1. A cord of mass 4 kg is stretched between two supports 8 m apart. If the tension in the cord is 200 N, how long will it take a wave to travel from one support to the other?
   (a) 0.1 s  (b) 0.2 s  (c) 0.3 s  (d) 0.4 s

2. In a _______________ wave the oscillations are along the line of travel of the wave.
   (a) transverse  (b) parallel  (c) longitudinal  (d) gravitational

3. A transverse wave on a wire is given by $D(x,t) = 0.040 \sin(40\pi x - 1200\pi t)$, where $D$ and $x$ are in meters and $t$ is in seconds. What is the velocity of this wave?
   (a) 30 m/s  (b) 36 m/s  (c) 40 m/s  (d) 48 m/s

4. An object that has been charged by contact has __________________________ the charged object that touched it.
   (a) the same charge as  (b) the opposite charge from

5. Two uniformly charged spheres are firmly fastened to and electrically insulated from the table. The charge on sphere 2 is three times the charge on sphere 1. Which diagram below correctly shows the magnitude and direction of the electrostatic forces?

*Hint: $F_{12}$ is the force on sphere 1 exerted by sphere 2, and $F_{21}$ is the force on sphere 2 exerted by sphere 1.*
Questions 6-7. Three charged particles are placed at the corners of an equilateral triangle with side a, as in the picture below. Their charges are $Q_1 = +2q$, $Q_2 = +2q$ and $Q_3 = -q$.

6. What is the magnitude of electrostatic force on the charge $Q_2$ due to charge $Q_3$?

(a) $\frac{1}{4\pi\varepsilon_0} \frac{2q^2}{a^2}$  
(b) $\frac{1}{4\pi\varepsilon_0} \frac{4q^2}{a^2}$  
(c) $\frac{1}{4\pi\varepsilon_0} \frac{q^2}{2a^2}$  
(d) $\frac{1}{4\pi\varepsilon_0} \frac{q^2\sqrt{2}}{2a^2}$

7. What is the magnitude of the net electrostatic force on the particle with charge $Q_3$?

(a) $\frac{1}{4\pi\varepsilon_0} \frac{q^2}{\sqrt{2a^2}}$  
(b) $\frac{1}{4\pi\varepsilon_0} \frac{2q^2}{\sqrt{3a^2}}$  
(c) $\frac{1}{4\pi\varepsilon_0} \frac{q^2\sqrt{2}}{2a^2}$  
(d) $\frac{1}{4\pi\varepsilon_0} \frac{2q^2\sqrt{3}}{a^2}$

Questions 8-9. Consider two charged objects with charges $q_1$ and $q_2 = -2q_1$.

8. Which diagram below represents their electric field lines?

(a)  
(b)  
(c)  

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

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

10. The electric field vector is always _______________ to the surface outside of a conductor.

(a) parallel  
(b) perpendicular  
(c) cannot be answered
**Questions 11-12.** Two parallel circular rings of radius $R$ have their centers on the $x$ axis separated by a distance $l$. The left ring carries uniformly distributed positive charge $+Q$, and the right ring carries uniformly distributed negative charge $-Q$, as shown in the picture below.

![Diagram of parallel circular rings](image)

11. What is the magnitude of the net electric field at the origin (point O)?

(a) 0  
(b) $\frac{2kQl}{(l^2 + R^2)^{\frac{3}{2}}}$  
(c) $\frac{kQl}{(\frac{1}{4}l^2 + R^2)^{\frac{3}{2}}}$  
(d) $\frac{2kQl}{(\frac{1}{4}l^2 + R^2)^{\frac{3}{2}}}$

12. What is the magnitude of the net electric field at the center of the negatively charged ring (point B)?

(a) 0  
(b) $\frac{kQl}{(l^2 + R^2)^{\frac{3}{2}}}$  
(c) $\frac{2kQl}{(l^2 + R^2)^{\frac{3}{2}}}$  
(d) $\frac{1}{2} \frac{kQl}{(\frac{1}{4}l^2 + R^2)^{\frac{3}{2}}}$

13. If a charge of $31.4 \, \mu\text{C}$ is uniformly distributed on the surface of a sphere of radius $0.5 \, \text{m}$, the charge per unit area will be:

(a) $1 \frac{\mu\text{C}}{\text{m}^2}$  
(b) $6 \frac{\mu\text{C}}{\text{m}^2}$  
(c) $10 \frac{\mu\text{C}}{\text{m}^2}$  
(d) $60 \frac{\mu\text{C}}{\text{m}^2}$

14. The SI unit of electric flux is:

(a) $\frac{Nm}{C^2}$  
(b) $\frac{Cm^2}{N}$  
(c) $\frac{N^2m}{C}$  
(d) $\frac{Nm^2}{C}$

15. Consider a combination of two equal charges of opposite sign, $+3Q$ and $-3Q$, separated by a distance $3l$. The dipole moment of this dipole is:

(a) $Ql$  
(b) $3Ql$  
(c) $9Ql$  
(d) $27Ql$
16. A charge is located at the center of a spherical volume and the electric flux through the surface of the sphere is \( \Phi_0 \). What is the flux through the surface if the radius of the sphere doubles?

(a) \( \frac{\Phi_0}{4} \)  
(b) \( \frac{\Phi_0}{2} \)  
(c) \( \Phi_0 \)  
(d) \( 4\Phi_0 \)

Questions 17-18. 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. (The mass of the electron is \( m \)).

![Diagram of electron and electric field](image)

17. The \( x \) component of electron acceleration is:

(a) \( a_x = 0 \)  
(b) \( a_x = -\frac{E}{v_0} \)  
(c) \( a_x = -\frac{em}{E} \)  
(d) \( a_x = -\frac{eE}{m} \)

18. The \( y \) component of electron 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 19-20. A very long solid non-conducting cylinder of radius \( R_0 \) possesses a uniform volume charge density \( \rho \), as in the picture below.

![Diagram of cylinder and electric field](image)

19. What is the electric field inside the cylinder (for \( r<R_0 \))?

(a) \( \frac{r\rho}{4\pi\varepsilon_0 R_0^2} \)  
(b) \( \frac{r\rho}{2\varepsilon_0} \)  
(c) \( \frac{\rho R_0}{4\varepsilon_0 r} \)  
(d) \( \frac{\rho R_0 r}{4\pi\varepsilon_0} \)

20. What is the electric field outside the cylinder (for \( r>R_0 \))?

(a) \( \frac{r\rho}{4\pi\varepsilon_0 R_0^2} \)  
(b) \( \frac{r\rho}{2\varepsilon_0} \)  
(c) \( \frac{\rho R_0}{4\pi r} \)  
(d) \( \frac{\rho R_0^2}{2r\varepsilon_0} \)