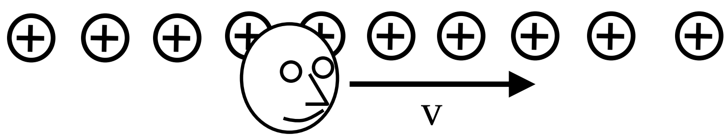
CTEM-1.
A row of positive charges is **stationary** on the ground. A person with a gauss-meter (which measures the magnetic field) is running to the right along the row of charges, at the same height as the charges and in front of them (in the diagram below).

Does the person measure a non-zero B-field?
A) Yes   B) No



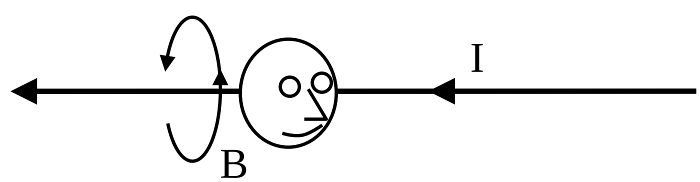
Answer: Yes. In the frame of reference of the moving person, the positive charges are moving to the left. From the person point of view, the positive charges constitute a current to the left. Currents make B-fields.

What is the direction of the B-field which the moving observer measures?

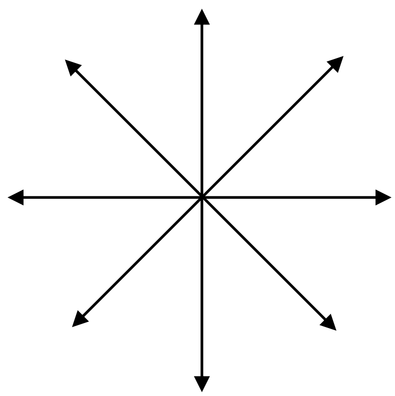
A) Up↑   B) Down↓   C) Forward direction →

D) backward direction ←   E) no direction, B-field zero

Answer: Upward. Note that the person is in front of the wire, not above or below the wire.



CTEM-2.
Consider a field line diagram that looks like this:



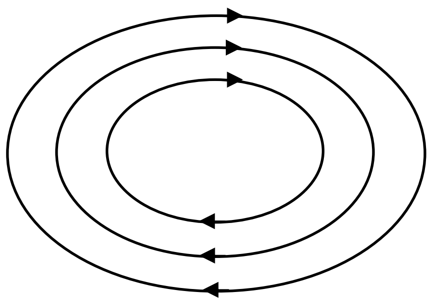
A) This could be a B-field only.

B) This could be an E-field only.

C) This could be either an E-field or a B-field.

Answer: This could only be an E-field.

Now, consider a field line diagram that looks like this:



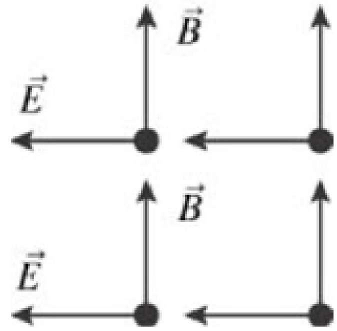
A) This could be a B-field only.

B) This could be an E-field only.

C) This could be either an E-field or a B-field.

Answer: This could be a B-field OR an E-field.

CTEM-3.
A plane electromagnetic wave has electric and magnetic fields at all points in the plane as noted below. With the fields oriented as shown, the wave is moving…



A) into the plane of the paper

B) out of the plane of the paper

C) to the left

D) to the right

E) toward the top of the paper

Answer: into the plane of the paper

CTEM-4.
How many of the following 8 things travel at the speed of light c?

Mircrowaves
Cell phone signals
Radio waves
Ultrasonic waves
Gamma rays
Radar
X-rays
Infrared radiation

A) all 8 B) 7 C) 6 D)5 E) 4 or less

Answer: 7, all of them except ultrasonic waves.

CTEM-5.
Which has higher frequency?

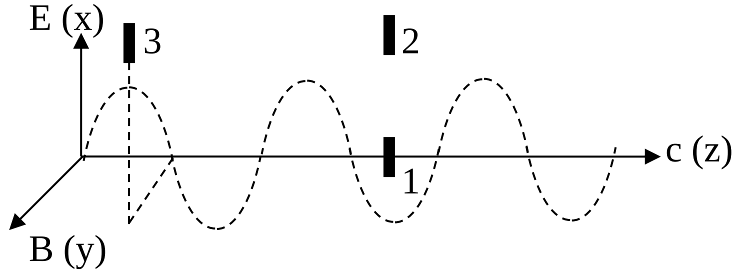
A) Red light B) Violet-blue light C) Same frequency

D) Depends on how the light is made

Answer: Red light has longer wavelength (λ = 700 nm). Violet-blue light has shorter wavelength λ (λ = 400 nm), and therefore higher frequency f. λ f = constant = c, so if λ is smaller, f must be higher.

CTEM-6.
An EM plane wave is described by

$$\vec{E} = E_0 \sin(kz - \omega t)\hat{x}, \ \vec{B} = B_0 \sin(kz - \omega t)\hat{y}$$

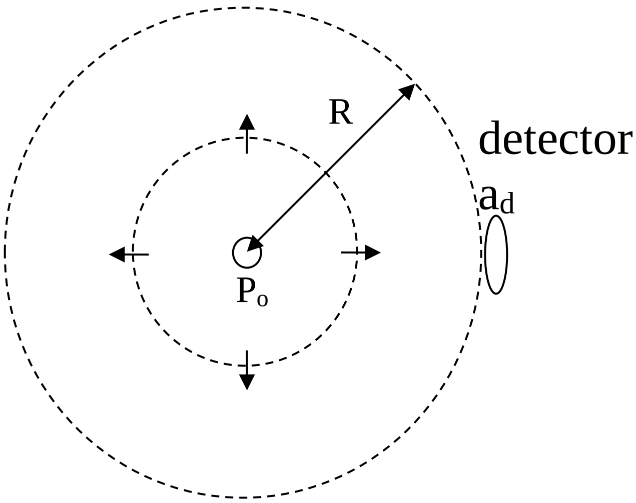


Consider 3 antennas, labeled 1, 2, and 3.
Antenna 1 is on the z axis.
Antenna 2 is in the xz plane, above 1.
Antenna 3 is is off the z-axis at the location shown.

Rank the antennas by average signal strength received, from largest to smallest:
A) 1 > 2 > 3 B) 1=2=3 C) 1 = 2 > 3

Answer: All the antennas experience the same average signal strength. The field amplitudes are completely indendent of xy position. And every antenna sees a sinusoidal wave of the same amplitude. 1=2=3

CTEM-7. A point source of radiation emits power P_o isotropically (in all directions uniformly). A detector of area a_d is located a distance R away from the source. What is the power p ***received*** by the detector?



A) $\dfrac{P_o}{4\pi R^2} a_d$

B) $P_o \dfrac{a_d^2}{R^2}$

C) $P_o \dfrac{a_d}{R}$

D) $\dfrac{P_o}{\pi R^2} a_d$

E) None of these.

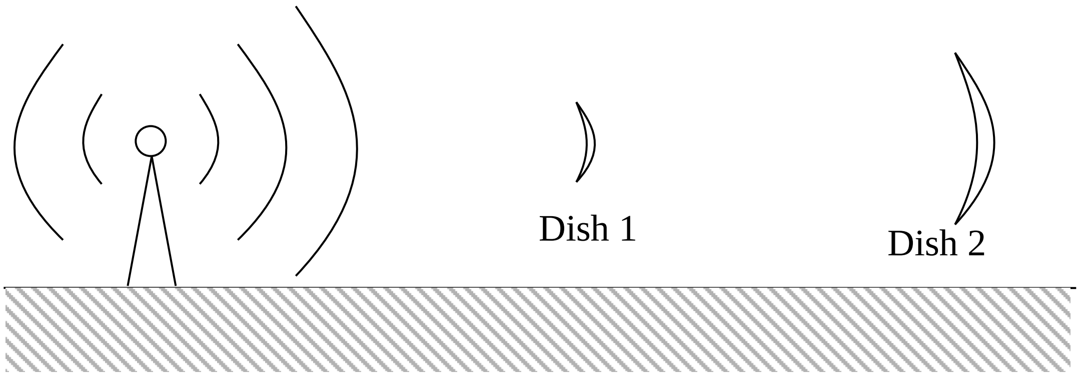
Answer: power received = (power/area) × (receiver area) = intensity× (receiver area) = $\dfrac{P_o}{4\pi R^2} a_d$

CTEM-8.

Two radio dishes (shaped like bowls) are receiving signals from a radio station which is sending out radio waves in all directions with power P. Dish 2 is twice as far away as Dish 1, but has twice the diameter. Which dish receives more power? (Dish 2 is not in the shadow of Dish 1.)

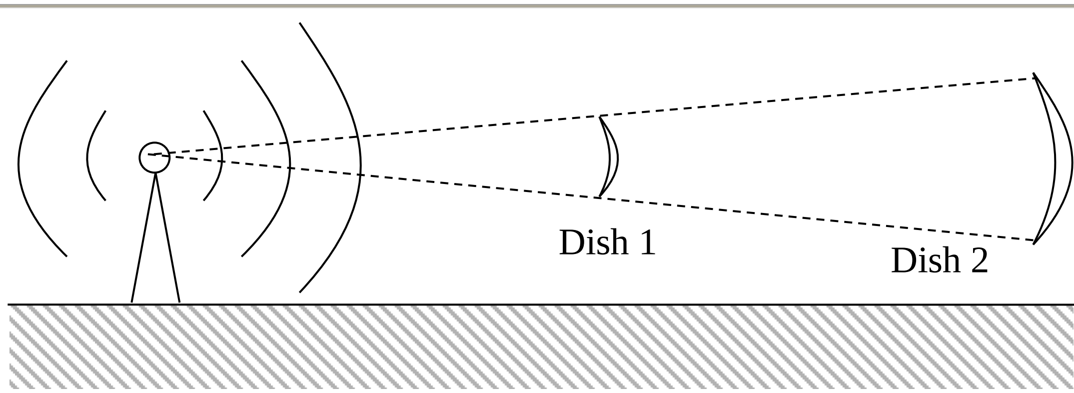
A: Dish 1 B: Dish 2

C: Both receive the same power



Answer: Both receive the same power. Dish 2 has <u>four</u> times the area (2 times the diameter). But dish 2 is twice as far away so it receive ¼ the power *per area* as dish 1. Remember: intensity = power per area is proportional to $1/R^2$, so if R doubles, R^2 increases by a factor of 4. The power received is given by the formula in the previous concept test: $\dfrac{P_o}{4\pi R^2} a_d$. For dish 2, a_d = detector area is 4 times as large as dish 1.

Notice that the dotted lines in the diagram below so that dish 1 and dish 2 both cover the same fraction of a big sphere centered on the transmitting tower. So dish 1 and dish 2 both receive the same fraction of the total energy coming from the tower.

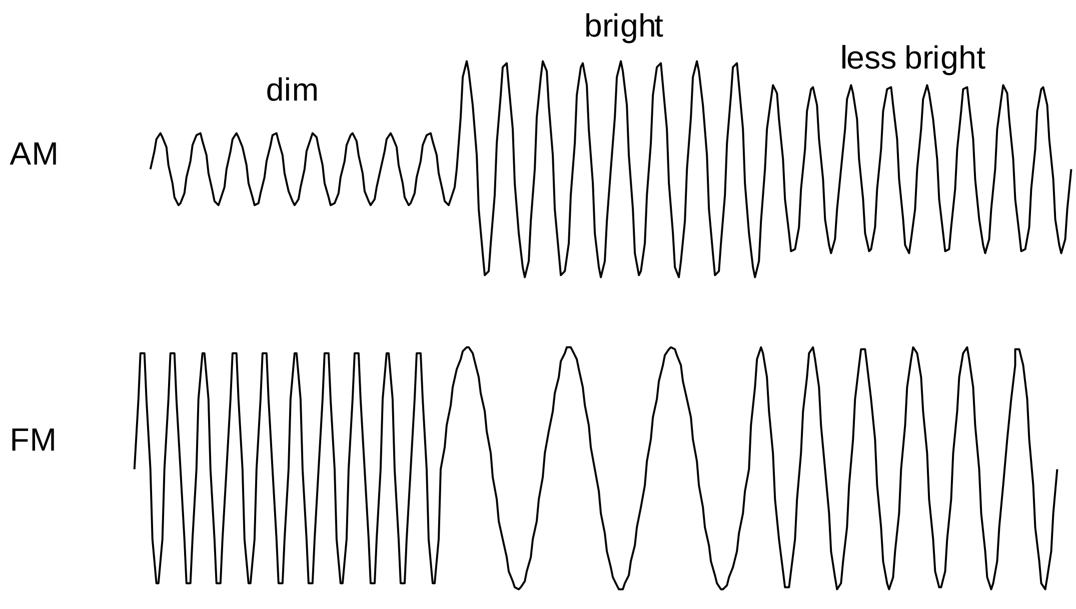


CTEM-9.
Under cover of night, a Girl scout signals her friends on a distant hill by alternately placing slabs of red or green Jell-O over her flashlight. This signal is most accurately described as..

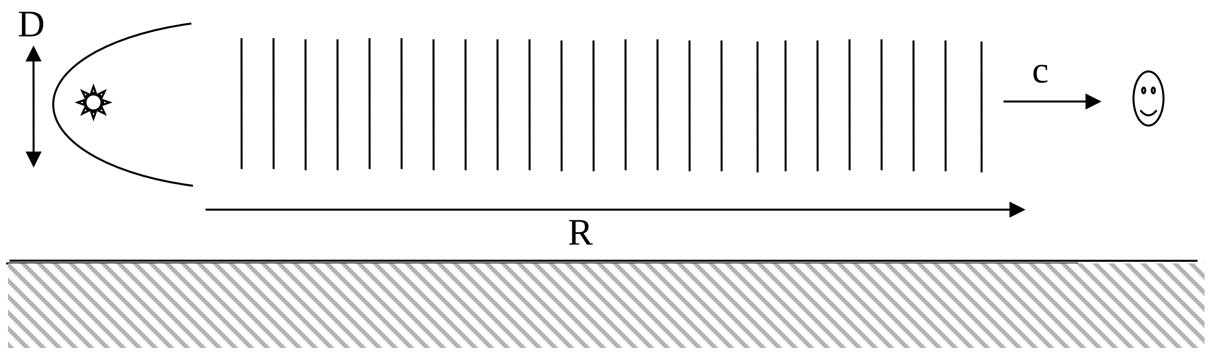
A) Frequency modulation.

B) Amplitude modulation.

Answer:
When the Girl scout signals by changing the color of the light (keeping the brightness fixed), this would be frequency modulation, because different frequencies of visible light correspond to different colors.
If the scout signals by alternately dimming and brightening the bulb, then that would be amplitude modulation. The brightness of the light is a measure of the amplitude of the electric field in the E/M waves from the light.



CTEM-10. A parabolic dish focuses the EM radiation from a source into a beam of constant diameter D :



The intensity of the light (I = power/area) in the beam falls with distance R as:

A) $I \propto \frac{1}{R^2}$

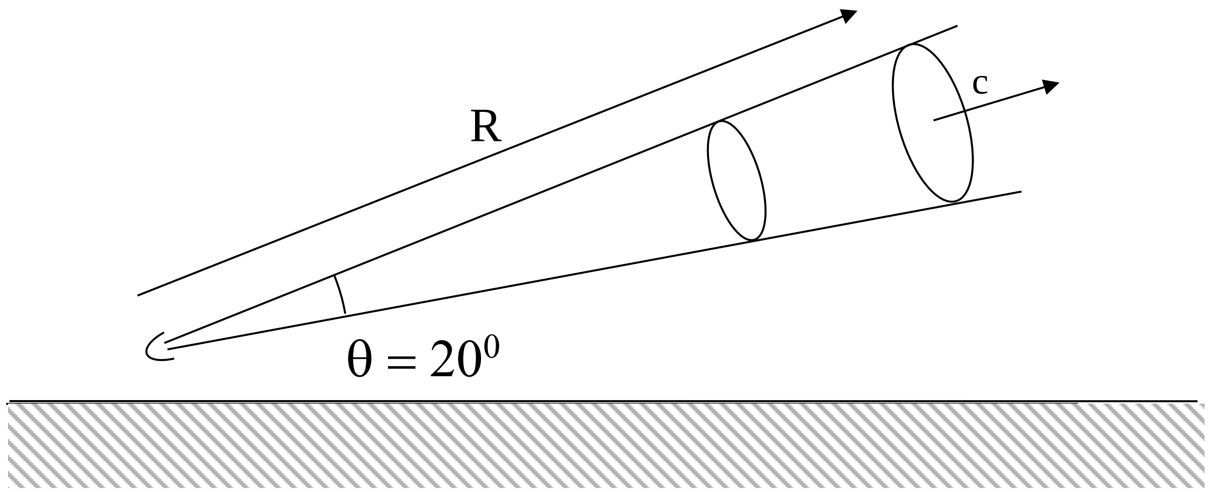
B) $I \propto \frac{1}{R}$

C) $I \propto \frac{1}{R^0} = \text{constant}$

D) Something else.

Answer: $I \propto \frac{1}{R^0} = \text{constant}$ The area over which the source power is spread is independent of the distance R.

CTEM-11. Light from a source is partially focused so that it diverges from the source uniformly over a cone of angle 20^0.



The intensity of the light in the beam falls with distance R as:

A) $I \propto \dfrac{1}{R^2}$

B) $I \propto \dfrac{1}{R^N}, \quad N > 2$

C) $I \propto \dfrac{1}{R^N}, \quad N < 2$

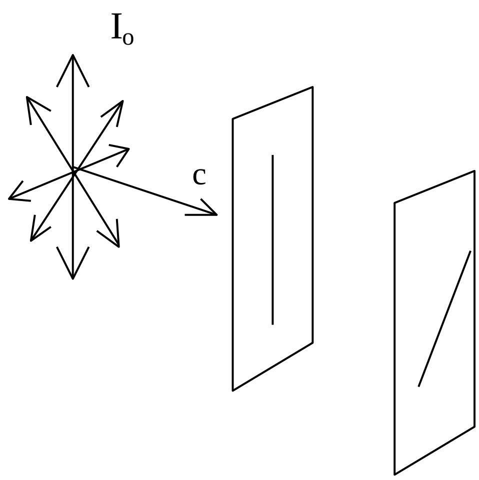
D) $I \propto \dfrac{1}{R^0} = \text{constant}$

D) Something else.

Answer: $I \propto \dfrac{1}{R^2}$. The cone is a constant fraction of a sphere.

CTEM-12. An unpolarized beam of light passes through 2 polaroid filters oriented at 45^o with respect to each other. The intensity of the original beam is I_o. What is the intensity of the light coming through both filters?

(Hints: $\cos 45^o = 1/\sqrt{2}$. The average of $\cos^2\theta$, average over all values of θ, is $\langle \cos^2\theta \rangle_{avg} = 1/2$.)



A: (1/2)Io

B: (1/4)Io

C: (1/8)Io

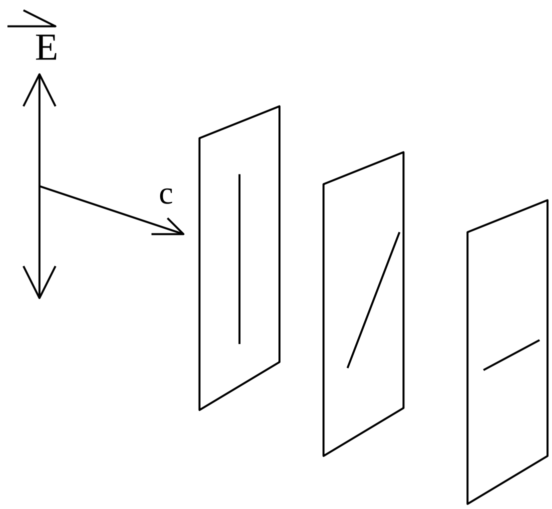
D: (1/16)Io

E: None

Answer: $(1/4)I_o$ After the first filter, the intensity is $I_1 = I_o(1/2)$. Reason: If the original beam were polarized, then after passing through one filter the intensity would be $I_1 = I_o \cos^2\theta$, but here the original beam is <u>unpolarized</u> so all angles θ are in the beam. The intensity after one filter is then $I_1 = I_o (\cos^2\theta)_{average} = I_o(1/2)$. After the second filter the intensity is $I_2 = I_1 \cos^2 45 = I_1 (1/2) = I_o(1/2)(1/2) = I_o(1/4)$.

CTEM-13.

A polarized beam of light passes through three ideal polaroid filters. The filters, in order 1^{st}, 2^{nd}, 3^{rd}, are tilted at 0^o, 45^o, and 90^o with respect to the incoming beam's axis. Does any light get through the all the filters and come out the other side?



A: Some light gets through.

B: No light gets through.

Answer: some light gets through. If the 2^{nd} filter were not present, then no light would get thru.

After the first filter, the E-field is unchanged, E_1=Eo. After the 2^{nd} filter the E-field is $E_2 = E_o \cos(45^o)$. After the third filter the E-field is $E_3 = E_2 \cos(45_o)=$
$E_o \cos(45^o) \cos(45^o) = E_o/2$. The intensity of the light (intensity I = S) is proportional to the E^2, so the final intensity is $I_o/4$.
