Official Starting Equations
PHYS 2135, Engineering Physics II

From PHYS 1135:

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

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

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

Constants:

$g = 9.8\,\frac{\text{m}}{\text{s}^2}$ $\quad m_{\text{electron}} = 9.11\times10^{-31}\text{kg}$ $\quad m_{\text{proton}} = 1.67\times10^{-27}\text{kg}$ $\quad e = 1.6\times10^{-19}\text{C}$

$c = 3.0\times10^8\,\frac{\text{m}}{\text{s}}$ $\quad k = \frac{1}{4\pi\epsilon_0} = 9\times10^9\,\frac{\text{Nm}^2}{\text{C}^2}$ $\quad \epsilon_0 = 8.85\times10^{-12}\,\frac{\text{C}^2}{\text{Nm}^2}$ $\quad \mu_0 = 4\pi\times10^{-7}\,\frac{\text{Tm}}{\text{A}}$

Electric Force, Field, Potential and Potential Energy:

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

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

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

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

Circuits:

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

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

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

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

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

Integral:

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

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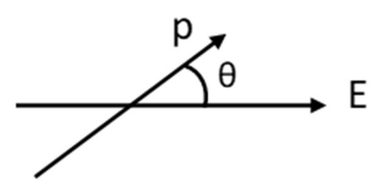
PHYS 2135 Exam I
September 20, 2022

Name: ______________________ Section: _________

For questions 1-5, select the best answer. For problems 6-10, solutions must begin with an Official Starting Equation, when appropriate. Work must be shown to receive credit. Calculators are not allowed. Use appropriate units. Provide answers in terms of given variable and fundamental constants.

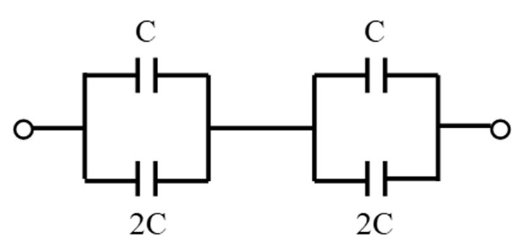
(8)___**C**___**1.** An electron is initially traveling horizontally (+*x*-direction) with a speed v_0 enters a region where there is a uniform electric field. The electron is observed to slow down. What is the direction of the electric field?
[A] +*y*-direction [B] -*y*-direction [C] +*x*-direction [D] -*x*-direction

(8)___**A**___**2.** The figure shows an electric dipole with its moment oriented at an angle *θ* with respect to a uniform electric field. For this orientation the torque on the dipole is ________.
[A] $pE\ sin\ \theta$ into the paper
[B] $pE\ sin\ \theta$ out of the paper
[C] $pE \cos\theta$ into the paper
[D] $pE \cos\theta$ out of the paper



(8)___**B**___**3.** A positive point charge *Q* is fixed at the origin so it cannot move. Another point charge of mass *m* and charge *q* is held at a distance *R* from *Q.* The charge *q* is then released. When *q* is a distance 4*R* away from *Q*, its speed will be:
[A] $\sqrt{\frac{2kQq}{mR}}$ [B] $\sqrt{\frac{6kQq}{4mR}}$ [C] $\sqrt{\frac{4kQ}{mR}}$ [D] $\sqrt{\frac{kQq}{2mR}}$

(8)___**C**___**4.** Four capacitors are arranged as shown. The equivalent capacitance for the arrangement is given by:
[A] 6 C [B] 3C [C] 3C/2 [D] 2C/3



(8)_________**5.** (Free) What is 42?
[A] Life
[B] The universe
[C] Everything
[D] Six times seven

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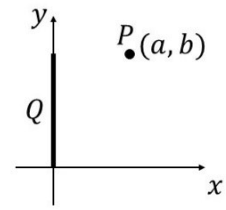
6. A charge Q is uniformly distributed along the y-axis between the origin and $(0, b)$, as illustrated. One wishes to determine the electric field at point P located at (a, b).



(25) Write the integral to determine $\vec{E}_P$ the electric field at P. [Do not solve the integral. Express your answer in unit vector notation.]

$$\vec{E}_P = \int_0^b \frac{k\left(\frac{Q}{b}\right)dy}{[a^2 + (b-y)^2]^{3/2}} a\hat{\imath} + \int_0^b \frac{k\left(\frac{Q}{b}\right)dy}{[a^2 + (b-y)^2]^{3/2}} (b-y)\hat{\jmath}$$

$$dQ = \left(\frac{Q}{b}\right) dy$$

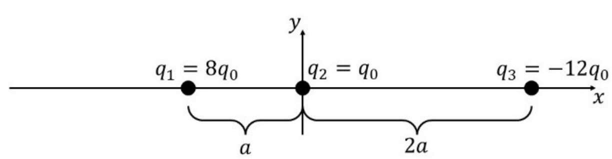
$$\vec{r} = a\hat{\imath} + (b-y)\hat{\jmath}$$

$$r = \sqrt{a^2 + (b-y)^2}$$

$$\hat{r} = \frac{a}{\sqrt{a^2+(b-y)^2}}\hat{\imath} + \frac{b-y}{\sqrt{a^2+(b-y)^2}}\hat{\jmath}$$

Alternatively, $\hat{r} = \cos\theta\,\hat{\imath} + \sin\theta\,\hat{\jmath}$, where θ is the angle between $\vec{r}$ and horizontal. This is used by students who first calculate $|\vec{E}|$ and then $E_x = |\vec{E}|\cos\theta$ and $E_y = \sin\theta$.

7. Three charges are arranged along the x-axis as illustrated. $q_1 = 8q_0$ is at $x = -a$. $q_2 = q_0$ is at the origin. $q_3 = -12q_0$ is at $x = 2a$.



(15) Determine $\vec{F}_{2T}$ the total force acting on q_2.

$$\vec{F}_{2T} = 11k\frac{q_0^2}{a^2}\hat{\imath}$$

$$\vec{F}_2 = \vec{F}_{12} + \vec{F}_{32}$$

$$\vec{F}_2 = k\frac{(8q_0)(q_0)}{a^2}\hat{\imath} + k\frac{(-12q_0)(q_0)}{(2a)^2}(-\hat{\imath})$$

$$\vec{F}_2 = k\frac{q_0^2}{a^2}(8+3)\hat{\imath}$$

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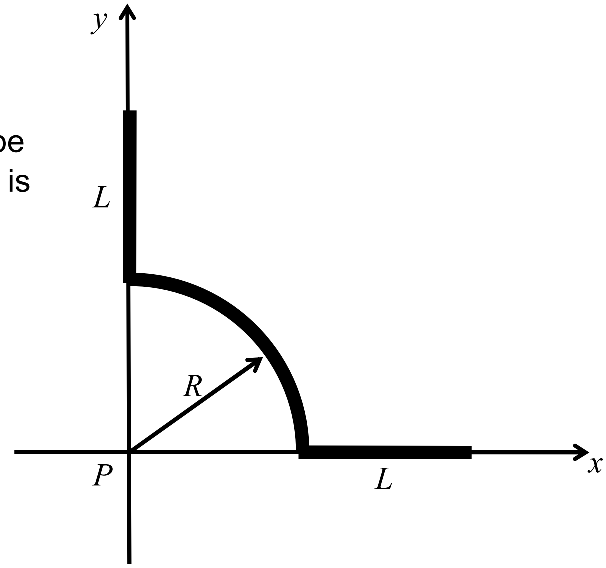
8. A wire of finite length has a uniform linear charge density λ_0 and is bent into the shape shown in the figure. Assume the potential is zero at infinity.



(20) Find V_A the electric potential at point *P* (the origin) due to the curved portion of the charged wire.

$$V_A = \int_0^{\pi/2} k \frac{\lambda_0 R d\phi}{R}$$

Alternatively, one could note that all of the charge

Is a distance R from P.

$$V_A = k \frac{\lambda_0 R\left(\frac{\pi}{2}\right)}{R}$$

$$V_A = \frac{k\lambda_0 \pi}{2}$$

(10) Find V_V the electric potential at point *P* due to the vertical linear portion of the charged wire.

For any location along the vertical charge distribution, $dq = \lambda_0 dy$ and $r = y$.

$$V_V = \int_R^{R+L} k \frac{\lambda_0 dy}{y}$$

$$V_V = k\lambda_0 \ln\left(\frac{R+L}{R}\right)$$

(10) Find V_H the electric potential at point *P* due to the horizontal linear portion of the charged wire.

Note that the horizontal contribution is the same as the vertical contribution, since V is a scalar. (Direction is irrelevant.)

$$V_H = k\lambda_0 \ln\left(\frac{R+L}{R}\right)$$

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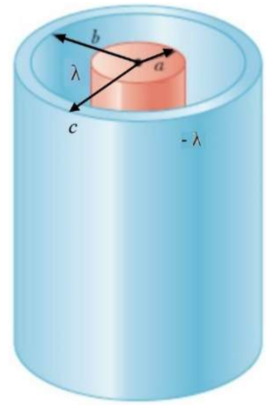
9. A very long (~infinite) cylindrical solid conductor of radius *a* carrying a positive charge per unit length λ is coaxial with an equally long conducting cylindrical shell of inner radius *b*>*a* and outer radius *c*>*b* carrying a negative charge per unit length -λ (see figure).



(10) a. Determine the electric field inside the inner conductor (*r*<*a*).

The field in the interior of a conductor is zero in electrostatics.

$\vec{E} = 0$

(5) b. Determine the surface charge per length λ_a on the surface of the inner conductor (*r*=*a*).

$q_{enc} = 0$ everywhere in the interior of the conductor requires that all of the charge is on the surface.

$\lambda_a = \lambda$

(5) c. Determine the surface charge per length λ_b on the inner surface of the outer conductor (*r*=*b*).

$0 = q_{enc} = \lambda_a + \lambda_b$

$-\lambda_a = \lambda_b$

$\lambda_b = -\lambda$

(5) d. Determine the surface charge per length λ_c on the outer surface of the outer conductor (*r*=*c*).

$\lambda_b + \lambda_c = \lambda_{conducting\ shell}$

$-\lambda + \lambda_c = -\lambda$

$\lambda_c = 0$

(15) e. Determine the electric field (magnitude and direction) between the two conductors (a<r<b) as a function of the surface charge per length λ_a, the distance from the axis of the coaxial cable, ε_0, and *a*.

$\vec{E} = \frac{\lambda_a}{2\pi\epsilon_0 r}\hat{r}$

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

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

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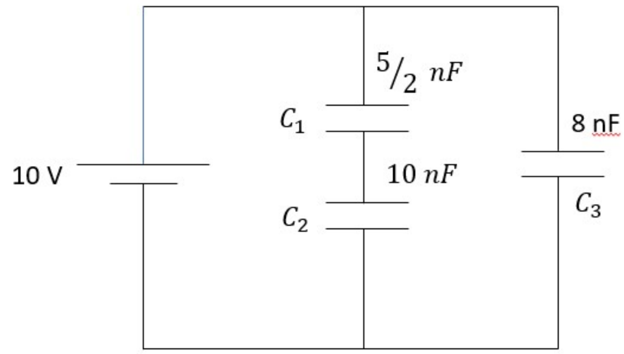
10. Three capacitors are connected to a 10 V battery as illustrated. The capacitors have values of $C_1 = {}^{5}/_{2}\,\mathrm{nF}, C_2 = 10\ \mathrm{nF}$ and $C_3 = 8\ \mathrm{nF}$.



(10) a. Calculate the equivalent capacitance C_{12} of capacitors C_1 and C_2.

$$C_{12} = \left(\frac{1}{C_1} + \frac{1}{C_2}\right)^{-1} = \left(\frac{2}{5\mathrm{nF}} + \frac{1}{10\mathrm{nF}}\right)^{-1} = \left(\frac{5}{10\mathrm{nF}}\right)^{-1}$$

$C_{12} = 2\mathrm{nF}$

(10) b. Calculate the equivalent capacitance of the entire circuit C_{eq}.

$$C_{eq} = C_{12} + C_8 = 2\mathrm{nF} + 8\mathrm{nF}$$

$C_{eq} = 10\mathrm{nF}$

(10) c. Calculate the charge Q_3 on capacitor C_3.

$$Q_3 = C_3V_3 = C_3V_B = (8\mathrm{nF})(10\mathrm{V})$$

$Q_3 = 80\mathrm{nC}$

(10) d. Calculate the voltage V_1 of capacitor C_1.

$$Q_1 = Q_{12} = C_{12}V_{12} = C_{12}V_B = (2\mathrm{nF})(10\mathrm{V}) = 20\mathrm{nC}$$

$$V_1 = \frac{Q_1}{C_1} = \frac{20\mathrm{nC}}{(5/2)\mathrm{nF}}$$

$V_1 = 8\mathrm{V}$

Alternatively, one could fine Q_{total}, calculate $Q_1 = Q_{total} - Q_3$ and then find V_1 as indicated.

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