Official Starting Equations
PHYS 2135, Engineering Physics II

From PHYS 1135:

$x = x_0 + v_{0x}\Delta t + \frac{1}{2}a_x(\Delta t)^2$ $v_x = v_{0x} + a_x\Delta t$ $v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$ $\sum \vec{F} = m\vec{a}$

$F_r = -\frac{mv_t^2}{r}$ $P = \frac{F}{A}$ $\vec{p} = m\vec{v}$ $P = \frac{dW}{dt}$ $W = \int \vec{F} \cdot d\vec{s}$

$K = \frac{1}{2}mv^2$ $U_f - U_i = -W_{\text{conservative}}$ $E = K + U$ $E_f - E_i = (W_{\text{other}})_{i\to f}$ $E = P_{\text{ave}}t$

Constants:

$g = 9.8\,\frac{\text{m}}{\text{s}^2}$ $m_{\text{electron}} = 9.11 \times 10^{-31}\text{kg}$ $m_{\text{proton}} = 1.67 \times 10^{-27}\text{kg}$ $e = 1.6 \times 10^{-19}\text{C}$

$c = 3.0 \times 10^8\,\frac{\text{m}}{\text{s}}$ $k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9\,\frac{\text{Nm}^2}{\text{C}^2}$ $\epsilon_0 = 8.85 \times 10^{-12}\,\frac{\text{C}^2}{\text{Nm}^2}$ $\mu_0 = 4\pi \times 10^{-7}\,\frac{\text{Tm}}{\text{A}}$

Electric Force, Field, Potential and Potential Energy:

$\vec{F} = k\frac{q_1q_2}{r_{12}^2}\hat{r}_{12}$ $\vec{E} = k\frac{q}{r^2}\hat{r}$ $\vec{F} = q\vec{E}$ $\Delta V = -\int_i^f \vec{E} \cdot d\vec{s}$

$U = k\frac{q_1q_2}{r_{12}}$ $V = k\frac{q}{r}$ $\Delta U = q\Delta V$ $E_x = -\frac{\partial V}{\partial x}$

$\vec{p} = q\vec{d}$ (from – to +) $\vec{\tau} = \vec{p} \times \vec{E}$ $U_{\text{dipole}} = -\vec{p} \cdot \vec{E}$

$\Phi_E = \int_S \vec{E} \cdot d\vec{A}$ $\oint_S \vec{E} \cdot d\vec{A} = \frac{q_{\text{enclosed}}}{\epsilon_0}$ $\lambda \equiv \frac{\text{charge}}{\text{length}}$ $\sigma \equiv \frac{\text{charge}}{\text{area}}$ $\rho \equiv \frac{\text{charge}}{\text{volume}}$

Circuits:

$C = \frac{Q}{V}$ $\frac{1}{C_T} = \sum \frac{1}{C_i}$ $C_T = \sum C_i$ $C_0 = \frac{\epsilon_0 A}{d}$ $C = \kappa C_0$

$U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}QV$ $I = \frac{dq}{dt}$ $J = \frac{I}{A}$ $\vec{J} = nq\vec{v}_d$

$\vec{J} = \sigma\vec{E}$ $V = IR$ $R = \rho\frac{L}{A}$ $\sigma = \frac{1}{\rho}$ $\rho = \rho_0[1 + \alpha(T - T_0)]$

$\sum I = 0$ $\sum \Delta V = 0$ $\frac{1}{R_T} = \sum \frac{1}{R_i}$ $R_T = \sum R_i$ $P = IV = \frac{V^2}{R} = I^2R$

$Q(t) = Q_{\text{final}}\left[1 - e^{-t/\tau}\right]$ $Q(t) = Q_0 e^{-t/\tau}$ $\tau = RC$

Integral:

$\int \frac{du}{(u^2+a^2)^{3/2}} = \frac{u}{a^2\sqrt{u^2+a^2}} + c$

Exam Total
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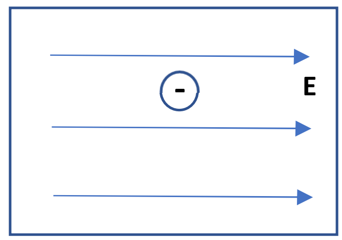
PHYS 2135 Exam I
September 21, 2021

Name: ______________________ Section: _________

For questions 1-5, select the best answer. For problems 6-11, solutions must begin with an Official Starting Equation, when appropriate. Work must be shown to receive credit. Calculators are not allowed.

(8)___A____**1.** Two charged particles Q_1 and Q_2 are placed a distance *d* apart and experience a Coulomb force of magnitude *F* from one another. If the magnitude of charge Q_2 is doubled and the distance *d* is tripled, what is the new magnitude of the Coulomb force?
[A] (2/9)*F* [B] (2/3)*F* [C] (4/3)*F* [D] *F*

(8)___A____**2.** A negatively charged electron is placed in an electric field which points to the right, as illustrated. In which direction will the electron be accelerated?
[A] Left
[B] Right
[C] Up
[D] Down



(8)___A____**3.** Two concentric spherical surfaces enclose a point charge *Q*. The radius of the outer sphere is three times that of the inner one. Which statement is true concerning the electric fluxes crossing these two surfaces?
[A] Inner Sphere Flux = Outer Sphere Flux
[B] Outer Sphere Flux > Inner Sphere Flux
[C] Inner Sphere Flux > Outer Sphere Flux
[D] One cannot compare the two fluxes

(8)___B____**4.** A charged particle with non-zero velocity enters a region where the electric potential is constant, and no other forces are present. Which statement best describes the particle's motion in this region?
[A] The particle will stop moving
[B] The particle's speed and direction remain constant
[C] Particle will accelerate due to the non-zero electric field
[D] Not enough information to know

(8)________**5.** (Free) Which best describes an S&T student?
[A] Naturally curious
[B] Unshakeable love of learning and discovery
[C] Craves immersive opportunities
[D] Desires to leave a mark on the world

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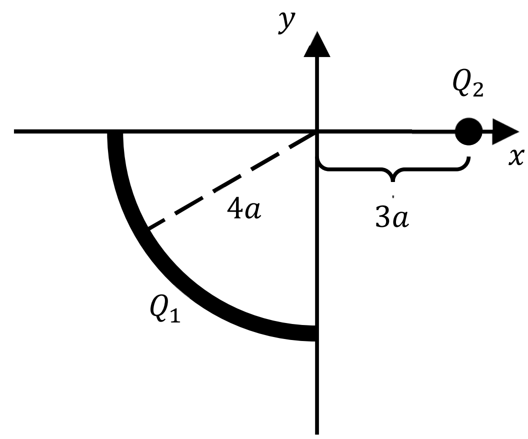
6. A charge $Q_1 = -4q_0$ is uniformly distributed along an arc of radius $R = 4a$ extending from the negative *x*-axis to the negative *y*-axis. A second charge $Q_2 = 6q_0$ is located on the *x*-axis at *x* = 3a.



(5) (a) Determine the charge per unit length λ_{arc} of the "arc" of charge.

$$\lambda_{arc} = \frac{Q_1}{(4a)\left(\frac{\pi}{2}\right)} = -\frac{4q_0}{2a\pi}$$

$$\boxed{\lambda_{arc} = -\frac{2q_0}{\pi a}}$$

(20) (b) Determine the electric field at the origin due to the "arc" of charge. Express your answer in unit vector notation.

$$\boxed{\vec{E}_{arc} = -\frac{kq_0}{2\pi a^2}(\hat{\imath} + \hat{\jmath})}$$

$$dq = \lambda(4a)d\phi = \left(-\frac{2q_0}{\pi a}\right)(4a d\phi) = -\frac{8q_0}{\pi}d\phi$$

$$r = 4a \qquad \hat{r} = -\cos\phi\,\hat{\imath} - \sin\phi\,\hat{\jmath}$$

$$\vec{E}_{arc} = \int k\frac{dq}{r^2}\hat{r} = \int_{\pi}^{3\pi/2} k\frac{-\frac{8q_0}{\pi}d\phi}{(4a)^2}(-\cos\phi\,\hat{\imath} - \sin\phi\,\hat{\jmath})$$

$$\vec{E}_{arc} = \frac{kq_0}{2\pi a^2}[\sin\phi\,\hat{\imath} - \cos\phi\,\hat{\jmath}]_{\pi}^{3\pi/2} = \frac{kq_0}{2\pi a^2}(-\hat{\imath} - \hat{\jmath})$$

(15) (c) Determine the electric field at the origin due to the point charge. Express your answer in unit vector notation.

$$\boxed{\vec{E}_{point} = -\frac{2kq_0}{3a^2}\hat{\imath}}$$

$$\vec{E}_{point} = k\frac{q}{r^2}\hat{r} = k\frac{6q_0}{(3a)^2}(-\hat{\imath})$$

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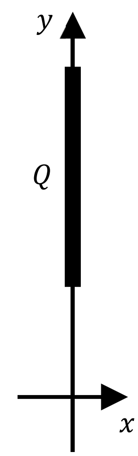
7. A charge Q is uniformly distributed along the y-axis from $y = 2a$ to $y = 6a$.



(15) (a) Determine the electric potential at the origin due to the line of charge.

$$dQ = \frac{Q}{4a}dy$$

$$V = \frac{kQ}{4a}\ln(3)$$

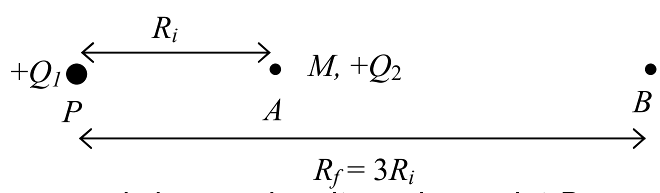
$$V = \int k\frac{dq}{r^2}\hat{r} = \int_{2a}^{6a} k\frac{\frac{Q}{4a}dy}{y} = \frac{kQ}{4a}\ln\left(\frac{6a}{2a}\right)$$

(5) (b) Determine the potential energy of a charge q_0 if it were placed at the origin

$$U = \frac{kQq_0}{4a}\ln(3)$$

$$U = qV$$

8. A positive point charge +Q_1 **is fixed at point *P***. A second positive charge with mass *M* and charge +Q_2 is initially fixed at point *A*, a distance R_i from point *P*. The second charge is then released.



(15) (a) Determine the speed of the second charge when it reaches point *B*, a distance $R_f = 3R_i$ from point *P*.

$$v = \sqrt{\frac{4kQ_1Q_2}{3MR_i}}$$

$$U_0 + K_0 = U_f + K_f$$

$$k\frac{Q_1Q_2}{R_i} + 0 = k\frac{Q_1Q_2}{3R_i} + \frac{1}{2}Mv^2$$

$$k\frac{Q_1Q_2}{R_i}\left(1 - \frac{1}{3}\right) = \frac{1}{2}Mv^2$$

(5) (b) Which point (*A* or *B*) is at a higher electric potential?

A

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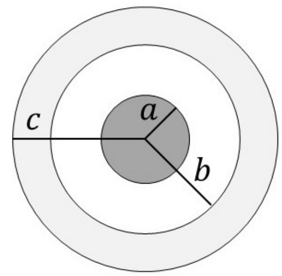
9. A long insulating cylindrical solid of radius a has a charge per length 2λ uniformly distributed throughout its volume. A conducting cylindrical shell of inner radius b and outer radius c has a charge per length 4λ and is coaxial with the insulating solid.

Side View



End View

(10) (a) Determine the electric field within the insulating cylindrical solid. $(r < a)$

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

$$\vec{E} = \frac{\lambda r}{\pi \epsilon_0 a^2} \hat{r}$$

$$E(2\pi r L) = \frac{2\lambda L \left(\frac{\pi r^2 L}{\pi a^2 L}\right)}{\epsilon_0}$$

(10) (b) Determine the electric field between the insulating cylindrical solid and the conducting shell. $(a < r < b)$.

$$\vec{E} = \frac{\lambda}{\pi \epsilon_0} \hat{r}$$

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

$$E(2\pi r L) = \frac{2\lambda L}{\epsilon_0}$$

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

$$\vec{E} = 0$$

(10) (d) Determine the charge per length on the inner and outer surfaces of the conducting shell.

$$\oint \vec{E} \cdot d\vec{A} = 0 \rightarrow 0 = q_{\text{enc}} = 2\lambda L + \lambda_b L$$

$$\lambda_b = -2\lambda$$

$$\lambda_b + \lambda_c = 4\lambda$$

$$\lambda_c = 6\lambda$$

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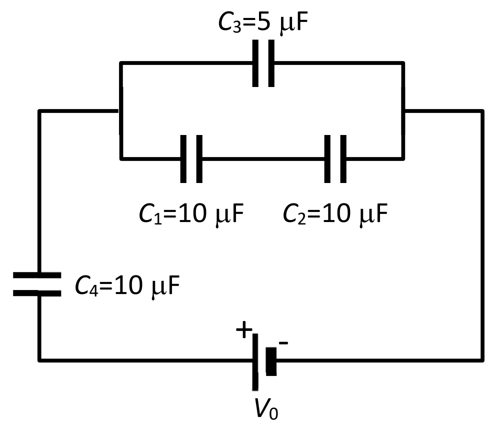
10. Consider the illustrated network.



(15) (a) Calculate the total (equivalent) capacitance of the network.

$$C_{12} = \left(\frac{1}{10\mu\text{F}} + \frac{1}{10\mu\text{F}}\right)^{-1} = 5\mu\text{F}$$

$$C_{123} = 5\mu\text{F} + 5\mu\text{F} = 10\mu\text{F}$$

$$C_T = \left(\frac{1}{10}\mu\text{F} + \frac{1}{10\mu\text{F}}\right)^{-1}$$

$C_T = 5\mu\text{F}$

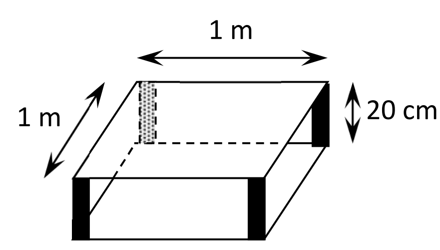
(15) (b) If the charge on capacitor C_4 is 100 μC, what is the battery voltage V_0?

$$C_T V_0 = Q_T = Q_4$$

$$V_0 = \frac{Q_4}{C_T} = \frac{100\mu\text{C}}{5\mu\text{F}}$$

$V_0 = 20\text{V}$

11. A small animal shed has a flat metal roof and a metal floor. The square roof and floor measure approximately one meter by one meter. The roof is supported by nonconducting wooden posts that are 20 cm tall. During a thunderstorm the potential difference between the roof and floor is measured to be 20,000 volts.



(10) Model the building as if it were a parallel-plate capacitor and calculate the amount of charge on the roof and the floor of the building.

$Q = 8.85\text{nC}$

$$Q = CV = \frac{A\epsilon_0 V}{d} = \frac{(1\text{m})^2(8.85\times\text{C}^2/\text{Nm}^2)(2\times10^4\text{V})}{2\times10^{-1}\text{m}}$$

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