Physics 1C Week 1

- **No** reading quiz today!
- **No** labs this week!
- HW has been assigned (see WWW page)
  - Problem Section Wed 6-7:30pm
  - HW solutions will be posted on WWW site
- Office hours Wed 11:15 - 12:30 pm, SERF 312
- **QUIZ ON FRIDAY**: Bring blue book

Week 2:

- Reading Quiz Monday (bring Scantron)
- Labs Tuesday, Thursday
  - check section and location

Tools and Rules

- **Friday Quizzes** (45%). Closed book, best 3 out of 4 (no make-ups)
  - need 1 blue book per quiz
  - + 2 pens (no pencil), small ruler, calculator

- **Monday Reading Quizzes** (5%). Best 3 out of 4
  - 4 multiple-choice questions + 1 "attendance" point
    [unreadable scantron = 0 points]
  - Need Scantron form 20788 + 2B pencil

- **Tues, Thurs labs** (25%):
  - Need a quadrille-ruled lab notebook (prefer "carbon copy" pages)
  - Pre-lab homeworks to be handed in at start
  - Rest of lab is COLLABORATIVE

- **Final Exam** (25%): Friday September 7 9.30 - 12.30pm
  - No make-ups, inform me of conflicts ASAP.

- "Zero tolerance" on cheating → we will catch you!

How to do well in Physics 1C . . .

- Lectures + demos
- Reading assignments (Monday reading quizzes)
- Attempt HW problems honestly
- Participate in Problem Section, office hours
- Prepare for labs : pre-lab homeworks
  + understand goals, procedure.
- Ask questions

Grading:

Friday quizzes (best 3)	: 45%
Monday (best 3)	: 5%
Lab HW + expt	: 25%
Final Exam	: 25%
	100%

- No "curve" ⇒ everyone can get an A
  + it pays to collaborate on labs

EM Waves (Hecht Chapter 22)

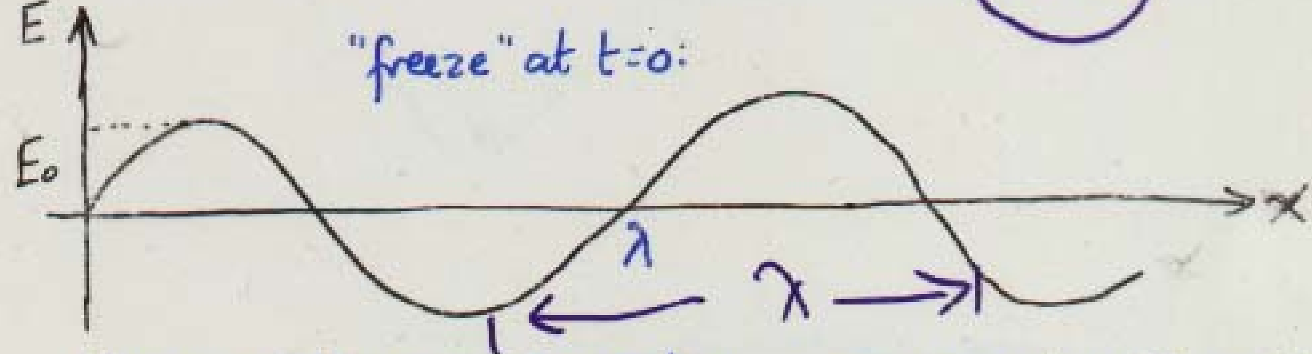
Solutions to Maxwell's eqns:

$$E = E_0 \sin \frac{2\pi}{\lambda}(x - ct) \quad ; B = E/c$$

($c = 3\times10^8$ m/s)

$\frac{2\pi}{\lambda}(x - ct)$: phase angle in radians

Harmonic wave with speed $v = c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$



Wave repeats every 2π radians i.e. $x = \pm\lambda, \pm2\lambda, \pm3\lambda$
wavelength λ

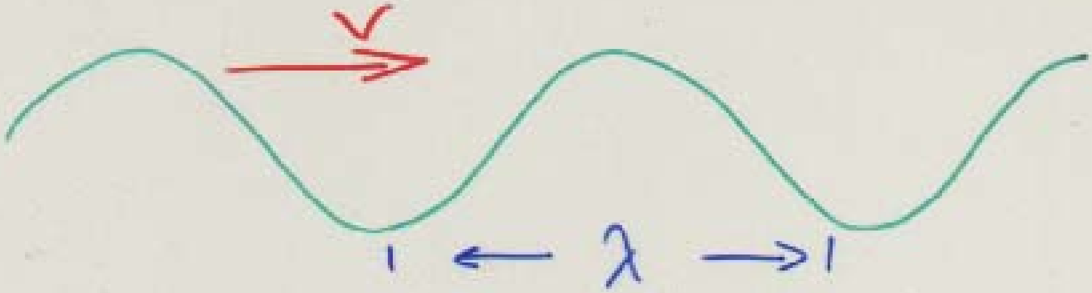
Now sit at $x = 0$ and watch $E(t)$

$$E(t) = E_0 \sin\left(\frac{2\pi c}{\lambda} t\right)$$

– repeats every 2π radians when $t = \pm\lambda/c, \pm2\lambda/c, \ldots$

i.e. repeat period $T = \lambda/c \Rightarrow f = c/\lambda$ [Hz]

$v = f\lambda$ for any Periodic Wave



As wave passes through a given point,

# of oscillations in time t = $\frac{\text{distance traveled}}{\text{wavelength}} = \frac{vt}{\lambda}$

(= # of wavelengths passed by)

= (# oscillations/s) × time = ft

$\therefore \quad ft = \frac{vt}{\lambda}$

or $\underset{m/s}{v} = \underset{s^{-1}}{f}\,\underset{m.}{\lambda}$

e.g. For $\lambda = 0.75m$ sound wave

freq. $f = \frac{v}{\lambda} = \frac{330 m/s}{0.75 m} = 440 Hz$

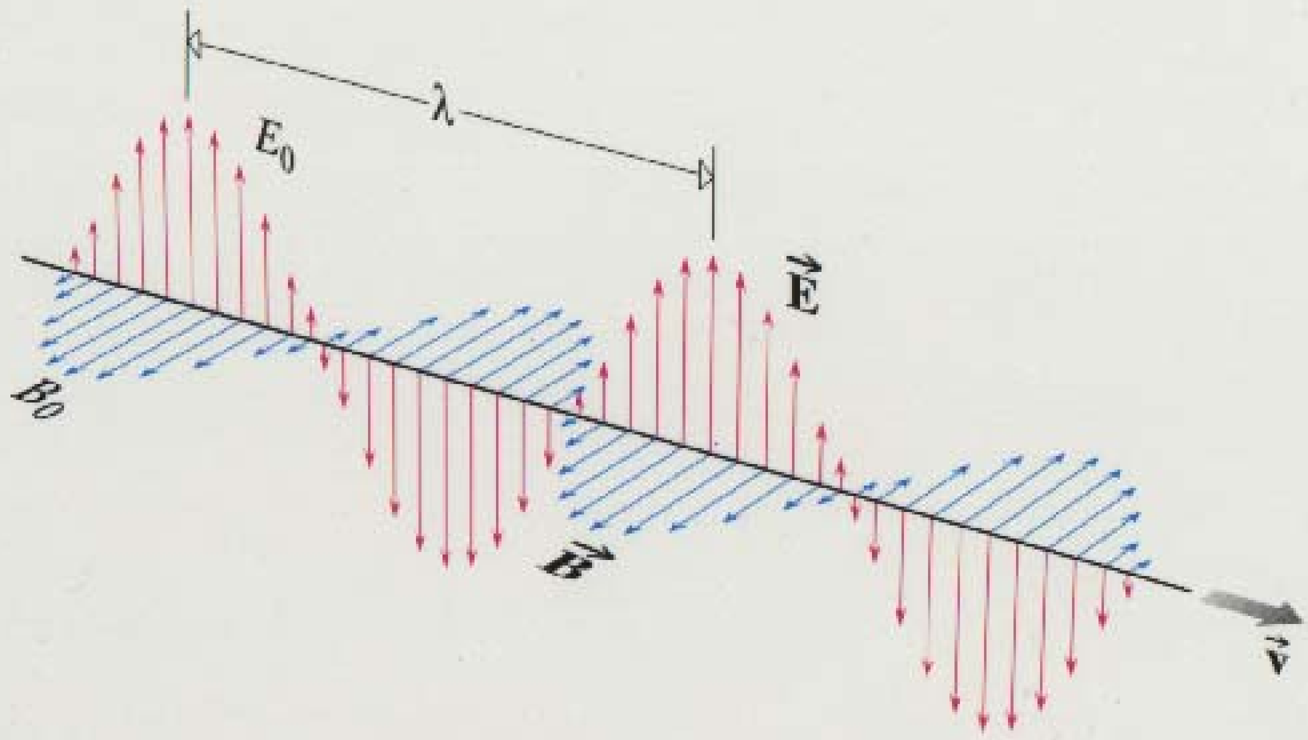
For $\lambda = 0.75m$ EM wave

$f = \frac{c}{\lambda} = \frac{3 \times 10^8 m/s}{0.75 m} = 4 \times 10^8 Hz$ or $400 MHz$

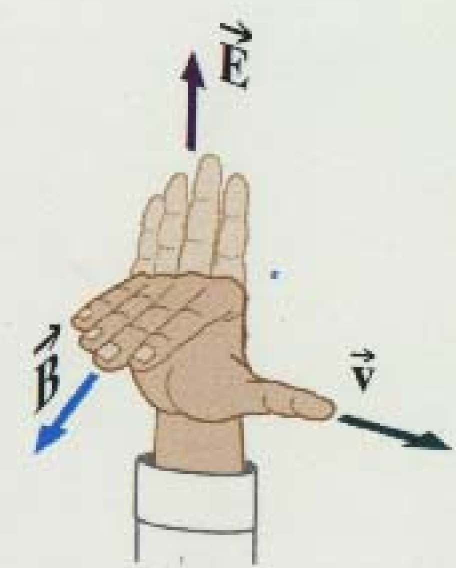
Transparency 139

Figure 22.8

Harmonic electromagnetic wave



(a)



(b)

$B = E/c$

$\underset{\sim}{E}$, $\underset{\sim}{B}$ fields in EM Waves

$\vec{E}$, $\vec{B}$ in EM wave are linked

: $\vec{E} \perp \vec{B}$, both $\perp$ to direction of travel (transverse)

$B = E/c$, small, in phase with $\vec{E}$

Force on charge q: $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$

$\vec{E}$ field does work on charge

Define Potential Difference (Voltage) as

$$V = \frac{\text{work done}}{\text{unit charge}} = [\text{Joule/Coulomb or Volt}]$$

Then work $= \int \vec{F} . d\vec{x} = q \int \vec{E} . d\vec{x} \equiv q V$

OR $\vec{E} = \frac{dV}{dx}$: electric field is gradient of potential difference [N/C or V/m]

e.g. Place 2·0m antenna $\parallel$ to $\vec{E}$ in EM wave

⇒ peak voltage difference between ends

$$\Delta V \approx \frac{dV}{dx} . \ell = E . \ell = 4\,mV \text{ when } E = 2\,mV/m.$$

Energy Transfer : Irradiance

$\underset{\sim}{E}, \underset{\sim}{B}$ hard to measure directly

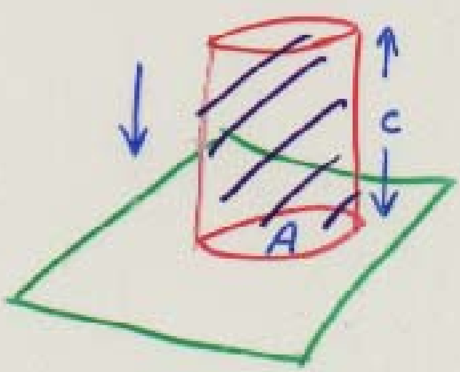
but <u>can</u> measure energy density of wave

$$U = u_E + U_M = \tfrac{1}{2}\varepsilon_0 E^2 + \frac{\tfrac{1}{2} B^2}{\mu_0} \quad [J/m^3]$$

Use $B = E/c$ in wave ; $\underline{U = \varepsilon_0 E^2}$

Average over sine wave $E^2 = E_0^2 [\sin^2 2\pi f t]$

$\Rightarrow U = \tfrac{1}{2}\varepsilon_0 E^2 \quad (\propto \text{amplitude}^2)$



In 1s, area A absorbs EM energy in volume = $\underline{Ac}$

$\Rightarrow$ energy absorbed / s / unit area :

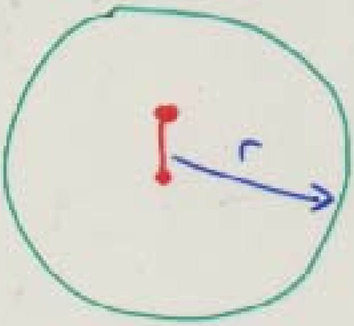
Irradiance $I = \dfrac{\tfrac{1}{2}\varepsilon_0 E_0^2 c A}{A} = \underline{\tfrac{1}{2} c \varepsilon_0 E_0^2 \quad [W/m^2]}$

Note: For isotropic source $I = \dfrac{P}{4\pi r^2}$: inverse square law

so $I \propto E_0^2 \propto 1/r^2$ $\Rightarrow$ electric field $E \propto \dfrac{1}{r}$

Example (cf. Hecht Ex. 22.3)

Radio station outputs 10kW spread over sphere



At $r = 100\text{km}$, $I = \dfrac{P}{4\pi r^2} = 8 \times 10^{-8}\ \text{W/m}^2$

$\therefore$ using $I = \frac{1}{2}\varepsilon_0 c E_0^2$

$\Rightarrow$ peak E field $E_0 = \sqrt{\dfrac{2I}{\varepsilon_0 c}} = 7.6\ \text{mV/m}$

So a 50cm car antenna $\Rightarrow \Delta V = 7.6\ \text{mV/m} \times 0.5\text{m} = 3.8\text{mV}$

- easy to detect + amplify

c.f. laser beam with $P = 1.0\text{mW}$

BUT focussed into 1mm radius circle $A = \pi r^2$

$\Rightarrow I = \dfrac{P}{A} = 320\ \text{W/m}^2$ and $E_0 = 0.5\text{kV/m}$

- enough to damage eyes

$\therefore$ low power, but high intensity lasers can cut metal!

The whole spread of radiant energy, which conceptually ranges in wavelength between zero and infinity, is referred to as the **electromagnetic spectrum**. It is usually subdivided into seven more or less distinct regions. These were delineated originally as much by historical circumstance as by physical necessity, and so there tends to be a good bit of overlap in the categories. Needless to say, light was discovered first, then infrared (1800), ultraviolet (1801), radiowaves (1888), X-rays (1895), gamma rays (1900), and, finally, it was just a technical matter of filling in the microwaves, which was done in the 1930s, primarily with an eye toward radar (Fig. 24.15).

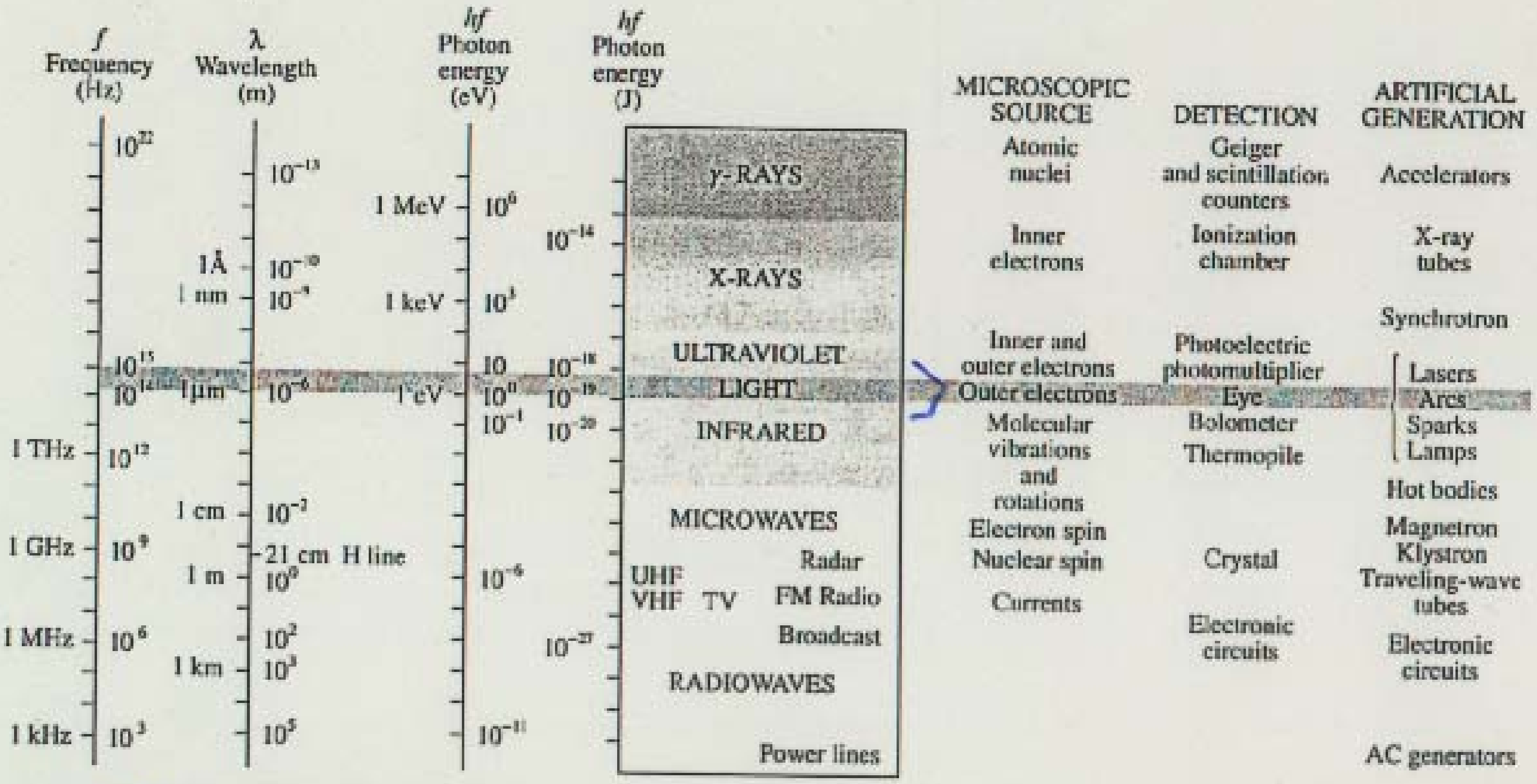


Figure 24.15 The electromagnetic spectrum.