sin 30° = cos 60° = \frac{1}{2} \quad sin 60° = cos 30° = \frac{\sqrt{3}}{2} \approx 0.87 \quad sin 45° = cos 45° = \frac{\sqrt{2}}{2} \approx 0.7

**Questions 1-2.** Consider a traveling sinusoidal wave, propagating with velocity 20 m/s and frequency 40 Hz.

1. What is the amplitude of the wave?
   - (a) 0.5 m
   - (b) 2 m
   - (c) 800 m
   - (d) cannot be answered

2. What is the wave-number of the wave?
   - (a) 2\pi m^{-1}
   - (b) 4\pi m^{-1}
   - (c) 8\pi m^{-1}
   - (d) cannot be answered

3. The velocity of a transverse wave on a stretched cord depends only on the tension in the cord.
   - (a) True
   - (b) False

**Questions 4-5.** Three charged particles are arranged as shown in the picture below. Their charges are \( q_1 = 1 \mu C, q_2 = -1 \mu C \) and \( q_3 = 2 \mu C \). Use \( k = 9 \times 10^9 \text{Nm}^2/\text{C}^2 \).

![Diagram of charged particles](image)

4. What is the electrostatic force on particle with charge \( q_2 \) due to charge \( q_3 \)?
   - (a) \( \frac{9}{5} \cdot 10^{-3} \text{N} \)
   - (b) \( \frac{1}{5} \cdot 10^{-3} \text{N} \)
   - (c) \( \frac{9}{5} \cdot 10^{-3} \text{N} \)
   - (d) \( 9 \cdot 10^{-3} \text{N} \)

5. What is the *net* electrostatic force on particle with charge \( q_1 \)?
   - (a) \( \sqrt{325} \cdot 10^{-3} \text{N} \)
   - (b) \( \sqrt{81} \cdot 10^{-3} \text{N} \)
   - (c) \( \sqrt{325} \cdot 10^{-3} \text{N} \)
   - (d) \( \sqrt{3} \cdot 10^{-3} \text{N} \)
6. The law of conservation of electric charge states: “The net amount of electric charge produced in any physical process is zero.”

(a) True   (b) False

Questions 7-8. Consider two charged objects $q_1$ and $q_2$ below.

7. Based on the electric field lines, charge $q_1$ is:

(a) positive  (b) negative  (c) cannot be answered

8. Based on the electric field lines, charge $q_2$ is:

(a) positive  (b) negative  (c) cannot be answered

Questions 9-10. Consider four objects with equal charges $q$, located at the corners of a square with side $a$, as shown below.

9. What is the magnitude of net electrostatic force on the object at the origin, due to the other three objects?

(a) $k \frac{q^2}{a^2}$  (b) $k \frac{q^2}{a^2} \left( \frac{1}{2} + \frac{1}{\sqrt{2}} \right)$  (c) $k \frac{q^2}{a^2} \left( \frac{1}{3} + \frac{1}{\sqrt{3}} \right)$  (d) $k \frac{q^2\sqrt{2}}{2a^2}$

10. The magnitude of electric field at the center of the square due to all four objects is:

(a) 0  (b) $k \frac{q}{2a^2}$  (c) $k \frac{q}{a^2} \left( \frac{1}{2} + \frac{1}{\sqrt{2}} \right)$  (d) $k \frac{q\sqrt{2}}{2a^2}$
11. The electric field is always _______________ to the surface outside a conductor.
   (a) parallel    (b) perpendicular    (c) cannot be answered

12. The combination of two equal charges of opposite sign, \( +Q \) and \( -Q \), separated by a distance \( l \), is referred to as:
   (a) electroscope    (b) ion    (c) electric dipole    (d) insulator

Questions 13-14. A uniform electric field \( \vec{E} \) is parallel to the axis of a hollow hemisphere of radius \( r \), as in the figure below.

13. What is the electric flux through the hemispherical surface?
   (a) 0    (b) \( \frac{4}{3} \pi r^3 E \)    (c) \( \pi r^2 E \)    (d) \( \frac{2}{3} \pi r^2 E \)

14. What is the electric flux through the hemispherical surface if the field \( \vec{E} \) is instead perpendicular to the axis?
   (a) 0    (b) \( \frac{4}{3} \pi r^3 E \)    (c) \( \pi r^2 E \)    (d) \( \frac{2}{3} \pi r^2 E \)

Questions 15-16. Suppose an electron traveling with speed \( v_0 \) enters a uniform electric field \( \vec{E} \), which is at right angles to \( \vec{v}_0 \), as in the picture below. **Hint:** The mass of the electron is \( m \).

15. The \( x \) component of electron’s acceleration is:
   (a) \( a_x = 0 \)    (b) \( a_x = -\frac{E}{v_0} \)    (c) \( a_x = -\frac{em}{E} \)    (d) \( a_x = -\frac{eE}{m} \)

16. The \( y \) component of electron’s acceleration is:
   (a) \( a_y = 0 \)    (b) \( a_y = -\frac{E}{v_0} \)    (c) \( a_y = -\frac{em}{E} \)    (d) \( a_y = -\frac{eE}{m} \)
Questions 17-20. Consider a non-conducting sphere of radius $r_0$ which has a spherical cavity of radius $r_1$ centered at the sphere’s center, as in the picture below. Assume the charge $Q$ is distributed uniformly in the “shell” (between $r_1$ and $r_0$).

17. What is the charge density $\rho$ on the shell?

(a) $\frac{Q}{4\pi \varepsilon_0 r_0^2}$
(b) $\frac{3Q}{4\pi (r_0^3 - r_1^3)}$
(c) $\frac{3Q}{4\pi (r_0^3 - r_1^3)}$
(d) $\frac{3Q}{4\pi (r_0^3 - r_1^3)}$

18. The electric field in the region $0 < r < r_1$ is:

(a) 0
(b) $\frac{1}{4\pi \varepsilon_0} \frac{Q}{(r_0 - r_1)^2}$
(c) $\frac{1}{4\pi \varepsilon_0} \frac{Q}{(r - r_1)^2}$
(d) $\frac{1}{4\pi \varepsilon_0} \frac{Q}{r^2}$

19. The electric field in the region $r_1 < r < r_0$ is:

(a) 0
(b) $\frac{Q}{4\pi \varepsilon_0 r^2} \frac{r^3 - r_1^3}{r_0^3 - r_1^3}$
(c) $\frac{Q}{4\pi \varepsilon_0 r^2} \frac{r^3 - r_0^3}{r_0^3 - r_1^3}$
(d) $\frac{3Q}{4\pi \varepsilon_0 r_0^2}$

20. The electric field in the region $r > r_0$ is:

(a) 0
(b) $\frac{1}{4\pi \varepsilon_0} \frac{Q}{(r_0 - r_1)^2}$
(c) $\frac{1}{4\pi \varepsilon_0} \frac{Q}{(r - r_1)^2}$
(d) $\frac{1}{4\pi \varepsilon_0} \frac{Q}{r^2}$