Final Exam

1. Three charges form an equilateral triangle of side length $d = 2$ cm. The top charge is $q_3 = 3 \, \mu C$, while the bottom two are $q_1 = q_2 = -6 \, \mu C$. What is the magnitude of the net force acting on $q_3$?

![Equilateral Triangle with Charges]

(1) 350 N (2) 810 N (3) 700 N (4) 405 N (5) 0 N

2. A glass rod forms a semi-circle of radius $r = 4$ cm with a charge of $-q$ distributed uniformly along the right quadrant and $+q$ distributed along the left quadrant, where $q = 5 \, pC$. What is the magnitude and the direction (as the polar angle relative to the direction of the x-axis) of the electric field at the center $P$ of the semi-circle.

![Semi-Circle with Charges]

(1) 45 N/C, $\theta = 180^\circ$ (2) 45 N/C, $\theta = 270^\circ$ (3) 0 N/C (4) 29 N/C, $\theta = 90^\circ$ (5) 29 N/C, $\theta = 0^\circ$

3. A parallel plate capacitor with capacitance $0.5\mu F$ is connected to a 6V battery. If the plates are squeezed to half of their original separation, what will be the charge stored on the capacitor?

(1) $0.5\mu C$ (2) $3\mu C$ (3) $1.5\mu C$ (4) $6\mu C$ (5) $12\mu C$
4. A beam of electrons ("cathode rays") is sent between two parallel electric plates with an electric field between them of \( E = -2 \times 10^4 \text{ N/C} \). If the electron beam travels perpendicular to the electric field with a velocity of \( v = 4.2 \times 10^7 \text{ m/s} \) in the \(+\hat{i}\)-hat direction, what magnetic field is necessary (direction and magnitude) so that the electrons continue traveling in a straight line without deflection by the electric field?

(1) \( 4.8 \times 10^{-4} \hat{k} \text{ T} \)  
(2) \( -4.8 \times 10^{-4} \hat{k} \text{ T} \)  
(3) \( 2.0 \times 10^4 \hat{j} \text{ T} \)  
(4) \( -2.0 \times 10^4 \hat{j} \text{ T} \)  
(5) \( 2.1 \times 10^3 \hat{i} \text{ T} \)

5. Part of a long insulated wire carrying current \( i = 4 \text{ A} \) is bent into a circular section of radius \( R = 1.5 \text{ cm} \) as shown in the figure. What is the magnitude of the magnetic field (in T) at the center of curvature \( C \) if the circular section lies in the plane of the page as shown?

(1) \( 1.1 \times 10^{-4} \) T  
(2) \( 5.3 \times 10^{-5} \) T  
(3) \( 1.7 \times 10^{-4} \) T  
(4) \( 2.2 \times 10^{-4} \) T  
(5) \( 5.0 \times 10^{-6} \) T

6. A series RLC circuit is driven by a sinusoidally-varying EMF source. The current lags the EMF by \( 30^\circ \). What can be concluded about the driving frequency \( \omega \)?

(1) \( \omega = \frac{1}{\sqrt{LC}} \)  
(2) \( \omega < \frac{1}{\sqrt{LC}} \)  
(3) \( \omega > \frac{1}{\sqrt{LC}} \)  
(4) \( \omega = 0 \)  
(5) \( \omega = \infty \)

7. A constant current of \( i = 3 \text{ A} \) is used to charge a parallel plate capacitor with circular plates of radius \( R = 1 \text{ cm} \). What is the magnitude of the magnetic field at a radius of \( r = 0.3 \text{ cm} \), which is less than \( R \), in the region between the plates?

(1) \( 3.8 \times 10^{-6} \text{ T} \)  
(2) \( 6 \times 10^{-5} \text{ T} \)  
(3) \( 1.2 \times 10^{-4} \text{ T} \)  
(4) \( 1.8 \times 10^{-5} \text{ T} \)  
(5) \( 0 \text{ T} \)
8. Light traveling horizontally enters a right prism as shown in the figure. The index of refraction of the prism is \( n = 1.6 \), and it is surrounded by air. What is the measure of the angle \( \theta_2 \) that the light deflected from horizontal when it exits the prism?

\[
\begin{align*}
\theta_1 &\quad 45^\circ \\
\theta_2 &
\end{align*}
\]

(1) 26° (2) 31° (3) 19° (4) 45° (5) 0°

9. An object is placed 40cm in front of a converging lens with a focal length of 60cm. Where is the image?

(1) 120 cm behind the lens
(2) 60 cm behind the lens
(3) 120 cm in front of the lens
(4) 17 cm behind the lens
(5) 40 cm in front of the lens

10. A thin anti-reflective coating with an index of refraction of \( n_1 = 1.4 \) is placed on a lens with an index of refraction of \( n_2 = 1.5 \). What is the minimum coating thickness in nm needed to ensure that light of wavelength 490nm in air and of perpendicular incidence will be reflected from the two surfaces of the coating with fully destructive interference? Assume that the lens+coating is in air.

(1) 245 (2) 122 (3) 490 (4) 175 (5) 88

11. A point particle with charge \( q \) is at the center of a Gaussian surface in the form of a cube. The electric flux through any one face of the cube is:

(1) \( q/16\varepsilon_0 \) (2) \( q/4\pi\varepsilon_0 \) (3) \( q/4\varepsilon_0 \) (4) \( q/\varepsilon_0 \) (5) \( q/6\varepsilon_0 \)
12. A total charge of $7 \times 10^{-8}$ C is uniformly distributed throughout a non-conducting sphere with a radius of 5 cm. The electric potential at the surface, relative to the potential far away, is about:

(1) $-1.3 \times 10^4$ V  (2) $1.3 \times 10^4$ V  (3) $7 \times 10^5$ V  (4) $-6.3 \times 10^4$ V  (5) 0

13. Five cylindrical wires are made of the same material. Their lengths and radii are

- wire 1: length $l$, radius $r$
- wire 2: length $3l/2$, radius $r/2$
- wire 3: length $l/2$, radius $r/2$
- wire 4: length $l$, radius $r/2$
- wire 5: length $5l$, radius $r/2$

Rank the wires according to their resistances, least to greatest.

(1) 1, 3, 5, 2, 4  (2) 5, 4, 3, 2, 1  (3) 1 and 2 tie, then 5, 3, 4  (4) 1, 3, 4, 2, 5  (5) 1, 2, 4, 3, 5

14. The current in the 5.0-Ω resistor in the circuit shown is:

![Circuit Diagram]

(1) 0.42 A  (2) 0.67 A  (3) 1.5 A  (4) 2.4 A  (5) 3.0 A
15. A rod with resistance $R$ lies across frictionless conducting rails in a constant uniform magnetic field $B$, as shown. Assume the rails have negligible resistance. The magnitude of the force that must be applied by a person to pull the rod to the right at constant speed $v$ is:

(1) $BLv/R$
(2) $BLv$
(3) $B^2L^2v/R$
(4) 0
(5) $B^2Lxv/R$

16. A parallel plate capacitor has circular plates with a radius $R=3cm$ and a time-dependent electric field between them of $(1.5 \times 10^6 \text{ V/m-s}) t$. What is the magnitude of the induced magnetic field at a radius of $r=4cm$ from the central axis connecting the centers of the plates, which is larger than the radius $R$ covered by electric field?

(1) 0 T (2) $1.4 \times 10^{-13}$ T (3) $2.5 \times 10^{-13}$ T (4) $6.6 \times 10^{-11}$ T (5) $1.9 \times 10^{-13}$ T

17. A sinusoidal electromagnetic wave with an electric field amplitude of 100 V/m is incident normally on a surface with an area of 1 cm$^2$ and is completely absorbed. The energy absorbed in 10 s is:

(1) 130 mJ (2) 1.3 mJ (3) 27 mJ (4) 13 mJ (5) 270 mJ

18. The figure shows a concave mirror with a small object located at the point marked 6. If the image is also at this point, then the center of curvature of the mirror is at the point marked:

(1) 3 (2) 4 (3) 6 (4) 9 (5) 12
19. The diagram shows a single slit with the direction to a point P on a distant screen shown. At P, the pattern has its second minimum (from its central maximum). If X and Y are the edges of the slit, what is the path length difference \((PX) - (PY)\)?

\((1) \lambda \quad (2) 2\lambda \quad (3) \frac{3}{2}\lambda \quad (4) \frac{\lambda}{2} \quad (5) \frac{5}{2}\lambda\)

20. Monochromatic light is normally incident on a diffraction grating that is 1 cm wide and has 10,000 slits. The first order line is deviated at a 30° angle. What is the wavelength, in nm, of the incident light?

\((1) 600 \quad (2) 400 \quad (3) 300 \quad (4) 500 \quad (5) 1000\)