Exam Total
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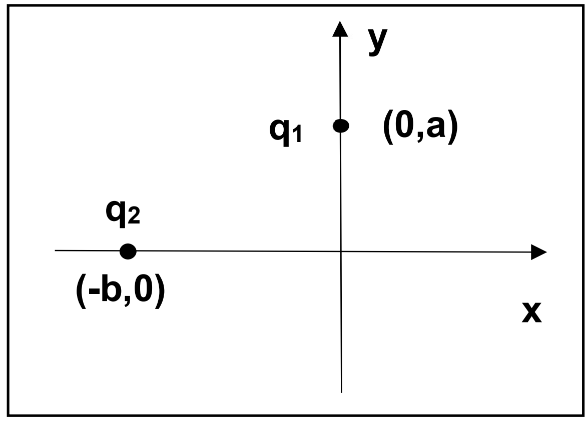
Physics 2135 Final Exam
December 15, 2021

Printed Name: ________________________________

1. A pair of charges are arranged as illustrated, where $q_1 > 0$ and $q_2 > 0$. The charge q_1 is located at (0, a) and q_2 at (-b, 0).



(10) a. Determine the electric field at the origin produced by q_1 and q_2.

$$\vec{E} = \vec{E}_1 + \vec{E}_2 = k\frac{q_1}{r_{10}^2}\hat{r}_{10} + k\frac{q_2}{r_{20}^2}\hat{r}_{20}$$

$$\boxed{\vec{E} = k\frac{q_2}{b^2}\hat{\imath} - k\frac{q_1}{a^2}\hat{\jmath}}$$

(10) b. A third positive charge q_3 is placed at the origin. Determine the electrical force experienced by q_3 from q_1 and q_2.

$$\boxed{\vec{F} = k\frac{q_2 q_3}{b^2}\hat{\imath} - k\frac{q_1 q_3}{a^2}\hat{\jmath}}$$

$$\vec{F} = q\vec{E}$$

(10) c. Determine the work required to bring q_3 from far away to the origin.

$$W = U_f - U_i = (U_{13} + U_{23}) - 0$$

$$W = k\frac{q_1 q_3}{r_{13}} + k\frac{q_2 q_3}{r_{23}}$$

$$\boxed{W = k\frac{q_1 q_3}{a} + k\frac{q_2 q_3}{b}}$$

$$\boxed{U = k\frac{q_1 q_2}{\sqrt{a^2 + b^2}} + k\frac{q_1 q_3}{a} + k\frac{q_2 q_3}{b}}$$

(10) d. Assuming q_3 is at the origin, determine the potential energy of the charge arrangement q_1, q_2, and q_3.

$$U = U_{12} + U_{13} + U_{23}$$

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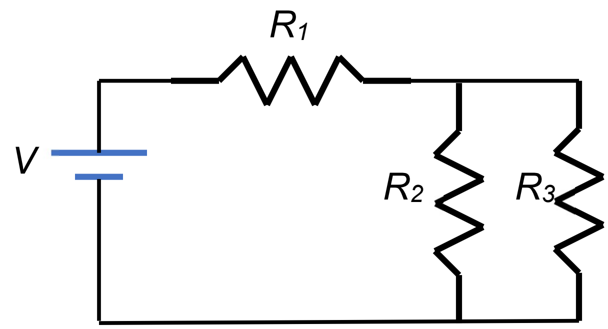
2. In the circuit shown, the voltage of the battery is 40 V. The resistors are: R_1 = 17 Ω, R_2 = 4 Ω, and R_3 = 12 Ω.



(10) a. Determine the total equivalent resistance of this circuit.

$$R_{23} = \left(\frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{4\Omega} + \frac{1}{12\Omega}\right)^{-1} = 3\Omega$$

$$R_T = R_1 + R_{23} = 17\Omega + 3\Omega$$

$R_T = 20\Omega$

(10) b. Determine the total current of this circuit.

$$I_T = \frac{V_T}{R_T} = \frac{40\text{V}}{20}$$

$I_T = 2\text{A}$

(10) c. Determine the voltage across the R_2 resistor.

$$V_2 = V_T - V_1 = V_T - I_1R_1 = V_T - I_TR_1$$

$$V_2 = 40\text{V} - (2\text{A})(17\Omega)$$

$V_2 = 6\text{V}$

(10) d. Determine the power dissipated in the R_3 resistor.

$P_3 = 3\text{W}$

$$P_3 = \frac{V_3^2}{R_3} = \frac{V_2^2}{R_3} = \frac{(6\text{V})^2}{12\Omega}$$

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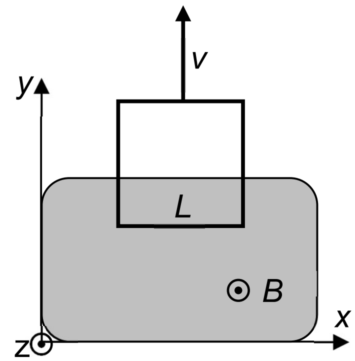
3. A conducting square loop with sides of length L and resistance R is pulled with steady speed v out of region of uniform magnetic field B pointing out of the page, as shown in the figure.



(10) a. Start with Faraday's law and find the magnitude of the electrical current I induced in the loop.

$$\mathcal{E} = -\frac{d}{dt}\left[\int \vec{B} \cdot d\vec{A}\right] = -\frac{d}{dt}[BLw] = BLv$$

$$I = \frac{\mathcal{E}}{R}$$

$$\boxed{I = \frac{BLv}{R}}$$

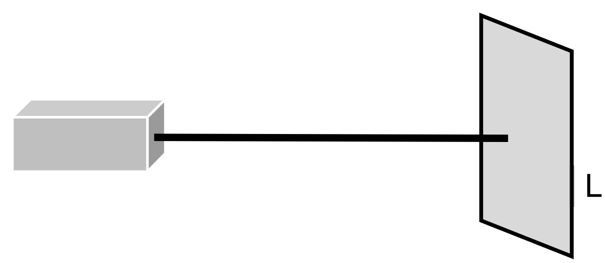
(5) b. What is the direction of the current induced in the loop? (circle one)

CLOCKWISE COUNTERCLOCKWISE

(5) c. What is the direction of the net force produced by the uniform magnetic field on the loop? (circle one)

↑ or ↓

4. A He-Ne laser produces a cylindrical beam of light of diameter d. The laser beam is directed at normal incidence on the center of a square, perfectly absorbing plate having an edge length L much greater than the diameter of the laser beam. The magnetic field amplitude of the laser beam as it comes out of the laser is B_{max}.



(10) a. What radiation force F does the laser beam exert on the square plate?

$$F = \langle P_{rad}\rangle A = \left(\frac{I}{c}\right)\left(\frac{\pi d^2}{4}\right) = \langle u\rangle\left(\frac{\pi d^2}{4}\right) = \left(\frac{B_{\max}^2}{2\mu_0}\right)\left(\frac{\pi d^2}{4}\right)$$

$$\boxed{F = \frac{B_{\max}^2 \pi d^2}{8\mu_0}}$$

(10) b. Determine the power output P of the laser.

$$P = IA = \langle P_{rad}\rangle cA = cF$$

$$\boxed{P = \frac{cB_{\max}^2 \pi d^2}{8\mu_0}}$$

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5. A spherical concave mirror has a radius of curvature of 32.0 cm. An object is placed 12.0 cm to the left of the mirror.

(10) a. What is the image distance?

$s' = -48\text{cm}$

$$s' = \left(\frac{1}{f} - \frac{1}{s}\right)^{-1} = \left(\frac{1}{16\text{cm}} - \frac{1}{12\text{cm}}\right)^{-1}$$

(5) b. The image is a __________ image. [Circle the correct word to put in the blank.]

REAL　　　**(VIRTUAL)**

(5) c. What is the magnification?

$m = 4$

$$m = -\frac{s'}{s} = -\frac{-4\ \text{cm}}{12\text{cm}}$$

6. An object is positioned 12 cm to the left of a lens. The image of the object is formed on a screen 6 cm to the right of the lens.

(10) a. Find the focal length of the lens.

$f = 4\text{cm}$

$$f = \left(\frac{1}{s} + \frac{1}{s'}\right)^{-1} = \left(\frac{1}{12\text{cm}} + \frac{1}{6\text{cm}}\right)^{-1}$$

(5) b. The lens is a __________ lens. [Circle the correct word to put in the blank.]

(CONVERGING)　　　DIVERGING

(5) b. Determine the magnification.

$$m = -\frac{s'}{s} = -\frac{6\text{cm}}{12\text{cm}}$$

$m = -\frac{1}{2}$

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7. A 400nm light source shines on a $2\mu\text{m}$ wide slit that is 6m in front of a screen. [Use the small angle approximation.]

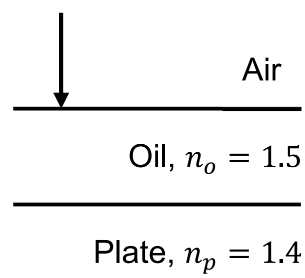
(15) Determine the distance on the screen from the central maximum to the first order dark fringe.

$y_1 = 1.2\text{m}$

$$\frac{m\lambda}{a} = \sin\theta \approx \tan\theta = \frac{y}{R} \qquad m = 1$$

$$y = \frac{\lambda R}{a} = \frac{(4\times10^{-7}\text{m})(6\text{m})}{2\times10^{-6}\text{m}}$$

8. A $0.2\mu\text{m}$ thick layer of oil with an index of refraction of 1.5 lies on top of a transparent plate with an index of refraction of 1.4. Light is normally incident on the combination from above as illustrated.



(15) Determine the longest wavelength of light that will be maximally reflected.

$\lambda = 1200\text{nm}$

Changes of phase:

due to reflection, 1

due to path (Total – reflection), Odd

Total (Constructive), Even

$$2t = \frac{\left(m+\frac{1}{2}\right)\lambda}{n_o}$$

$$\frac{2tn_o}{m+\frac{1}{2}} = \lambda = \frac{2(2\times10^{-7}\text{m})1.5}{0+\frac{1}{2}}$$

Maximum from $m = 0$

9. A diffraction grating with 1000lines/mm is used to resolve light from two light sources with wavelengths of 604nm and 596nm.

(10) Determine the number of lines that must be illuminated to resolve the two light sources in 3rd order.

$N = 25$

$$\frac{\lambda}{\Delta\lambda} = R = Nm$$

$$N = \frac{\lambda}{\Delta\lambda m} = \frac{600\text{nm}}{(8\text{nm})3}$$

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