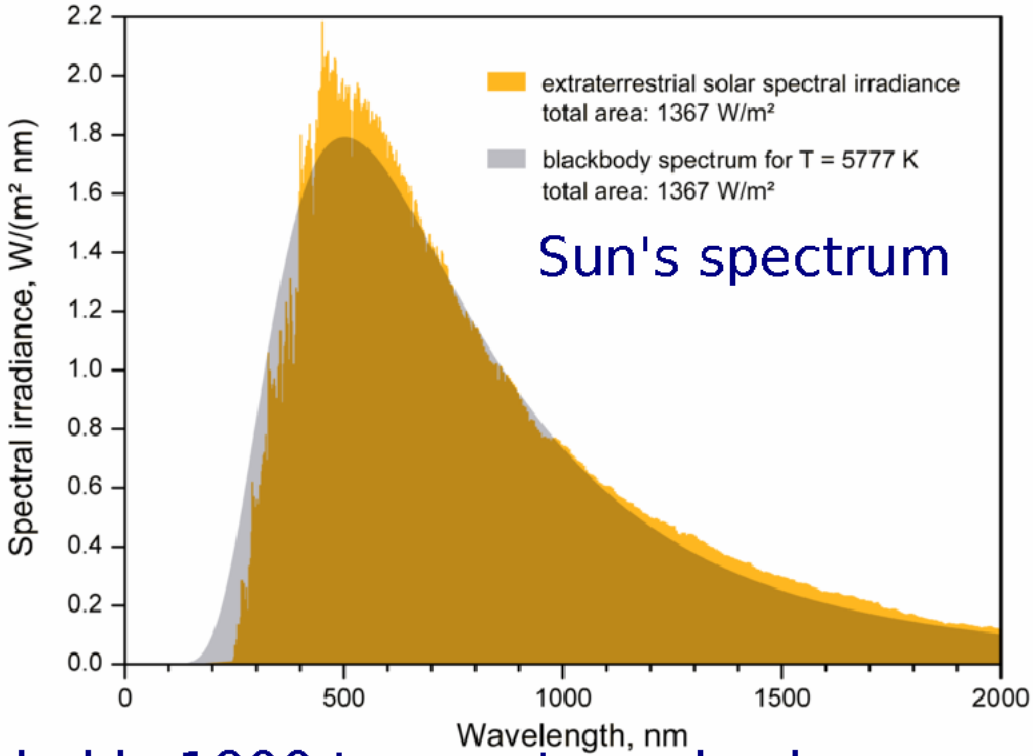
ANY LIGHT THAT COMES OUT IS A PERFECT REPRESENTATION OF A PERFET EMITTER

Black Body radiation

- Black body: an object that absorbs all light (no reflection)
- At temperature T, it's a perfect radiator
- Think of a hole in an oven: the spectrum of the hole's radiation will be continuous and will not depend on the material of the cavity
- The spectrum only depends on the Temperature







- The study of this spectrum led in 1900 to quantum physics
- Max Planck explained it by stating that the energy coming out of the hole was quantized (integer multiples of a quantity)

http://www.mhhe.com/physsci/astronomy/applets/Blackbody/frame.html

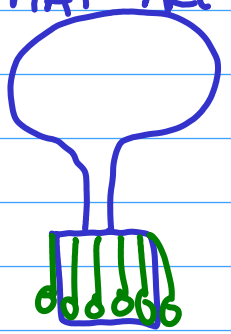
PLANCK (1900) SUCCEDED IN DESCRIBING THESE OBSERVATIONS MATHEMATICALLY.

BUT HE HYPOTHESIZED: LIGHT → LITTLE PACKETS OF ENERGY GIVEN BY $E = hf$

PLANCK'S CONSTANT

ENERGY → $E = hf$ ← FREQUENCY

WHAT ARE QUANTA?



A BALLOON CONTROLS ACCELERATION BY BALLAST

M

$m_b \ll M$

EACH BALLAST REMOVED: $F_b = m_b g$

$a_N = a_0 + N\frac{m_b g}{M}$

$a_1 = a_0 + \frac{m_b g}{M}$

a_0

$\Delta a = \frac{F_b}{M} = \frac{m_b g}{M} = a_0$ (REMOVE 1)

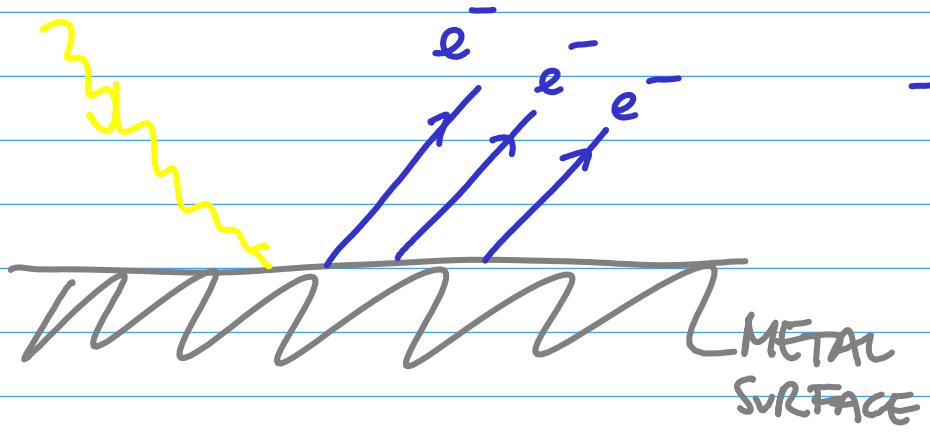
$\Delta a = \frac{2F_b}{M} = \frac{2m_b g}{M} = 2a_0$ (REMOVE 2)

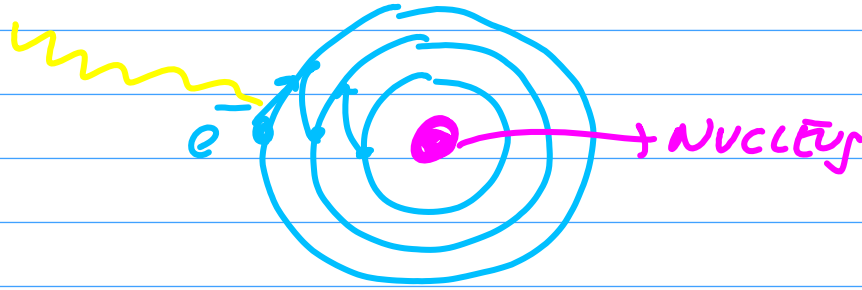
$\Delta a = N\frac{m_b g}{M}$ (REMOVE N)

ACCEL. IS IN "DISCRETE" JUMPS.

ANOTHER PHENOMENON NOT UNDERSTOOD :

PHOTOELECTRIC EFFECT





- THE ENERGY OF EMITTED e^- DOES NOT DEPEND ON THE INTENSITY OF INCOMING LIGHT, BUT ON ITS FREQ!
- IF LIGHT WAS A WAVE, THE E TRANSMITTED TO THE e SHOULD DEPEND ON ITS AMPLITUDE, NOT FREQ!

EINSTEIN WAS ABLE TO EXPLAIN THIS EFFECT ASSUMING LIGHT COMES IN LITTLE PACKETS OF QUANTA WITH AN ENERGY :

$$E = hf$$

THESE QUANTA ARE "PARTICLES" OF LIGHT

SUDDENLY WE HAVE TO FACE THE FACT THAT LIGHT IS BOTH A WAVE AND A PARTICLE. !!

IS LIGHT A WAVE OR A PARTICLE?

IT DEPENDS ON THE EXPERIMENT!

- WAVE { INTERFERENCE, DIFFRACTION; λ, f
- PARTICLE { P.E.; ENERGY OF QUANTA.

IT ACTUALLY GETS WORSE!
IF LIGHT (KNOWN TO BE A WAVE) CAN BEHAVE AS A PARTICLE, PERHAPS PARTICLES CAN BEHAVE AS WAVES.

LOUIS DE BROGLIE (1926): MATTER WAVES

WAVELENGTH OF A PARTICLE OF MATTER → $\lambda = \frac{h}{p}$ ← PLANCK'S CONST.

p ↖ MOMENTUM: $p = mv$

FOR A BASEBALL: mass ~ 142 g, $v = 92\ mph = 41\ m/s$

$h = 6.67 \times 10^{-34}\ Js$

1 JOULE [UNIT OF ENERGY] ~ ALSO WORK
WORK ~ FORCE × DISTANCE $= [N \cdot m]$

$$\lambda = \frac{6.67 \times 10^{-34}}{0.142 \times 41} = \frac{6.67 \times 10^{-34}\ Js}{5.8\ kg\ \frac{m}{s}} \sim 1 \times 10^{-34}\ m \rightarrow \text{UNDETECTABLE}$$

COMPARE WITH BLUE LIGHT $\lambda = 6 \times 10^{-7}\ m$