Physics 2C 1/14

1. Summary of EM & Sound Waves
2. Power vs. Intensity
3. Absolute Intensity vs. Decibels
4. Doppler Effect (start if time)

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(1) EM waves $c = 3.00 \times 10^8$ m/s <u>vacuum</u>

In medium, light moves slower by a factor $\underline{n} \geq 1$ "index of refraction"

$$\boxed{v = \frac{c}{n}}$$

EM spectrum

Sound waves $v_{sound} = 343$ m/s (@ room temp.)

human audible range f: 20 Hz – 20 kHz
λ: 17 m – 17 mm

higher freq → ultrasound

During a thunderstorm you see a flash of lightning in the distance. 5 s later, you hear thunder. How far away was the lightning?

A) 1 mile (1.6 km)

B) 0.5 miles (0.8 km)

C) 2 miles (3.2 km)

D) 0.25 miles (0.4 km)

E) 5 miles (8.0 km)

$$\Delta x = c(t_1 - t_0)$$

$$\Delta x = v_{sound}(t_2 - t_0)$$

$$t_2 - t_1 = \frac{c\Delta x}{c\, v_{sound}} - \frac{\Delta x\, v_{sound}}{c\, v_{sound}}$$

$$\Delta x = \frac{(t_2 - t_1)\, c\, v_{sound}}{c - v_{sound}}$$

$$= \frac{(5\text{ s})(3\times10^8\text{ m/s})(343\text{ m/s})}{(3\times10^8\text{ m/s} - 343\text{ m/s})}$$

$$= 1.7\text{ km}$$

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② Power vs. Intensity

$A_{sphere} = 4\pi r^2$

$$\text{Power} = \frac{\text{Energy}}{\text{Time}}$$

$$\text{Intensity} = \frac{\text{Power}}{\text{Area}}$$

SI units: $\frac{W}{m^2}$

<u>Prob</u>: Light bulb has power P_{bulb}. Your eyeball is a distance d away, with area A. How much energy enters your eye in a time T?

The index of refraction of water is 1.33. What is the speed of light in water? ③

(A) 1.7×10^8 m/s

(B) 2.3×10^8 m/s

(C) 3.0×10^8 m/s

(D) 4.0×10^8 m/s

A red laser pointer with frequency f_0 in air is shining on a glass of water. What is the frequency of the light when it is inside the water?

A) $f = 1.33 f_0$ B) $f = f_0$ C) $f = \frac{f_0}{1.33}$

(a) What's the intensity?

$$I_{@eye} = \frac{P_{bulb}}{4\pi d^2}$$

(b) Energy?

$$P_{\substack{entering\\eye}} = (I_{@eye})A = \frac{P_{bulb}A}{4\pi d^2}$$

$$E = \frac{P_{bulb}AT}{4\pi d^2}$$

3

Quiet classroom : **39 dB**

Loud : **103 dB**

	absolute intensity I	decibel β
threshold of human hearing →	$I_0 = 10^{-12}\ W/m^2$	0 dB
	$10^{-11}\ W/m^2$	10 dB
	$10^{-10}\ W/m^2$	20 dB
	$10^{-9}\ W/m^2$	30 dB
	⋮	⋮
	$1\ W/m^2$	120 dB

$$\beta = (10\,dB)\log_{10}\left(\frac{I}{I_0}\right)$$

Convert 56 dB to SI units

$$56\,dB = (10\,dB)\log_{10}\left(\frac{I}{I_0}\right) \Rightarrow I = I_0(10)^{5.6} \approx 4\times10^{-7}\ W/m^2$$

Stop to Think 16.6

4 trumpet players are playing the same note. If three of them suddenly stop, the sound intensity level decreases by:

a) 40 dB b) 12 dB c) 6 dB d) 4 dB

$$\beta_{after} - \beta_{before} = 10\,dB \log_{10}\left(\frac{I_{after}}{I_{before}}\right)$$

$I_{after} = \frac{1}{4} I_{before}$

$$= 10\,dB \log_{10}\left(\frac{1}{4}\right)$$

$$= 10\,dB\,(-0.6) = -6\,dB$$

A satellite radio station puts out 10 kw of cool jazz for an hour at 99.3 MHZ on your radio dial. How much energy per unit time goes through a sphere 50 kilometers in diameter that is centered on the satellite. The drawing below is not to scale.

1. (10 kw)/(25 km)^2
2. 10 kw
3. (10 kw) (4π)(25 km)^2
4. (10 kw)(4π)(25 km)^2(time)
5. None of the above

ANS: 2

Now, the sphere enclosing the satellite that is broadcasting at 10 kw for an hour is way off center, as shown. The total power going through the sphere is now:

1. (10 kw)/(25 km)^2
2. 10 kw
3. (10 kw) (4π)(25 km)^2
4. (10 kw)(4π)(25 km)^2(1 hour)
5. None of the above

ANS: 2

A ground-based radio station puts out 50 kw, and your radio needs to receive at least 1×10^{-6} w/m^2 of power per unit area in order to faithfully reproduce the sound of cool jazz. What is the maximum distance that you can be from the broadcast antenna?

1. 1000 km
2. 630 km
3. 316 km
4. 0
5. 32 km
6. 63 km

ANS: 6

$$I = \frac{P}{4\pi r^2}$$

$$10^{-6}\ \frac{W}{m^2} = \frac{50 \times 10^3 W}{4\pi r^2}$$

$$r^2 = \left(\frac{50}{4\pi} \times 10^9\right) m^2$$

$$\approx 4 \times 10^9\ m^2$$

$$r \approx 2 \times 10^{4.5}\ m$$

$$\approx 6 \times 10^4\ m$$

Doppler Effect

observer/receiver moving w/ speed v_r (book v_o)

source (speed v_s)

runaway bird scooter

f: freq. of sound waves of source

f': freq I hear.

$$f' = f\left(\frac{1 \pm v_r/v_s}{1 \pm v_s/v}\right) = f\left(\frac{v \pm v_r}{v \pm v_s}\right)$$

v: speed of sound
v_r: speed of receiver
v_s: speed of source

If moving towards, $f' > f$
away, $f' < f$

Case 1

$$f' = f\left(\frac{v \pm \cancel{0}}{v \pm v_s}\right)$$

$$= f\left(\frac{v}{v - v_s}\right)$$

A) $f'/f > 1$

B) $f'/f < 1$

Case 2

$$f' = f\left(\frac{v \pm v_r}{v}\right)$$

$$= f\left(\frac{v - v_r}{v}\right)$$

A) +

B) −

Case 3

$$f' = f\left(\frac{v \pm v_r}{v \pm v_s}\right)$$

A) + top, − bottom
B) + top, + bottom
C) − top, − bottom
D) − top, + bottom

A speaker broadcasting at a frequency of 2 MHZ is moving with a velocity of 200 m/s toward a stationary detector. What is the frequency that the detector will hear? The speed of sound is 343 m/s and the Doppler formula is:

$$f' = f\left(\frac{v \pm v_{DETECTOR}}{v \pm v_{SOURCE}}\right)$$

1. 0.83 MHz
2. 4.8 Mhz
3. 3.2 MHz
4. 1.3 MHz
5. 2 MHz

ANS: 2

A detector is moving 200 m/s toward a stationary speaker broadcasting at a frequency of 2 MHZ. What frequency will the detector hear? The speed of sound is 343 m/s and the Doppler formula is:

$$f' = f\left(\frac{v \pm v_{DETECTOR}}{v \pm v_{SOURCE}}\right)$$

1. 0.83 MHz
2. 4.8 Mhz
3. 3.2 MHz
4. 1.3 MHz
5. 2MHz

ANS: 3

A speaker is moving with a velocity of 200 m/s toward a detector, ***and*** the detector is moving with a velocity of 100m/s away from the speaker. The speaker's frequency is 2 MHz, what is the frequency that the detector will hear? (The speed of sound is 343 m/s, and all speeds are relative to the ground.)

Method 1: According to the detector, the speaker is approaching at 200-100=100 m/s, so the frequency is

$$2 \times \frac{1}{1-100/343} = 2.82 \text{ MHz}$$

Method 2: the speaker is moving 200 m/s towards the detector, and the detector is moving 100m/s away. So the frequency is

$$2 \times \frac{1-100/343}{1-200/343} = 3.40 \text{ MHz}$$

1. Both methods are right
2. Both methods are wrong.
3. Only method 1 is right.
4. Only method 2 is right.

ANS: 4

A ***combined*** speaker and detector system is moving at 100 m/s toward a wall. The speaker's frequency is 2 MHZ and the detector will hear the wave ***reflected*** by the wall. What frequency will the detector hear? The speed of sound is 343 m/s and the doppler formula is:

$$f' = f\left(\frac{v \pm v_{DETECTOR}}{v \pm v_{SOURCE}}\right)$$

1. 2.82 MHZ
2. 2.58 MHZ
3. 3.65 MHZ
4. 1.10 MHZ
5. 2.00 MHZ

ANS: 3