Instructor(s): *P. Hirschfeld*

PHYSICS DEPARTMENT

PHY 2005, Spring 2017 Final Exam April 27, 2017

Name (print, last first): ______________________ Signature: ______________________

On my honor, I have neither given nor received unauthorized aid on this examination.

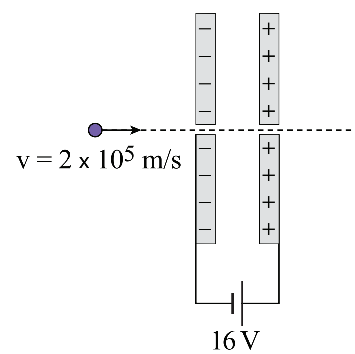
YOUR TEST NUMBER IS THE 5-DIGIT NUMBER AT THE TOP OF EACH PAGE.

(1) **Code your test number on your answer sheet (use lines 76–80 on the answer sheet for the 5-digit number).** Code your name on your answer sheet. **DARKEN CIRCLES COMPLETELY**. Code your UFID number on your answer sheet.
(2) Print your name on this sheet and sign it also.
(3) Do all scratch work anywhere on this exam that you like. **Circle your answers on the test form.** At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout.
(4) **Blacken the circle of your intended answer completely, using a #2 pencil or blue or black ink**. Do not make any stray marks or some answers may be counted as incorrect.
(5) **The answers are rounded off. Choose the closest to exact. There is no penalty for guessing. If you believe that no listed answer is correct, leave the form blank.**
(6) Hand in the answer sheet separately.

Physical Constants:

$g = 9.8$ m/s^2	$m_e = 9.11 \times 10^{-31}$ Kg
$m_p = 1.67 \times 10^{-27}$ Kg	$e = 1.6 \times 10^{-19}$ C
constant k in Coulomb's Law: $k = 8.99 \times 10^9$ Nm^2/C^2	$c = 3.0 \times 10^8$ m/s
$\mu_o = 4\pi \times 10^{-7}$ N/A^2	$\varepsilon_o = 8.85 \times 10^{-12}$ C^2/Nm^2

1. A proton (+e) originally has a speed of 2.0×10^5 m/s as it goes through a plate as shown in the figure. It shoots through the tiny holes in the two plates across which 16 V of electric potential is applied. Find the speed as it leaves the second plate in m/s.



(1) 1.92×10^5
(2) 5.0×10^7
(3) 505.3
(4) 7.8×10^4
(5) 1.1×10^5

2. An object is 8 cm in front of a spherical mirror. A virtual image is formed 4.5 cm away from the mirror and smaller than the object. What is the focal length of this mirror in cm?

(1) −10.3 (2) 4.5 (3) −7.5 (4) 7.5 (5) −11.5

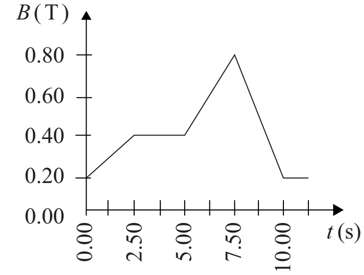
3. It is desired to use a 60-cm focal length diverging lens to form a virtual image of an object. The image is to be one-fourth as large as the object. Where should the object be placed and what will be the image distance in cm?

(1) (180, −45) (2) (120, −40) (3) (55, −22.5) (4) (−155, 41.3) (5) (55, 22.5)

4. In a Young's double-slit experiment, the slit separation is 0.100 mm and the slit-to-screen distance is 1.50 m. The yellow light of wavelength 589 nm is used. Find the distance from the center bright fringe (m = 0) to the third-order bright fringe (m = 3) in cm.

(1) 2.65 (2) 1.33 (3) 1.77 (4) 2.65 (5) 1.77

5. A circular coil of wire has 25 turns and has a *radius* of 0.075 m. The coil is located in a variable magnetic field whose behavior is shown on the graph. At all times, the magnetic field is directed to the normal to the plane of a loop. What is the average magnitude of EMF induced in the coil in the time interval from $t = 7.5$ s to 10.0 s? (in mV)



(1) 106
(2) 140
(3) 70.7
(4) 180
(5) 92

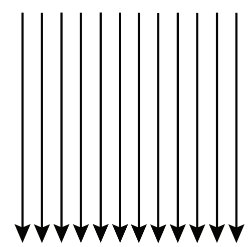
6. *Unpolarized* light with an average intensity of 750.0 W/m^2 enters a polarizer with a vertical transmission axis. The transmitted light then enters a second polarizer. The light that exits the second polarizer is found to have an average intensity of 250 W/m^2. What is the orientation angle of the second polarizer relative to the first one? (in degree)

(1) 35.3 (2) 29.0 (3) 48.2 (4) 54.7 (5) 70.5

7. A magnifying glass is simply a ______ lens. The object should be placed ______ the focal length of the lens. Then the image is larger than the object and ______ .

(1) converging, within, up-right
(2) converging, outside of , upside-down
(3) diverging, within, up-right
(4) diverging, outside of, upside-down
(5) converging, within, upside-down

8. A uniform parallel electric field is set up in space as shown in the figure. Particle #1 has +3 mC charge and a 3 mg-mass and Particle #2 has -10 mC charge and a 2 mg-mass. These particles are released in the field region. Which of the following statements is wrong? Ignore gravity and consider the electric force and the Newton's second law.



(1) After 1 second, particle #1 has the larger speed.
(2) Particle #2 has the larger magnitude of acceleration.
(3) Particle #1 and #2 move in the opposite direction.
(4) Particle #1 will feel the smaller magnitude of force than Particle #2 does.
(5) The forces acting on the particles are in the opposite direction.

9. Choose a wrong statement.

(1) The total internal reflection occurs when the light propagates from the lower refractive index material to the higher refractive index material.
(2) Nearsightedness can be corrected using an appropriate strength diverging lens.
(3) An object placed at the focal point of a convex spherical mirror will not form an image.
(4) The focal length of a glass converging lens is longer in water than in air.
(5) The refractive index of a material varies for different wavelengths.

10. Two microwave emitters send out identical waves along the x axis. The wavelength of the microwaves is 60 cm. One emitter is at x = 0. An observer is at x = 10 m. The other emitter is at x = 0 initially but is slowly moving towards the observer. At what emitter position will the observer detect the *second* intensity minimum (in m)?

(1) 0.9 (2) 0.3 (3) 0.6 (4) 1.2 (5) 1.5

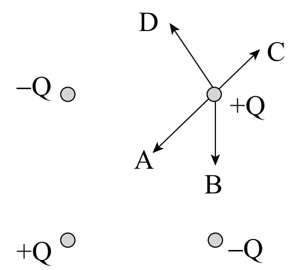
11. Which of the following statements concerning electromagnetic waves is(are) false?
(A) The Sun radiates broad spectrum of linearly polarized electromagnetic waves.
(B) Electromagnetic waves transfer energy through space.
(C) In electromagnetic waves, magnetic field fluctuates in the direction of propagation.
(D) Electromagnetic waves do not require a physical medium for propagation.

(1) A and C (2) B (3) A only (4) B and C (5) D only

12. A hydrogen atom is composed of a nucleus containing a single proton (+e), about which a single electron (-e) orbits. Let's assume that the electron is making a uniform circular motion with a radius 5.3×10^{-11} m. What is the speed of the electron orbiting? (in m/s)

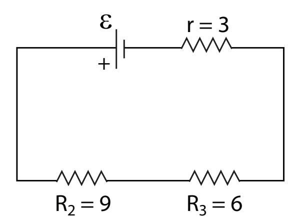
(1) 2.18×10^6 (2) 7.19×10^6 (3) 3.10×10^8 (4) 1.56×10^4 (5) 4.20×10^4

13. There are four charges arranged at the corner of a square as shown in the figure. Which of the vectors correctly represents the net force acting on the charge in the upper right corner?



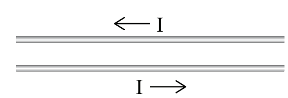
(1) A
(2) C
(3) B
(4) D
(5) not enough information.

14. It takes 4 seconds for R_2 to produce 400 joules of heat. What is the value of ε? (in V)



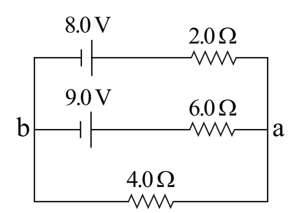
(1) 60
(2) 48
(3) 72
(4) 12
(5) 36

15. Figure B shows two long wires with current flowing in opposite directions. What is the direction of the force on the top wire?



(1) Up on the paper. ↑
(2) Down on the paper. ↓
(3) To the right. →
(4) Perpendicular, out of the paper. ⊙
(5) To the left. ←

16. Find the current through the 2Ω resistor. (in A)



(1) 1.0
(2) 0.5
(3) 1.5
(4) 2.0
(5) 2.5

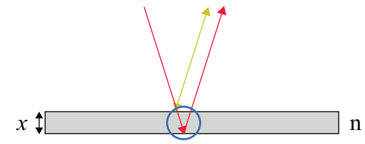
17. An overhead electric power line carries a maximum current of 125 A. What is the magnitude of the maximum magnetic field at a point 4.50 m directly below the power line? (in tesla)

(1) 5.56×10^{-6} (2) 3.49×10^{-5} (3) 7.95×10^{-3} (4) 1.75×10^{-5} (5) 4.69×10^{-4}

18. A flat loop of wire has an area of 40 cm^2. It is in a region where $B = 4 \times 10^{-2}$ T and is directed a long the $x-axis$. Call θ the angle between the axis of the loop and the $x - axis$. What is the change in flux through the loop as θ is changed from 30° to 60°? (in Tm^2)

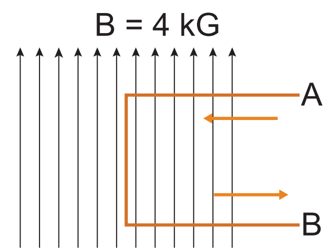
(1) -5.86×10^{-5} (2) -4.67×10^{-6} (3) 5.6×10^{-6} (4) 1.42×10^{-4} (5) 3.3×10^{-3}

19. A thin film of polymer used in an antireflective coating has an index of refraction of 1.5. If light of wavelength 545 nm is incident on the film, but is found to be entirely transmitted and not reflected, what is a possible thickness x of the film (in m)?



(1) 9.1×10^{-8} (2) 1.8×10^{-7} (3) 1.3×10^{-7} (4) 0 (5) 3.6×10^{-7}

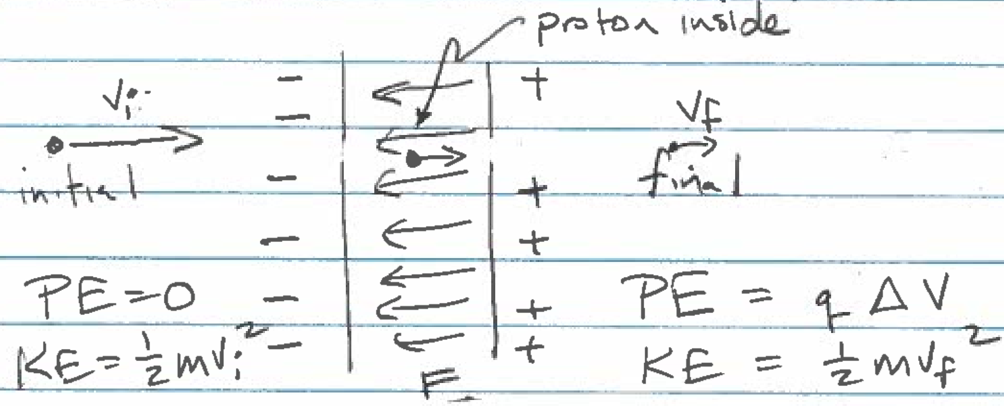
20. A wire is placed in a uniform magnetic field of 4 kG as shown in the figure. 1 A of current flows into the port A and comes out of the port B. What is the magnetic and direction force acting on the 1 m-long vertical portion of the wire?



(1) 0
(2) 0.4 N to the left
(3) 4 N into the screen
(4) 4 N out of the screen
(5) 0.4 N to the right

Solutions Final Exam PHY2005 S'17

1. The electric field E exists only between the two plates, which then have a potential difference between them of $\Delta V = 16\,V$



The electric field slows the proton down, but not so much that it can't exit through the tiny hole. Energy is conserved, so total energy initially must be = to total energy finally. Recall that potential is potential energy / charge, i.e. $\Delta V = \Delta PE/q$.

So total energy before $= 0 + \frac{1}{2}mv_i^2$

after $= q\Delta V + \frac{1}{2}mv_f^2$

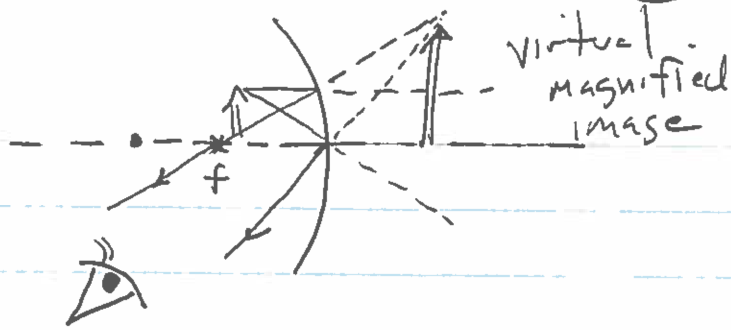
Cons. of energy $\Rightarrow \frac{1}{2}mv_i^2 = q\Delta V + \frac{1}{2}mv_f^2$

$$v_f^2 = \frac{2}{m}\left(\frac{1}{2}mv_i^2 - q\Delta V\right) = v_i^2 - \frac{2q\Delta V}{m}$$

$$= (2\times10^5)^2 - \frac{2(1.6\times10^{-19})16}{1.67\times10^{-27}} = 3.7\times10^{10}\,\frac{m^2}{s^2}$$

$$v_F = 1.92\times10^5\ m/s$$

2.



$p = 8\text{ cm}$
$q = -4.5\text{ cm}$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} = \frac{1}{8} - \frac{1}{4.5} = \frac{0.097}{\text{cm}}$$

$$f = -10.3\text{ cm}$$

3. $f = -60\text{ cm}$ ← "diverging"

$$M = \frac{h_i}{h_o} = \frac{1}{4} = \frac{-q}{p} \qquad q = \frac{-p}{4}$$

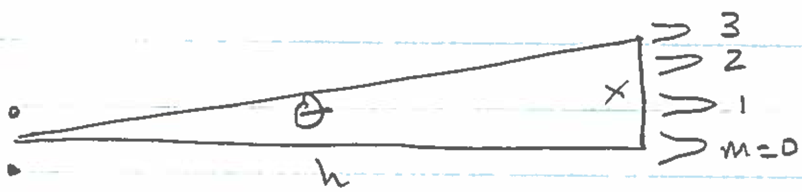
$$\frac{1}{p} + \frac{1}{q} = \frac{1}{p} - \frac{4}{p} = \frac{-1}{60}$$

$$= \frac{-3}{p} = \frac{-1}{60} \Rightarrow \boxed{p = 180\text{ cm}}$$

$$\Rightarrow \boxed{q = -45\text{ cm}}$$

4. $d \sin\theta = m\lambda$ for constructive interference

$d = 0.1\text{ mm} = 10^{-4}\text{ m}$



$$\tan\theta \cong \sin\theta = \frac{x}{h} \Rightarrow \frac{dx}{h} \cong m\lambda$$

$$x = \frac{m\lambda h}{d}$$

0th order $x = 0$

3rd order $x = \dfrac{3\cdot(589\times10^{-9}\text{ m})(1.5\text{ m})}{(1\times10^{-4}\text{ m})} = 0.0265\text{ m} = 2.65\text{ cm}$

5.

Faraday's law $V_{ind} = -N \frac{\Delta \Phi}{\Delta t}$

where $\Phi = B \cdot A$ is flux through 1 turn of the coil.

$$\Delta \Phi = (\pi r^2) \cdot (B_f - B_i)$$

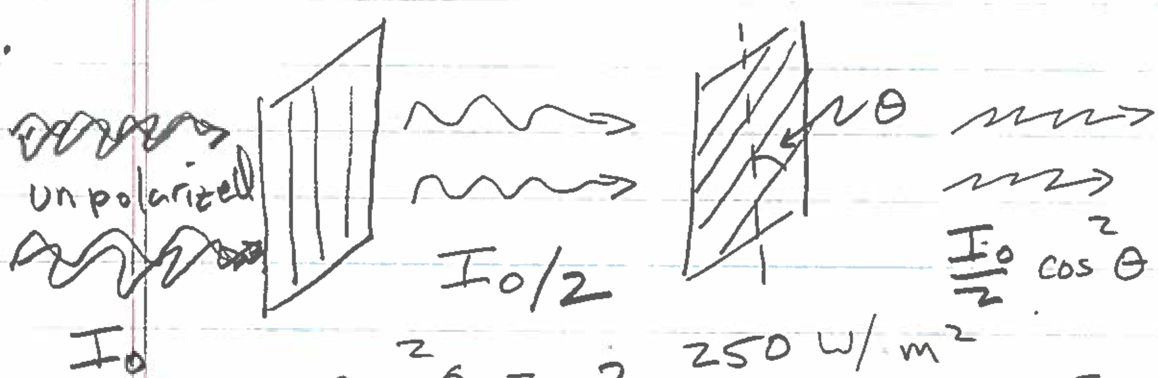
$$= \pi (0.075)^2 (0.2 - 0.8)$$

$$\Delta t = 2.5 \text{ s} \qquad N = 25$$

$$V_{ind} = \frac{25 \pi (0.075)^2 (0.2 - 0.8)}{2.5}$$

$$= 0.106 \text{ V} = 106 \text{ mV}$$

6.

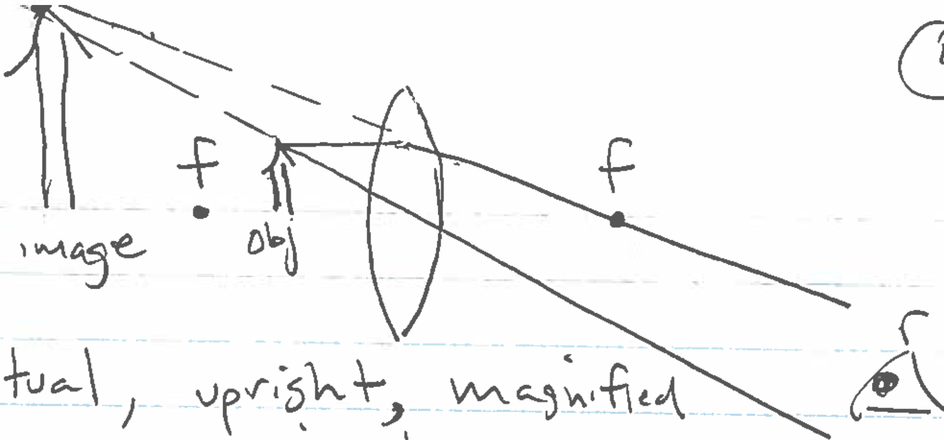


$$\cos^2\theta = 2 \frac{250 \text{ W/m}^2}{750 \text{ W/m}^2} = \frac{2}{3}$$

$$\theta = \cos^{-1}\sqrt{\frac{2}{3}} = 35.3°$$

→ Note unpolarized light has 2 perpendicular polarization states, and the 1st polarizer removes 1 of them, so intensity drops by 2.

7.



virtual, upright, magnified
converging lens

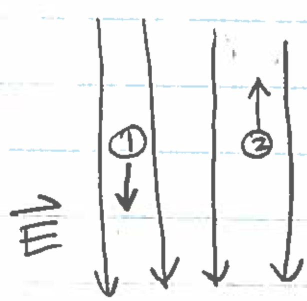
8. $F = ma = qE$

$$a_1 = \frac{q_1}{m_1} E \quad \text{same for 2}$$

E is the same for both, so acceleration depends only on q/m ratio

① : $\frac{q_1}{m_1} = \frac{3}{3} = 1$ in mC/mg ② : $\frac{q_2}{m_2} = \frac{-10}{2} = -5$

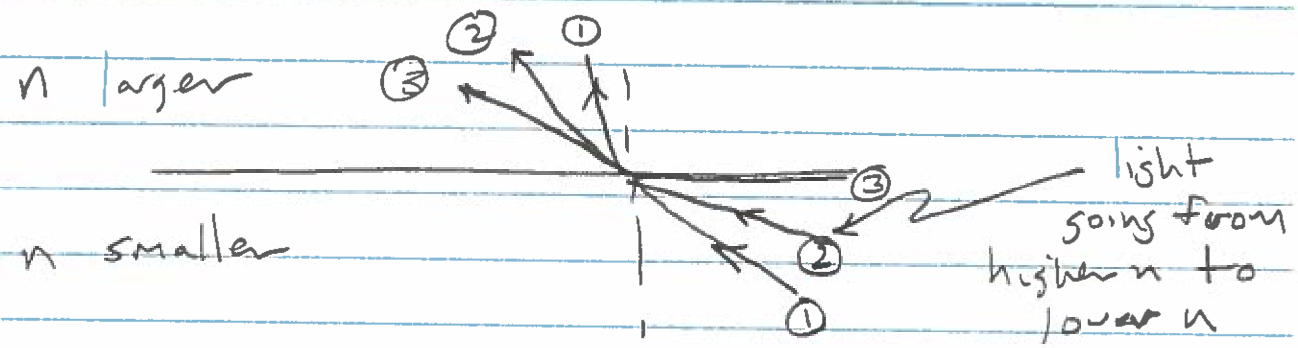
So: ② accelarates faster than ① but in the opposite direction:



So: ① feels smaller magnitude of force than ② since $|\vec{F}_1| = 3E$, $|\vec{F}_2| = 10E$

Since $|a_1| < |a_2|$, + both are "released", $v_2 > v_1$ after after a fixed time.

9. Total internal reflection:

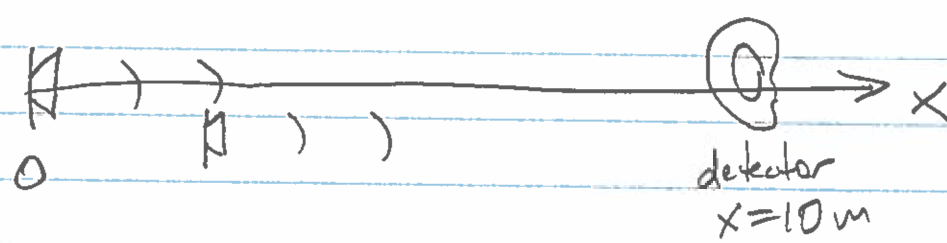


Light bends closer to the normal in the larger n medium. The ray 3 shown is largest angle incident on the interface from the large n medium. But it does not correspond to total internal reflection — even this ray transmits energy into the large n medium.

If you reverse the direction of propagation then ray (3) corresponds to total internal reflection — all light stays on the high n side.

All other statements correct.

10.



"lowest intensity" => destructive interference

$\Delta x = \frac{\lambda}{2}, \frac{3\lambda}{2}, \ldots$

1st position $\Delta x = \frac{\lambda}{2} = 30$ cm

2nd position $\Delta x = \frac{3\lambda}{2} = 90$ cm

$\Delta x = 0.9$ m

11. (A) is false because sunlight is unpolarized, not linearly polarized

(C) is false because the magnetic field $\vec{B}$ in a traveling wave is $\perp$ to direction of wave propagation.

Other statements are true.

12. Coulomb force = centripetal force in order that the electron goes in a circle

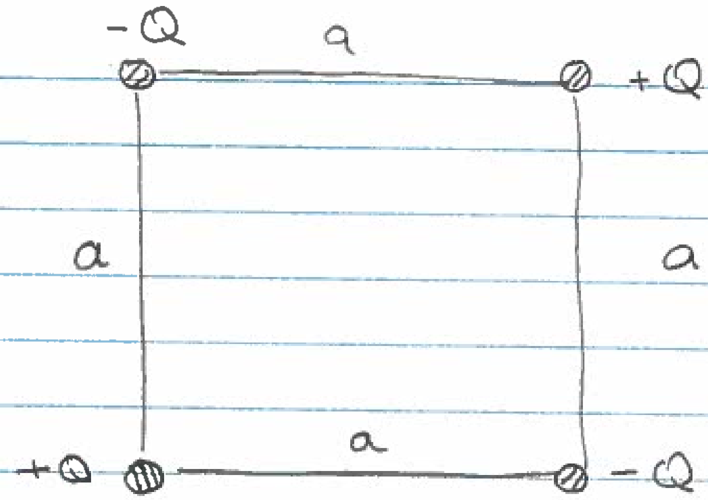
$$|\vec{F}| \quad \frac{ke^2}{r^2} = \frac{mv^2}{r}$$

$$v^2 = \frac{ke^2}{rm} = \frac{(9\times10^9)(1.6\times10^{-19})^2}{(5.3\times10^{-11})(9.11\times10^{-31})}$$

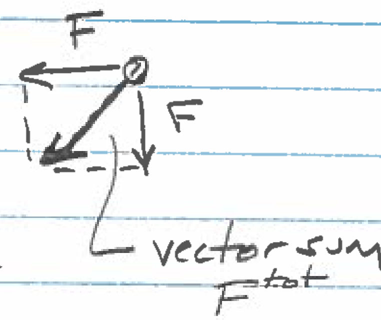
$$= 4.77\times10^{12}\, m^2/s^2$$

$$v = 2.18\times10^6\, m/s$$

13.



2 $-Q$ charges produce forces



$$F_{-Q} = \frac{kQ^2}{a^2}$$

$$F_{-Q}^{tot} = \sqrt{2}F = \sqrt{2}\frac{kQ^2}{a^2}$$

1 $+Q$ charge produces forces

$$F_{+Q} = \frac{kQ^2}{(\sqrt{2}a)^2} = \frac{1}{2}\frac{kQ^2}{a^2} = \frac{1}{2}F$$

So the $-Q$ charges win, and (A) is correct answer

14. Total $R = 3 + 9 + 6 = 18\Omega$

total current $I = \frac{\varepsilon}{R} = \frac{\varepsilon}{18}$

Power dissipated in resistor $R_2 = 9\Omega$ is

$$P_2 = I^2 R_2 = \left(\frac{\varepsilon}{18}\right)^2 \cdot 9 = \frac{\varepsilon^2}{36}$$

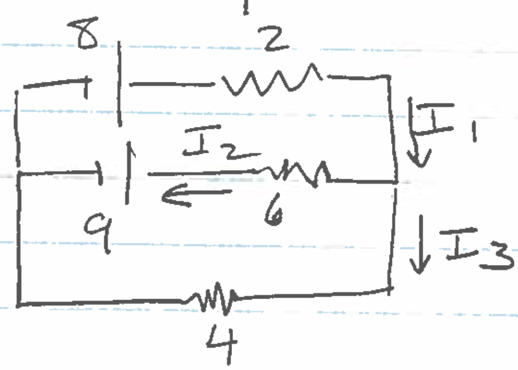
Power is energy / time $= \frac{400 J}{4 sec} = 100 W$

So $100 = \frac{\varepsilon^2}{36} \Rightarrow \varepsilon = 60 V$

15. In figure lower wire produces magnetic field out of page at position of upper wire, by rh rule,

F on upper wire $= I l B$
so F is up on paper by rh rule

16. Top loop:



$8 - 2I_1 - 6I_2 - 9 = 0$

or $2I_1 + 6I_2 + 1 = 0$ (1)

Bottom loop

$9 + 6I_2 - 4I_3 = 0$ (2)

node law: $I_1 = I_2 + I_3$ (3)

Want $I_1 \Rightarrow$ eliminate $I_3 = I_1 - I_2$ then I_2

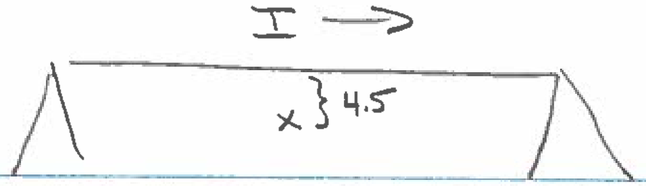
(2) $9 + 6I_2 - 4(I_1 - I_2) = 9 + 10I_2 - 4I_1 = 0$

$\frac{3}{5} \times$ (2) $\frac{27}{5} + 6I_2 - \frac{12}{5} I_1 = 0$

(1) $1 + 6I_2 + 2I_1 = 0$

$\frac{22}{5} - \frac{22}{5} I_1 = 0$ $\boxed{I_1 = 1A}$

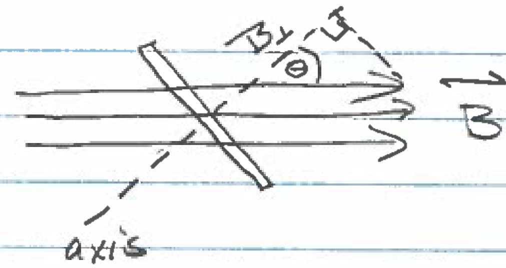
17.



field of a current-carrying wire

$$B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7})(125)}{2\pi(4.5)} = 5.55 \times 10^{-6}\ T$$

18.



$$\Phi = B_\perp A = BA\cos\theta$$

$$\Delta\Phi = BA(\cos 60^\circ - \cos 30^\circ)$$

$$= (4 \times 10^{-2}\ T)(40\ 10^{-4}\ m^2)\left(\frac{1}{2} - \frac{\sqrt{3}}{2}\right)$$

$$= -5.9 \times 10^{-5}\ Tm^2$$

19. $2\Delta x = \frac{\lambda_{med}}{2}, \frac{3\lambda_{med}}{2}, \ldots$ (destructive interference)

$$\lambda_{med} = \frac{\lambda_{vac}}{n} = \frac{545\,nm}{1.5} = 363\,nm$$

$$\Delta x = \frac{\lambda_{med}}{4}, \frac{3\lambda_{med}}{4} \ldots = 90.1\,nm,\ 272\,nm \ldots$$

$$90.1\,nm = 9 \times 10^{-8}\,m$$

20. Vertical wire is || to field so force is 0