

Questions 1–5:

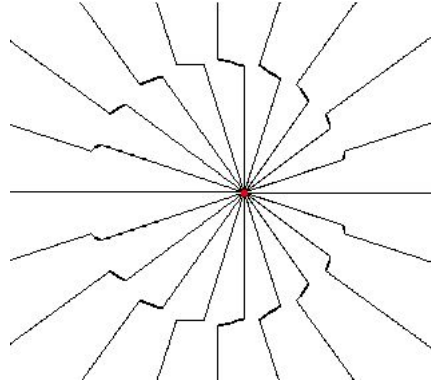


Figure 1:

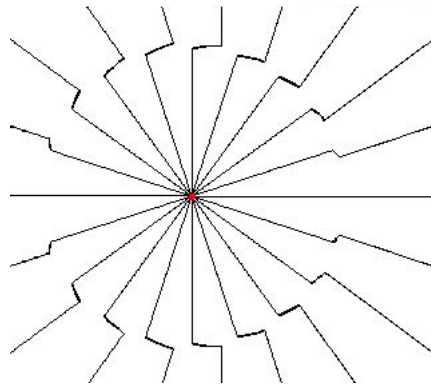


Figure 2:

Figure ?? and Figure ?? show a proton at rest that is briefly accelerated (“kicked”) by an external electric field and then moves at constant velocity. The electric field lines are shown (and point away from the particle). The direction of the brief acceleration of the proton is different in the two cases.

1. In which case was the proton briefly accelerated to the left?
 - (a) Figure ??
 - (b) Figure ??
 - (c) in both cases
 - (d) in neither case

2. In which case was the proton briefly accelerated to the right?
 - (a) Figure ??
 - (b) Figure ??
 - (c) in both cases
 - (d) in neither case

3. Suppose that “electric field detectors” are placed around a sphere at the same distance r from the source particle when the electromagnetic pulse is emitted (as a result of the brief kick). Which detector would measure the largest radiative (or transverse) electric field as the pulse passes the detector?
- the detector on the x-axis
 - the detector on the y-axis
 - the detector on the z-axis
 - Detectors on the y and z axes would both measure the largest radiative electric field.
 - All of the detectors would measure the same magnitude of radiative electric field.
4. Which detector would measure zero radiative (or transverse) electric field?
- the detector on the x-axis
 - the detector on the y-axis
 - the detector on the z-axis
 - Detectors on the x and z axes would both measure zero radiative electric field.
 - All of the detectors would measure zero radiative electric field.
5. Suppose that at $t=0$, the particle received the “kick” that changed its momentum during a very short time interval. At what time would a detector 1 km away from the particle detect the radiative (i.e. transverse) electric field?
- 3.00×10^5 s
 - 3.00×10^8 s
 - 3.33×10^{-9} s
 - 3.33×10^{-6} s
 - 1000 s

Questions 6–12: The radiative (i.e. transverse) electric field at a location \vec{r} from a previously accelerating *positively* charged particle as an electromagnetic pulse passes by is given by

$$\vec{E}_{radiative} = \frac{1}{4\pi\epsilon_0} \frac{-q\vec{a}_\perp}{c^2 r} \quad (1)$$

In Figure ?? is a particle with acceleration \vec{a} . At some later time, an electromagnetic pulse reaches point P. On Figure ??, sketch the following vectors:

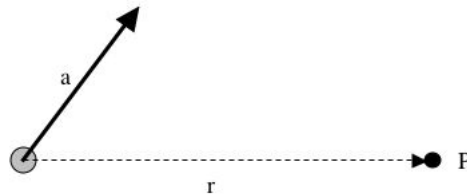


Figure 3:

- the vector \vec{a}_\perp
- the vector $\vec{E}_{radiative}$ (at the instant the EM pulse reaches point P)
- the vector $\vec{B}_{radiative}$ (at the instant the EM pulse reaches point P)
- the velocity of the pulse \vec{v}

10. Suppose the acceleration of the particle at time $t = 0$ is $1 \times 10^{20} \text{ m/s}^2$ and the angle between the acceleration vector and the vector \vec{r} to the point P is 30° . Point P is 5 m from the particle.
When (at what time) does an electromagnetic pulse reach point P?

11. What is the magnitude of the radiative electric field when the EM pulse reaches point P?

12. What is the magnitude of the radiative magnetic field when the EM pulse reaches point P?

Questions 13–14: White light (light that contains sinusoidal electromagnetic radiation composed of all wavelengths that make up visible light) is incident on a gas containing various types of atoms. The transmitted light (light that passes through the gas) is green.

13. Use a photon model of light to explain this phenomenon.

14. Use the classical model of light (as a sinusoidal electromagnetic wave) and the idea of scattering to explain this phenomenon.

Questions 15–20: (*reprinted from a Kaplan topical test on light and optics*) The propagation of plane polarized light is described by traveling electromagnetic waves. A vector \vec{S} , called the Poynting vector, points along the direction of propagation. The electric field vector \vec{E} points perpendicular to \vec{S} , and the magnetic field vector \vec{B} points perpendicular to both \vec{S} and \vec{E} . The plane of polarization is defined by S and E , and the magnitude of \vec{S} is given by $S = EB/\mu_0$, where μ_0 is the permeability constant.

The Poynting vector does more than just define the direction of propagation of an electromagnetic wave. It also measures the flux of energy carried by the wave. In fact, the time average of S over one period equals the power transmitted per unit area, which is the intensity of the wave. For plane polarized radiation propagating in a vacuum, \vec{E} and \vec{B} are not independent. Their magnitudes are related by $E = cB$, where c is the speed of the wave in a vacuum. The intensity I can therefore be written as $I = E_{rms}^2/(c\mu_0)$, where E_{rms} is the root-mean-square electric field.

Not only do electromagnetic waves carry energy, but they also carry momentum. Therefore, by Newton's second law, when light is either reflected or absorbed by a surface, a force is exerted on the surface. The radiation pressure for total absorption of light by the surface, p_a , is given by the equation $p_a = I/c$. (Note: the permeability constant is $\mu_0 = 4\pi \times 10^{-7} \text{ N}\cdot\text{s}^2/\text{C}^2$, the permittivity constant is $\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$, and the speed of light in a vacuum is $c = 3.00 \times 10^8 \text{ m/s}$.)

15. The permeability constant and the permittivity constant are related to the speed of light. Which of the following gives the correct relation?
 - (a) $c = \epsilon_0\mu_0$
 - (b) $c = 1/(\epsilon_0\mu_0)$
 - (c) $c = \sqrt{\epsilon_0/\mu_0}$
 - (d) $c = 1/\sqrt{\epsilon_0\mu_0}$
16. A circularly polarized beam of light propagates through a vacuum with wavelength equal to 600 nm. What is the frequency of the wave?
 - (a) $5 \times 10^{12} \text{ Hz}$
 - (b) $2 \times 10^{13} \text{ Hz}$
 - (c) $5 \times 10^{14} \text{ Hz}$
 - (d) $2 \times 10^{15} \text{ Hz}$
17. A plane polarized electromagnetic wave propagates with $E_{rms} = 30 \text{ V/m}$. What is the power transmitted to a circular disk of radius $r = 2 \text{ m}$, if all of the light is absorbed by the disk and \vec{S} is perpendicular to the disk?
 - (a) 10 J/s
 - (b) 30 J/s
 - (c) 60 J/s
 - (d) 90 J/s
18. λ and f are the respective wavelength and frequency of an electromagnetic wave traveling in a vacuum. Which of the following statements are true of the wave traveling in a medium having index of refraction n ?
 - I. Its speed equals c/n .
 - II. Its wavelength equals λ/n .
 - III. Its frequency equals fn .
 - (a) I only
 - (b) I and II only
 - (c) II and III only
 - (d) I, II, and III
19. A monochromatic electromagnetic wave propagates so that \vec{S} points out of the page, \vec{E} oscillates in the vertical direction, and \vec{B} oscillates in the horizontal direction. If the light passes through a polarizing filter with horizontal polarizing direction, then it will:
 - (a) have zero intensity.
 - (b) be polarized in the horizontal direction with half the intensity.
 - (c) be polarized in the horizontal direction with twice the intensity.
 - (d) be unpolarized with the same intensity.
20. When an electromagnetic wave is totally reflected by a surface, its change in momentum is double that when it is totally absorbed. The radiation pressure for total reflection, p_r , is therefore given by:
 - (a) $p_r = I/(2c)$
 - (b) $p_r = I/c$
 - (c) $p_r = 2I/c$
 - (d) $p_r = 4I/c$

21. Two polarizing lenses are aligned so that the intensity of transmitted light is a maximum. If the first lens is rotated 45° in a clockwise direction, through what angle must the second lens be rotated in a counterclockwise direction so that the intensity of transmitted light is again at a maximum?
- (a) 20°
 - (b) 45°
 - (c) 90°
 - (d) 135°

