Practice Test 2 Solutions

**Problems 1-5. Multiple Choice/Short Answer (5 points each / 25 points total)**

1. A proton (mass = 1.67 x $10^{-27}$ kg, charge = +e) moves 0.050 m in the $\underline{+X \text{ direction}}$ through a uniform electric field E which increases its speed from $v_0$ = 2.0 x $10^6$ m/s to $3v_0$. The magnitude and direction of E are (in N/C)

   (A) 0.42, +*X* direction

   [✓ (B) 3.3 x $10^6$,+*X* direction]

   (C) 3.3 x $10^6$, -*X* direction

   (D) 1.7 x $10^6$,+*X* direction

   (E) 1.7 x $10^6$, -*X* direction

$V = 6E6\,m/s \quad v_0 = 2E6\,m/s \quad m = 1.67E{-}27\,kg$

$F = ma \quad \Delta x = 0.05\,m \quad q = 1.6E{-}19C$

$V^2 = V_0^2 + 2a\Delta x \quad E = \frac{F}{q}$

$$a = \frac{v^2 - v_0^2}{2\Delta x} = \frac{(6E6\,m/s)^2 - (2E6\,m/s)^2}{2 \cdot .05m} = 3.2E14\,m/s^2$$

$$F = 1.67E{-}27\,kg \cdot 3.2E14\,m/s^2 = 5.34\,E{-}13\,N$$

$$E = \frac{5.3E{-}13N}{1.6E{-}19C} = 3.3\,E6\,N/C$$

2. Two point charges, -30 μC and +10 μC, are both inside a (closed) Gaussian surface. A third point charge, +20 μC, is outside the Gaussian surface. The net flux through the Gaussian surface is, (in Nm2/C)

   (A) zero

   [✓ (B) -2.3 x $10^6$]

   (C) +2.3 x $10^6$

   (D) +4.5 x $10^6$

   (E) -4.5 x $10^6$

$$\Phi = \frac{q_{enc}}{\varepsilon_0} = \frac{(-30\mu C + 10\mu C)}{8.85E{-}12\ C^2/Nm^2} = -2.3E6\ \frac{Nm^2}{C}$$

3. A thin wire is charged uniformly with 1.5 coulombs per meter. A cylindrical Gaussian surface with end caps is centered on the wire as shown. Its radius is r and its length is L. Applying Gauss's law to this closed surface gives (E is the magnitude of the field at the surface of the cylinder)

   (A) E (π $r^2$ L) = (λ L)/$\varepsilon_0$

   (B) E (r L) = (λ L)/$\varepsilon_0$

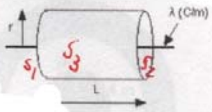
   (C) E (π $r^2$) = (λ L)/$\varepsilon_0$

   (D) E (π $r^2$ L) = (λ π $r^2$)/$\varepsilon_0$

   (E) E (2πr L) = (λ L)/$\varepsilon_0$

   Answer is

   [✓ (E) E (2πr L) = (λ L)/$\varepsilon_0$]



$LHS = RHS$

$q_{enc} = \lambda L =$ [redacted] $C/m \cdot m = C$ ✓

$$RHS = \frac{q_{enc}}{\varepsilon_0} = \frac{\lambda L}{\varepsilon_0}$$

$$LHS = \oint \vec{E} \cdot d\vec{A} = \underbrace{\int_{S_1} \cancel{\vec{E} \cdot d\vec{A}}^{\,0}}_{E \perp d\vec{A}} + \underbrace{\int_{S_2} \cancel{\vec{E} \cdot d\vec{A}}^{\,0}}_{E \perp d\vec{A}} + \int_{S_3} \vec{E} \cdot d\vec{A}$$

$$= \int_{S_3} |\vec{E}| \cdot |d\vec{A}| \underbrace{\cos\theta}_{\theta = 0}{}^{1} = |\vec{E}| \int |d\vec{A}| = E \cdot Area_{S_3} = E(2\pi r L)$$

$$\Phi_G = E(2\pi r L) = \frac{\lambda L}{\varepsilon_0}$$

4. A +20 µC point charge moves 2 m parallel to a uniform electric field of magnitude $6.0 \times 10^5$ N/C. The work done on the charge by the electric field is

(A) 48 Nm [redacted]

(B) 12 Nm

$\vec{F} = q\vec{E} = 2E\text{-}5 C \cdot 6E5 N/C = 12 N$

(C) 6.0 Nm

force constant

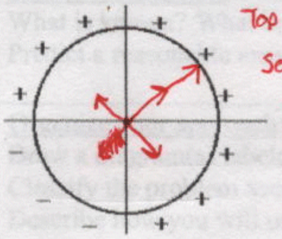
[✓ (D) 24 Nm]

$W = \int \vec{F} \cdot d\vec{r} = \int |A| \cdot |\vec{br}| \overset{\parallel}{\underset{\theta=0}{\cancel{\cos\theta}}} =$ [redacted] $|F| \int |d\vec{r}| = F \cdot \text{displacement} = 12N \cdot 2m = 24Nm$

(E) $1.2 \times 10^6$ Nm

[redacted]

5. A circular ring of charge is made by joining four-quarter circles, each having the same magnitude of charge as the others. Each quarter circle has its net charge uniformly distributed over its length. Let the field at the center of the circle due to one quarter circle be $E_1$. The magnitude of the total electric field at the center is then

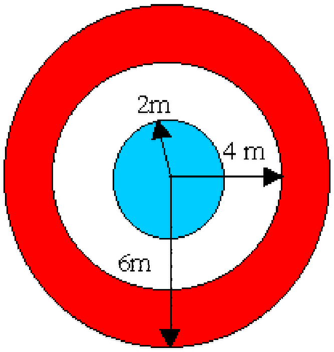


Top left & bottom right of the circle cancel, as can be seen with vector addition so their charge does not contribute to Enet. The bottom left & top right combine w/ vector addition Each ~~being~~ contributing $E_1$, so $2E_1$ will be the total E-field at the center

(A) zero (B) E1 [✓ (C) 2 E1] (D) 3 E1 (E) 4 E1

6. Essay (15 points): You may use diagrams and equations but no calculations for this problem.

A positively charged conducting sphere of radius 2m is inside a conducting shell as shown below. There is an air gap between the two spheres. The spherical conducting shell has no net charge on it. Sketch a graph of the E-field as a function of the radial distance *r* (an E-field vs. *r* graph). Explain why the graph appears as you have drawn it.



Name & Group ________________________________

7. (GOAL Problem: 20 points) For the following problem, do the **G** and **O** steps of **GOAL only**. Your O step should include a statement of the main physics principles used, why you are using them, and how you would use them to solve the problem. **Do not solve the problem**..

You have landed a summer job working with an Astrophysics group investigating the origin of high-energy particles in the galaxy. The group you are joining has just discovered a large spherical nebula with a radius 1.0 million km. The nebula consists of about 5 x $10^9$ hydrogen nuclei (protons) which appear to be distributed uniformly in the shape of a sphere (the protons are distributed uniformly throughout the sphere. At the center of this sphere of positive charge is a very small neutron star. Your group had detected electrons emerging from the nebula. A friend of yours has a theory that the electrons are coming from the neutron star. To test that theory, she asks you to calculate the E-field inside the nebula as a function of radial distance. From the inside cover of your trusty physics text you find that the charge of a proton (and an electron) is 1.6 x $10^{-19}$ C, the mass of the proton is 1.7 x $10^{-27}$ kg, and the mass of the electron is 9.1 x $10^{-31}$ kg.

Find the E-field at a distance of half the radius of the nebula.

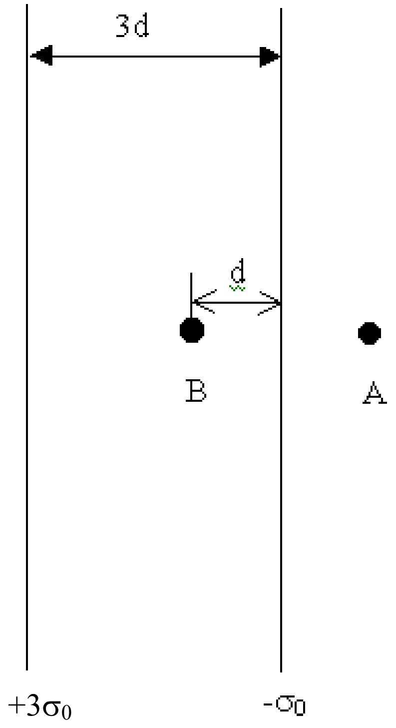
### GOAL Problem-solving Protocol

| |
|---|
| **G**ather information:<br>What is known? What are you looking for?<br>Predict a reasonable answer with units. (Consider limiting cases.) |
| **O**rganize your approach:<br>Draw a diagram(s) labeled with variables from **G** step.<br>Classify the problem according to the general physics principle(s) used.<br>Describe how you will use the general principle(s) to solve the problem. |

8. (20 points) Two very large charged sheets are placed a distance 3d apart (only a small portion of the plates is shown). The sheet on the left has an area charge density of $+3\sigma_0$ and the sheet on the right has area charge density $-\sigma_0$.

   A. Find the net electric field vector at points A (at a distance d to the right of the right plate) and B (at a distance d to the left of the right plate).

   B. What is the minimum amount of work you would have to do to move an electron from the + sheet to the negative sheet if $\sigma_0 = 1.5\ \mu C/m^2$ and d = 10 cm.



9. Suppose a hole is made in the middle of the positive plate in problem 8. If an electron were released from the middle of the (–) plate, it would accelerate towards the positive plate. What speed would the electron have when it passed through the hole in the positive plate. (This is one of the simplest forms of particle accelerator.)