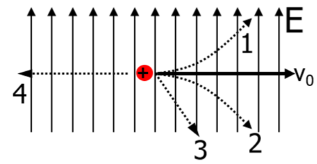
Exam Total
/200

PHYS 2135 Exam I
September 17, 2019

Name: ____________________ Section: _________

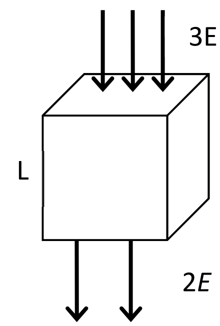
For questions 1-5, select the best answer. For problems 6-9, solutions must begin with an Official Starting Equation, when appropriate. Work must be shown to receive credit. Calculators are not allowed.

(8) __**A**__ **1.** A proton is moving with speed $\vec{v}_0$ in a uniform electric field. Which of the four dotted lines best represents the trajectory of the proton?
[A] 1 [B] 2 [C] 3 [D] 4

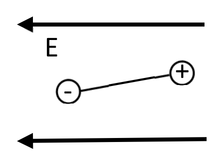


(8) __**A**__ **2.** The electric potential in a certain region of space is $V = 6xy^2(\mathrm{V/m^4}) - 4x^2(\mathrm{V/m^3}) + 62y(\mathrm{V/m^2})$. The *x*-component of the electric field at *x* = 2.0 m, y = 1.0 m is …
[A] +10 V/m
[B] -10 V/m
[C] -65 V/m
[D] 58 V/m

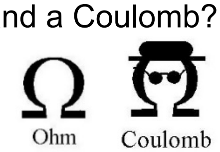
(8) __**C**__ **3.** A cube of side *L* has a vertical electric field of uniform magnitude 3*E* at its top surface and of magnitude 2*E* at its bottom surface. What is the charge contained in the cube?
[A] 0 [B] $\varepsilon_0 EL^2$ [C] $-\varepsilon_0 EL^2$ [D] $5\varepsilon_0 EL^2$.



(8) __**B**__ **4.** An electric dipole is released in a uniform electric field, as illustrated. Which direction will the dipole rotate and what is its potential energy? [The dipole is in the plane of the paper.]
[A] counterclockwise, U is near its minimum
[B] counterclockwise, U is near its maximum
[C] clockwise, U is near its minimum
[D] clockwise, U is near its maximum



(8) ________ **5** (Free). For those reading ahead, what's the difference between an Ohm and a Coulomb?

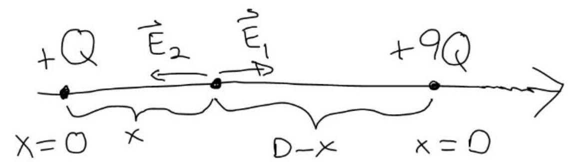
[A]


[B] Ask Sherlock Ohms
[C] Only Ohm can resist Coulomb.
[D] Ohm doesn't know how to conduct himself.

/40

6. Two point charges are placed on the x-axis. The first point charge $+Q$ is placed at $x = 0$ and the second point charge $+9Q$ is placed at $x = D$.

(10) (a) Find a location on the x-axis that the net electric field is zero. Express your answer in terms of the given parameters.



OSE: $\vec{E} = k\frac{q}{r^2}\hat{r}$

$\vec{E}_T = \vec{E}_1 + \vec{E}_2$ $0 = k\frac{Q}{x^2}\hat{\imath} - k\frac{9Q}{(D-x)^2}\hat{\imath}$

$$\frac{9}{(D-x)^2} = \frac{1}{x^2}$$

$$3x = D - x$$

$$\boxed{x = \frac{D}{4}}$$

(10) (b) A third point charge $+q_0$ is located midway between the two point charges, $+Q$ and $+9Q$. What is the net force on the third charge? Express your answer in unit vector notation.

OSE: $\vec{F} = k\frac{q_2 q_2}{r_{12}^2}\hat{r}_{12}$

$$\vec{F}_T = \vec{F}_1 + \vec{F}_2 = \frac{kq_0Q}{\left(\frac{D}{2}\right)^2}\hat{\imath} - \frac{kq_0(9Q)}{\left(\frac{D}{2}\right)^2}\hat{\imath} = \frac{4kq_0Q}{D^2}(1-9)\hat{\imath}$$

$$\boxed{\vec{F}_T = -\frac{32kq_0Q}{D^2}\hat{\imath}}$$

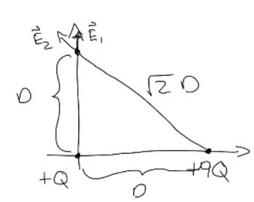
(20) (c) Find the electric field at point (0, D). If a third point charge $+q_0$ is located at (0, D), what is the net force on the third charge? Express your answer in unit vector notation.

OSE: $\vec{E} = k\frac{q}{r^2}\hat{r}$ $\hat{r} = -\cos 45°\,\hat{\imath} + \sin 45°\,\hat{\jmath}$

$$\vec{E}_T = \vec{E}_1 + \vec{E}_2 = \frac{kQ}{D^2}\hat{\jmath} + \frac{9kQ}{2D^2}\left(-\frac{1}{\sqrt{2}}\hat{\imath} + \frac{1}{\sqrt{2}}\hat{\jmath}\right)$$ $\hat{r} = -\frac{\hat{\imath}}{\sqrt{2}} + \frac{\hat{\jmath}}{\sqrt{2}}$

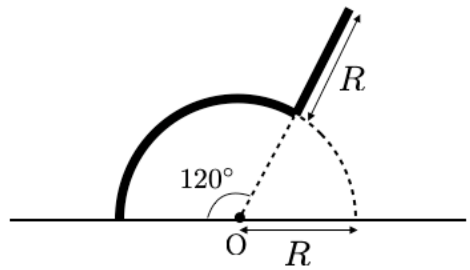
$$\vec{E}_T = -\frac{9kQ}{2D^2\sqrt{2}}\hat{\imath} + \frac{kQ}{D^2}\left(1 + \frac{9}{2\sqrt{2}}\right)\hat{\jmath}$$

$$\boxed{\vec{F} = q_0\vec{E} = -\frac{9kq_0Q}{2D^2\sqrt{2}}\hat{\imath} + \frac{kq_0Q}{D^2}\left(1 + \frac{9}{2\sqrt{2}}\right)\hat{\jmath}}$$



/40

7. An arc of radius *R* and a rod of length *R* are located as shown. The arc subtends an angle of 120 degrees. Both the arc and the rod have a negative uniform charge per unit length $-\lambda$. Express your answers with *R*, λ, and constants. If your work involves an integral, you need to perform the integral to get a full credit.



(6) (a) Determine the total charge sum of the arc and the rod.

OSE: $\lambda \equiv \frac{\text{charge}}{\text{length}}$

$$Q = -\lambda[2\pi R\left(\frac{1}{3}\right) + R]$$

$$\boxed{Q = -\lambda R(\frac{2}{3}\pi + 1)}$$

(12) (b) Determine the electric potential from **the arc** at the origin. You may assume that *V = 0* at infinity.

OSE: $V = k\frac{q}{r}$

$$dV = k\frac{dq}{r}$$

$$dV = -k\lambda d\phi$$

$$V = -k\lambda \int_{\pi/3}^{\pi} d\phi = \boxed{-\frac{2\pi k\lambda}{3}}$$

(12) (c) Determine the electric potential from **the rod** at the origin. You may assume that *V = 0* at infinity.

OSE: $V = k\frac{q}{r}$

$$V = -k\lambda \int_{R}^{2R} \frac{dr}{r} = \boxed{-k\lambda \ln 2}$$

$$dV = k\frac{dq}{r}$$

(10) (d) An electron (mass *m* and charge *-e*) is released from rest at the origin. Determine the maximum velocity of the electron after it is released.

OSE: $E_f - E_i = (W_{\text{other}})_{i\to f}$

$$U_i + K_i = U_f + K_f$$

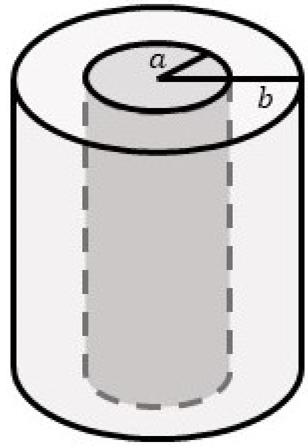
$$U_i = -eV = ek\lambda\left(\frac{2}{3}\pi + \ln 2\right)$$

$$U_i = \frac{1}{2}mv^2 + U_f \leq \frac{1}{2}mv_{\text{max}}^2$$

$$\boxed{v_{\text{max}} = \sqrt{\frac{2ek\lambda}{m}(\frac{2}{3}\pi + \ln 2)}}$$

/40

8. An infinitely long insulating cylinder of radius a with uniform charge density ρ lies along the axis of symmetry of an infinitely long conducting cylindrical shell of inner radius a and outer radius b, as illustrated. The electric field outside the conducting cylindrical shell ($r > b$) is found to be zero.



(15) (a) Determine the electric field inside the insulating cylinder ($0 < r < a$).

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0}$$

$$E(2\pi rL) = \frac{\rho(\pi r^2 L)}{\epsilon_0}$$

$$\boxed{\vec{E} = \frac{\rho r}{2\epsilon_0}\hat{r}}$$

(10) (b) Determine the electric field within the conducting cylindrical shell ($a < r < b$).

$\vec{E} = 0$, inside the conductor

(10) (c) Express the surface charge density σ_a at the inner surface of the conducting shell in terms of variables introduced above.

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0}$$

$$0 = \frac{q_{\text{enc}}}{\epsilon_0} \Rightarrow q_{\text{enc}} = 0$$

$$\pi a^2 L\rho + 2\pi a L\sigma_a = 0$$

$$\boxed{\sigma_a = -\frac{a\rho}{2}}$$

(5) (d) Express the surface charge density σ_b at the outer surface of the conducting shell in terms of variables introduced above.

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0}$$

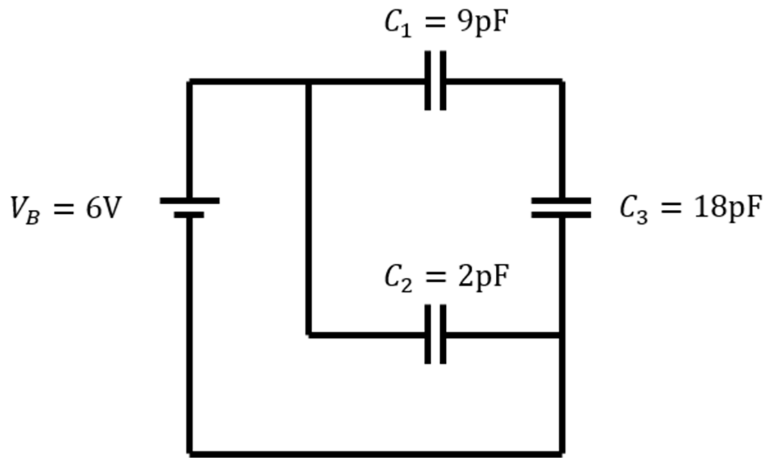
$$0 = \frac{q_{\text{enc}}}{\epsilon_0}$$

$$\pi a^2 L\rho + 2\pi a L\sigma_a + 2\pi b L\sigma_b = 0$$

$$\boxed{\sigma_b = 0}$$

/40

9. Consider the given circuit. [Provide numerical answers for each part.]



(15) (a) Determine C_T, the total equivalent capacitance.

$$C_{13} = \left(\frac{1}{9\text{pF}} + \frac{1}{18\text{pF}}\right)^{-1} = 6\text{pF}$$

$$C_T = 6\text{pF} + 2\text{pF}$$

$$\boxed{C_T = 8\text{pF}}$$

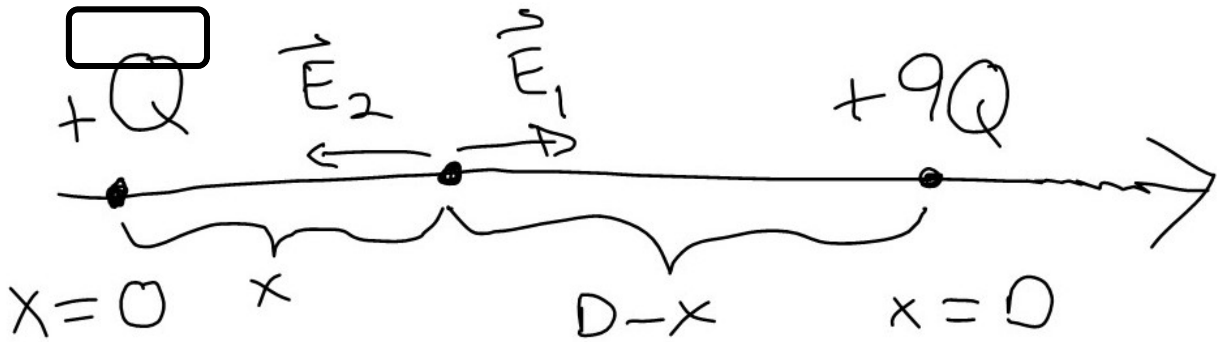
(15) (b) Determine Q_3, the charge on C_3.

$$Q_3 = Q_{13} = C_{13}V_B = (6\text{pF})(6\text{V})$$

$$\boxed{Q_3 = 36\text{pC}}$$

(10) (c) Determine V_3, the potential across C_3.

$$V_3 = \frac{Q_3}{C_3} = \frac{36\text{pC}}{18\text{pF}}$$



$V_3 = 2\text{V}$

/40