November 28

Example: Source of spherical waves with Power P,

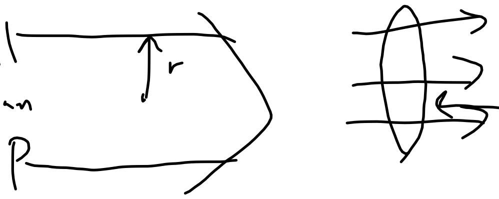
Then

sphere of radius r

$$I = \frac{P}{\text{area of sphere}} = \frac{P}{4\pi r^2}$$

Suppose we have a beam of waves

cylindrical beam of Power P



$$I = \frac{P}{\text{area of circle}}$$

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

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Speaker example

Let $r = 4\ m$

$P_a = 200\,W$ = electrical power

P_s = acoustic power $= 0.01\ P_a$

$$I = \frac{P_s}{4\pi r^2} = \frac{(.01)(200\ W)}{4\pi\ (4\ m)^2} = 10^{-2}\ \frac{W}{m^2}$$

Note in Chap 17, we use $\beta(dB) = 10 \log_{10}\left(\frac{I}{I_0}\right)$

where β is sound intensity level, and $I_0 = 10^{-12}\frac{W}{m^2}$

typical threshold for hearing at 1 KHz.

In this example, $\beta = 10 \log_{10}\left(\frac{10^{-2}}{10^{-12}}\right) = 100$

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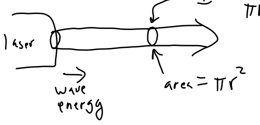
Laser pointer example:

Consider a laser pointer with power $P = 3.1\ mW$ and a beam diameter of $d = 2\ mm$. What is the intensity of the beam?

$$I = \frac{P}{\pi r^2} = \frac{3.1\times10^{-3}\ W}{\pi\ (10^{-3}\ m)^2}$$



$$I = 10^3\ \frac{W}{m^2}$$

Notes: (1) For an electromagnetic wave,

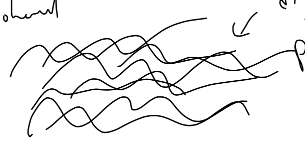
$$P \propto (\text{electric field amplitude})^2$$

(2) In direct sunlight at noon,

$$P \approx 10^3\ \frac{W}{m^2}$$

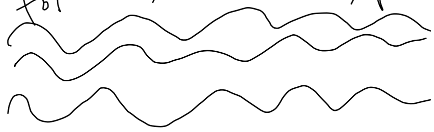
incoherent

different phases



for laser, coherent

all in phase



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Superposition of waves:

Example: add 2 waves with same A, ω, k, but different phase ϕ

$$y_1(x,t) = A\sin(kx-\omega t+\phi)$$
$$y_2(x,t) = A\sin(kx-\omega t)$$
$$y_R = y_1+y_2 = A\left[\sin(kx-\omega t+\phi)+\sin(kx-\omega t)\right]$$

Let $u = kx-\omega t+\phi$

$v = kx-\omega t$

$$\sin u+\sin v = 2\sin\left(\frac{u+v}{2}\right)\cos\left(\frac{u-v}{2}\right)$$

Then $y_R = 2A\sin\left(kx-\omega t+\frac{\phi}{2}\right)\cos\left(\frac{\phi}{2}\right)$

$$y_R = \left[2A\cos\left(\frac{\phi}{2}\right)\right]\sin\left(kx-\omega t+\frac{\phi}{2}\right)$$

y_R is another travelling wave with <u>same</u> ω and k, but $A_R = 2A\cos\left(\frac{\phi}{2}\right)$ and phase $\frac{\phi}{2}$

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Standing waves on a string:

$$y_1 = A \sin(kx - \omega t)$$

$$y_2 = A \sin(kx + \omega t + \phi)$$

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