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:

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

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

Electric Force, Field, Potential and Potential Energy:

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

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

$\vec{p} = q\vec{d}$ (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:

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

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

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

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

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

Magnetic Force, Field and Inductance:

$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$ $\vec{F} = I\vec{L} \times \vec{B}$ $\Phi_B = \int \vec{B} \cdot d\vec{A}$ $\oint \vec{B} \cdot d\vec{A} = 0$

$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enclosed}}$ $\vec{\mu} = NI\vec{A}$ $\vec{\tau} = \vec{\mu} \times \vec{B}$ $U_{\text{dipole}} = -\vec{\mu} \cdot \vec{B}$

$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$ $d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{s} \times \hat{r}}{r^2}$ $\mathcal{E} = -N \frac{d\Phi_B}{dt}$ $\oint \vec{E} \cdot d\vec{s} = -\frac{d\phi_B}{dt}$

$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enclosed}} + \mu_0 \epsilon_0 \frac{d\phi_E}{dt}$ $B = \frac{\mu_0 I}{2\pi r}$ $B = \mu_0 n I$

Electromagnetic Waves:

$I = \frac{P}{A}$ $u = \frac{1}{2}\left(\epsilon_0 E^2 + \frac{B^2}{\mu_0}\right) = \epsilon_0 E^2 = \frac{B^2}{\mu_0}$ $\langle u \rangle = \frac{1}{4}\left(\epsilon_0 E_{\text{max}}^2 + \frac{B_{\text{max}}^2}{\mu_0}\right) = \frac{1}{2}\epsilon_0 E_{\text{max}}^2 = \frac{B_{\text{max}}^2}{2\mu_0}$

$\frac{E}{B} = c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$ $\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$ $I = \langle S \rangle = c\langle u \rangle$ $\langle P_{\text{rad}} \rangle = \frac{I}{c}$ or $\frac{2I}{c}$

$k = \frac{2\pi}{\lambda}$ $\omega = 2\pi f$ $T = \frac{1}{f}$ $v = f\lambda = \frac{\omega}{k} = \frac{c}{n}$

Optics:

$I = I_{\text{max}} \cos^2 \phi$ $\theta_r = \theta_i$ $n = \frac{c}{v} = \frac{\lambda_0}{\lambda_n}$ $n_r \sin\theta_r = n_i \sin\theta_i$

$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$ $m = \frac{y'}{y} = -\frac{s'}{s}$ $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ $f = \frac{R}{2}$

$\frac{n_a}{s} + \frac{n_b}{s'} = \frac{n_b - n_a}{R}$ $m = \frac{y'}{y} = -\frac{n_a s'}{n_b s}$ $\Delta L = m\lambda$ $\Delta L = \left(m + \frac{1}{2}\right)\lambda$

$\Delta L = d \sin\theta$ $\phi = 2\pi\left(\frac{\Delta L}{\lambda}\right)$ $I = I_0 \cos^2 \frac{\phi}{2}$ $R = \frac{\lambda}{\Delta\lambda} = Nm$

$m\lambda = a \sin\theta$ $\beta = \frac{2\pi}{\lambda} a \sin\theta$ $I = I_0 \left[\frac{\sin(\beta/2)}{\beta/2}\right]^2$

Integral:

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

Last updated, June 10, 2021

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PHYS 2135 Exam II
October 26, 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)___**B**___**1.** A 30 W light bulb and a 60 W light bulb are connected in series. Both power ratings are at 120 V. If the potential across the two bulbs in series is 120 V, which statement is true?

[A] The 30 W bulb glows brighter and carries a smaller current than the 60 W bulb.
[B] The 30 W bulb glows brighter and carries the same current as the 60 W bulb.
[C] The 60 W bulb glows brighter and carries a larger current than the 30 W bulb.
[D] The 60 W bulb glows brighter and carries the same current as the 30 W bulb.

(8)___**D**___**2.** An ammeter is constructed by using a galvanometer with an internal resistance, R_G. A shunt resistor, R_{sh}, is used to make it into an ammeter. The shunt resistor is chosen so that the maximum deflection of the galvanometer will correspond to a maximum current *I*. When the ammeter reading corresponds to the maximum current *I*, the potential difference across the 'ammeter' will be:

[A] IR_{sh}
[B] IR_G
[C] $I(R_{sh} + R_G)/(R_{sh}R_G)$
[D] $I(R_{sh}R_G)/(R_{sh} + R_G)$

(8)___**A**___**3.** A proton of mass m_p is moving at a constant velocity $\vec{v}$. Also, an electron of mass m_e is moving with a constant velocity $2\vec{v}$. They both enter a region of constant magnetic field $\vec{B}$, which is perpendicular to $\vec{v}$. Thus, both particles will move in circular paths. Let R_e be the radius of the electron path and R_p be the radius of the proton path. Then the ratio R_e/R_p will be:

[A] $2m_e/m_p$ [B] $2m_p/m_e$ [C] $m_e/(2m_p)$ [D] $m_p/(2m_e)$

(8)___**C**___**4.** The resistance of a cylindrical copper conductor that carries a current along its length may be reduced by

[A] decreasing the potential difference across the conductor.
[B] decreasing the radius of the conductor.
[C] decreasing the length of the conductor.
[D] decreasing the current in the conductor.

(8)________**5.** (Free) William Shatner

[A] was Captain James T Kirk of the Enterprise.
[B] is 90 years old.
[C] is the oldest man to have been in space.
[D] spent 10 min. total aloft in the Blue Origin New Shepard Rocket.

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6. A light bulb connected across 120V is heating up. The thermal coefficient of resistivity of the filament is positive.

(10) The rate at which energy is dissipated in the bulb as the bulb heats is … [Select the correct completion of the sentence.]
[A] decreasing.
[B] remaining constant.
[C] increasing.

Answer: **A**

7. A parallel plate capacitor initially has an insulating material completely filling the gap yielding a capacitance C_i. The capacitor is fully charged using a battery with potential difference V_B. After the capacitor is fully charged, the battery is disconnected and then the insulating material is removed from the gap yielding a new capacitance $\frac{2}{3}C_i$. [Express answers in terms of given quantities (V_B and C_i).]

(10) Determine the work done in removing the insulator from the capacitor gap.

$W = U_f - U_i$ $\qquad$ $Q_f = Q_i = C_i V_B$

$W = \frac{1}{4} C_i V_B^2$

$W = \frac{1}{2}\frac{Q_f^2}{C_f} - \frac{1}{2}\frac{Q_i^2}{C_i}$

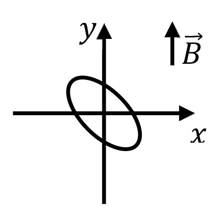
$W = \frac{1}{2}\frac{C_i^2 V_B^2}{\frac{2}{3}C_i} - \frac{1}{2}\frac{C_i^2 V_B^2}{C_i} = \frac{3}{4}C_i V_B^2 - \frac{1}{4}C_i V_B^2$

(10) If $V_B = 24\text{V}$ determine the final potential difference across the plates of the capacitor.

$V_f = \frac{Q_f}{C_f} = \frac{Q_i}{\frac{2}{3}C_i} = \frac{3}{2}V_B = \frac{3}{2}(24\text{V})$

$V_f = 36\text{V}$

8. A loop of current initially in the *xy*-plane, as illustrated is in a region with a uniform magnetic field in the *y*-direction.



(10) Around which axis would the loop of current begin to spin? [Select the correct answer.]
[A] *x*-axis [B] *y*-axis [C] *z*-axis
[D] There is no torque.

Note that $\vec{\mu}$ is in either $+\hat{k}$ or $-\hat{k}$.

Answer: **A**

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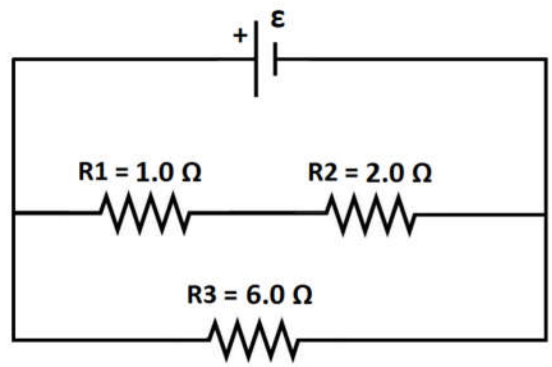

9. In the circuit illustrated, the voltage across the 2.0 Ω resistor is 12.0 V.

(10) (a) What is the total equivalent resistance for this circuit?

$$R_{12} = R_1 + R_2 = 1\Omega + 2\Omega = 3\Omega$$

$$R_T = \left(\frac{1}{R_{12}} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{3\Omega} + \frac{1}{6\Omega}\right)^{-1} = \left(\frac{3}{6\Omega}\right)^{-1}$$

$R_T = 2\Omega$

(10) (b) What is the current through the 6.0 Ω resistor?

$$I_{12} = I_2 = \frac{V_2}{R_2} = \frac{12\text{V}}{2\Omega} = 6\text{A}$$

$$V_3 = V_{12} = I_{12}R_{12} = (6\text{A})(3\Omega) = 18\text{V}$$

$$I_3 = \frac{V_3}{R_3} = \frac{18\text{V}}{6\Omega}$$

$I_3 = 3\text{A}$

(10) (c) What is the emf ε of the battery?

$$\mathcal{E} = V_3$$

$\mathcal{E} = 18\text{V}$

(10) (d) How much power is dissipated in the 1.0 Ω resistor?

$$P_1 = I_1^2 R_1 = I_{12}^2 R_1 = (6\text{A})^2(1\Omega)$$

$P_1 = 36\text{W}$

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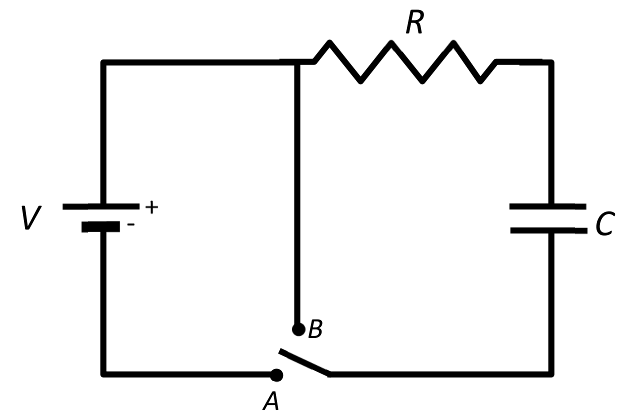
10. The circuit shown has a switch with two positions. The capacitor is initially uncharged. [Express answers in terms of given quantities (*V*, *R*, *C* and t_1).]



(20) (a) How long after the switch is set to position *A* will the charge on the capacitor be 1/3 of its maximum charge?

$$\frac{1}{3}Q_f = Q = Q_f\left(1 - e^{-t/RC}\right)$$

$$\frac{1}{3} = 1 - e^{-t/RC}$$

$$e^{-t/RC} = \frac{2}{3}$$

$$-\frac{t}{RC} = \ln\left(\frac{2}{3}\right)$$

$$t = -RC\ln\left(\frac{2}{3}\right)$$

(20) (b) After the switch has been at position *A* for a long time, it is moved to position B. After a time t_1 with the switch in position *B*, what is the current in the resistor *R*?

$$I = -\frac{dQ}{dt}$$

$$I = -\frac{d}{dt}\left(Q_0 e^{-t/RC}\right)$$

$$I = \frac{Q_0}{RC}e^{-t/RC}$$

$$I = \frac{CV}{RC}e^{-t/RC}$$

$$I = \frac{V}{R}e^{-t_1/RC}$$

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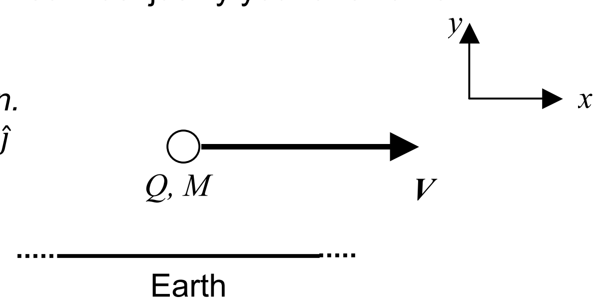
11. A proton (mass M_P and charge e) is traveling in the positive x-direction (parallel to the surface of the earth) at constant speed V under the influence of the earth's gravitational force. There is a constant magnetic field of magnitude B in this region that is perpendicular to both the gravitational force and the proton's velocity.

(15) (a) If the proton continues to move straight along the x-direction what is the direction of the magnetic field? You must justify your answer to receive full credit.

Gravitational force is in the $-\hat{\jmath}$ direction. Thus, magnetic force must be in the $+\hat{\jmath}$ direction. This occurs if $\vec{B}$ is into the page.



Direction of $\vec{B}$ is $-\hat{k}$

(25) (b) What speed must the proton have to continue to move in a straight path along the positive x-direction?

$$0 = \vec{F}_T = -M_P g\hat{\jmath} + eV\hat{\imath} \times B(-\hat{k})$$

$$M_P g\hat{\jmath} = eVB\hat{\jmath}$$

$$V = \frac{M_P g}{eB}$$

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