# Physics 102H Final Exam
# May 12 2023

Name (please print): _____

*This test is administered under the rules and regulations of the honor system of the College of William & Mary.*

Signature: _____

Final score: _____

**Some useful constants**

$k = 1.38 \times 10^{-23}$ J/K $N_A = 6.022 \times 10^{23}$ $R = kN_A = 8.315$ J/mol・K $0^oC=273K$

one atmosphere = 760 mm Hg = $10^5$ Pa 1 cal = 4.186 J 1amu = $1.66\times10^{-27}$kg

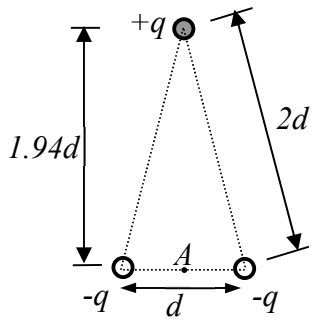
$e=1.6\cdot10^{-19}$ C $\varepsilon_0=8.84\cdot10^{-12}$ $C^2/Nm^2$ $k=9\cdot10^9$ $Nm^2/C^2$ $k = \frac{1}{4\pi\varepsilon_0}$

$\mu_0=4\pi\cdot10^{-7}$ H/m $c=3\cdot10^8$ m/s

*Show all work to receive credit, and circle your final answers. This exam is closed book, and you can use calculators only for simple arithmetical operations.*

Problem 1 (15 points)
Three charged particles are fixed at the vertices of an isosceles triangle, as shown. Consider $q$ = 7.00 μC and $d$=2.00 cm.

a) What is the magnitude and the direction of the electric force acting on the positive charge?




b) Determine the magnitude and direction of the electric field at point A, the midpoint of the base.

c) Determine the value of the electric potential at point A.

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Problem 2 (10 points)

Two speeding lead bullets, one of mass $m_1$=12.0g moving to the right at $v_1$=300m/s and one of mass $m_2$=9.0g moving to the left at $v_2$=400m/s, collide head-on, and all the material sticks together. Both bullets are originally at temperature $T_0$=30.0ºC. Assume the change in kinetic energy of the system appears entirely as increased internal energy.

*Some possibly useful properties of lead: melting point* =327.3ºC*, boiling point* =1750ºC, *latent heat of fusion* = $2.45\times10^4$ *J/kg, latent heat of evaporation* = $8.7\times10^5$ *J/kg, specific heat* = 128 *J/kg·K, mass density of liquid lead* = 10,215 *kg/m*$^3$; *mass density of solid lead* = 11,340 *kg/m*$^3$.

What is the temperature of the combined lead blob after the collision? Is it still solid, or partially or completely melted?

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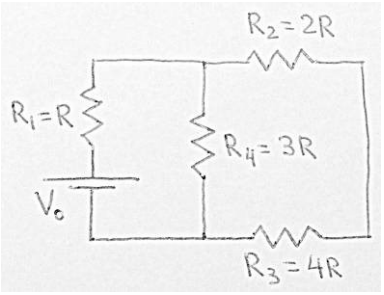
Problem 3 (15 points)




Four resistors are connected to a battery as shown. The battery emf is $V_0$, and the resistor values are $R_1=R$, $R_2=2R$, $R_3=4R$, and $R_4=3R$.

a) Rank resistors according to the current through them, from largest to smallest, note any cases of equal currents.

b) What is the current drawn from the battery, in terms of $V_0$ and $R$?

c) What is the potential difference across the resistor $R_2$?

d) The resistor $R_4$ is replaced by a capacitor with capacitance $C$. What is the current through the resistor $R_2$ when the capacitor is fully charged?

e) What is the charge on the capacitor when it is fully charged?

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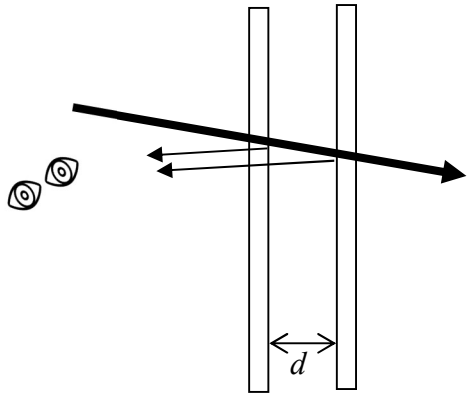
Problem 4 (10 points)

A beam of $\lambda$=580 nm light passes through two closely spaced glass plates ($n_{glass}$=1.5) at close to normal incidence. Consider only the beams reflected off the inner surfaces of the gap, as shown (not in scale!)




a) What is the smallest (non-zero) value of separation *d* for which the reflected light is the brightest?

b) How does the answer in a) changes if the spacing between two slits is filled with transparent oil (index of refraction $n_{oil}$=1.6)?

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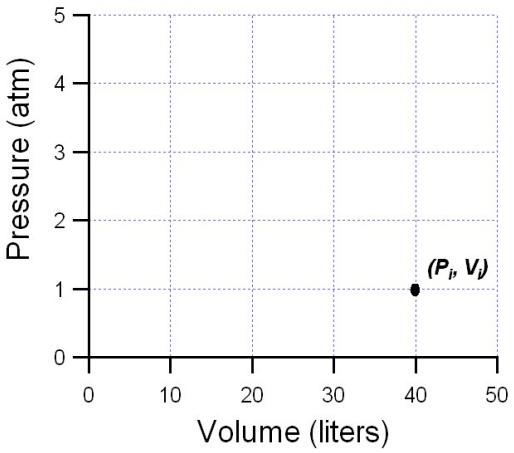
Problem 5 (10 points)

One mole of an ideal gas is contained in a cylinder with a movable piston. The initial pressure and volume $P_i$=1.0 atm, and $V_i$=40 liters, respectively (1liter = $10^{-3}m^3$). Then the gas can undergo one of three processes:

i) an isobaric compression in which the final volume is one-half the initial volume.

ii) an isothermal compression in which the final pressure is four times the initial pressure.

iii) an isovolumetric process in which the final pressure is three times the initial pressure.




a) Show each process in P-V diagram, assuming the same starting point.

b) Calculate the values of temperature at the end of each process. Which one results in the highest final temperature?

c) Find the work done by the gas and the change in internal energy of the gas in each process.

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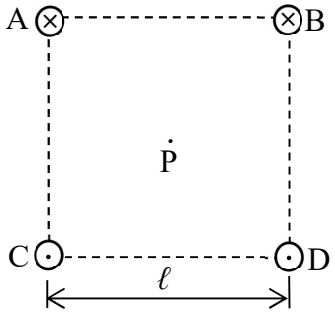
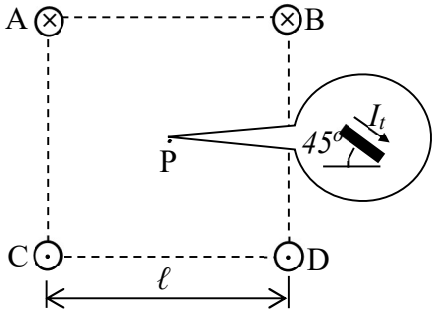
Problem 6 (15 points)

Four long, parallel conductors carry equal currents of $I$=3.0A. Figure shows the end view of the conductors. The current direction is into the page at points A and B and out of the page at points C and D.

a) Calculate the magnitude and the direction of the magnetic field at point P, located at the center of the square of edge length $\ell$=0.20m.




b) A very small test wire of length d=300μm carrying current $I_t$=0.12A as shown is placed at the point P and is in plane of the drawing. What is the magnitude and direction of the magnetic force (consider the magnetic field, calculated in a), to be uniform across the test wire).




c) A very small test sphere of radius $R$=30μm carrying a positive charge $q$=+7μC is placed at the point P. What is the magnitude and direction of the magnetic force (consider the magnetic field, calculated in a), to be uniform across the sphere).

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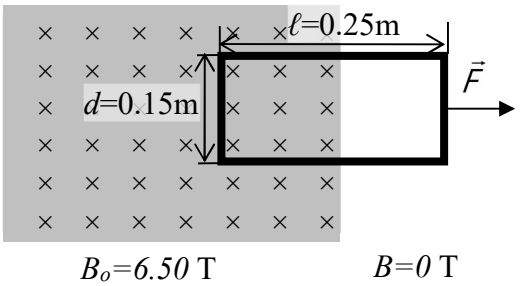
Problem 7 (10 points)

Part of a single rectangular loop of wire with dimensions as shown is situated inside a region of uniform magnetic field of $B_0$=6.50T. The total resistance of the loop is $R$=0.8 Ω.

a) What is the magnitude and the direction of the induced electrical current if the loop is pulled from the field-filled region at a constant velocity of $v$ = 2.4m/s. Neglect gravity.




b) Calculate the force required to pull it with this constant speed.

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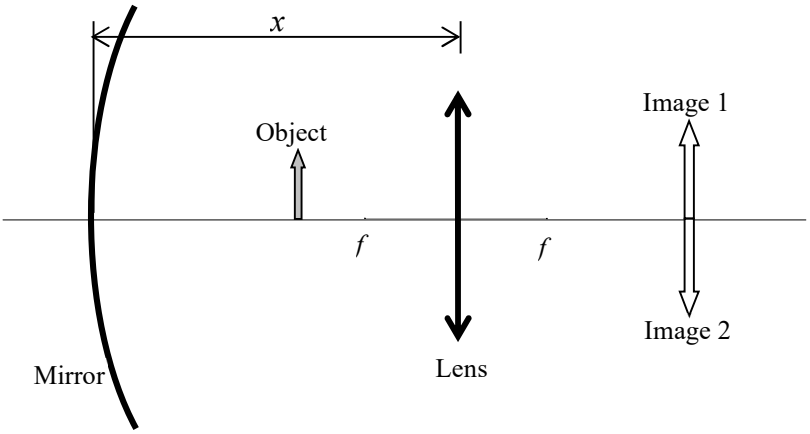
Problem 8 (15 points)

An observer to the right of the mirror-lens combination shown below sees two images that are the same size and in the same location (one is the direct image of the object by the lens, while the other is the lens's image of the object's reflection in the mirror). Image 1 is upright, while the image 2 is inverted. Both images are 1.50 times larger than the object. The lens has a focal length $f$=10cm, and the lens and mirror are separated by $x$=40.0 cm.





Observer

a) If the mirror is removed, which of the two images will disappear? Explain.

b) How far is the object from the lens?

c) Calculate the radius of the curvature of the mirror.

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