**Physics 1215 – Final Exam**
**Spring 2008 – May 6, 2008**

Name (Print):_____Key____________________________

My signature below is a statement that all work contained in this exam is my own work. I have not copied work from any other source, or used any material other than the official equation sheet and my calculator.

Name (Signature):____________________________________

**DO NOT TURN THIS PAGE OVER UNTIL YOU ARE INSTRUCTED TO DO SO.**

**STOP WORKING ON THIS EXAM AS SOON AS YOU ARE INSTRUCTED TO DO SO.**

- The following exam consists of 10 multiple-choice questions and 5 worked problems.
  - Point values are assigned to each problem in the exam.
- It is a good idea to first skim through the entire test and begin with the problems that seem most familiar. If you get stuck on a problem, skip to another.
- For the computational problems, please show all problem solving steps and all your work.
  - All work must be done on the pages provided.
  - Please write neatly and put a BOX around your final answer.
  - Use significant figures in your answers.
- Calculators may be used only to do arithmetic. You cannot use your calculator for solving algebraic equations, for graphing, for vectors, etc.
- One equation sheet may be used. No books or other notes are allowed.

| Problem # | Max Points | Score | Problem # | Max Points | Score |
|---|---|---|---|---|---|
| 1 | 5 | | 9 | 5 | |
| 2 | 5 | | 10 | 5 | |
| 3 | 5 | | 11 | 30 | |
| 4 | 5 | | 12 | 30 | |
| 5 | 5 | | 13 | 30 | |
| 6 | 5 | | 14 | 30 | |
| 7 | 5 | | 15 | 30 | |
| 8 | 5 | | Total | 200 | |

$R = 8.314$ J/mol·K
$\mu_0 = 4\pi\times10^{-7}$ T·m/A

Have a Great Summer!

1. Diatomic gas $A$ is at the same temperature as diatomic gas $B$. If the rms speed of gas $A$ is four times the speed of gas $B$, what is the ratio of the molecular mass of gas $A$ ($m_A$) to the molecular mass of gas $B$ ($m_B$)? $m_A/m_B =$

$U = \frac{5}{2}kT = \frac{1}{2}m_A v_A^2 = \frac{1}{2}m_B v_B^2$

$v_A = 4v_B$

$\frac{m_A}{m_B} = \left(\frac{v_B}{v_A}\right)^2 = \left(\frac{1}{4}\right)^2 = \frac{1}{16}$

- [x] 1/16
- [ ] 1/2
- [ ] 4
- [ ] 1/4
- [ ] 2
- [ ] 16

2. One mole of an ideal gas undergoes a reversible isothermal expansion from a volume of 1 liter to a volume of 2 liters. The change in entropy of the gas in terms of the universal gas constant $R$ is

$Q = \Delta U + W$

$= N_f \frac{1}{2} nR\Delta T + P\Delta V$

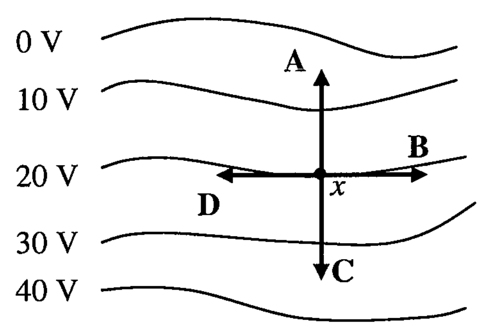
$= P\Delta V$

$\Delta S = \int \frac{dQ}{T} = \int \frac{P\,dV}{T} = \int \frac{nRT}{T}\frac{dV}{V}$

$= nR \ln \frac{V_f}{V_i} = R \ln 2$

- [ ] $R/2$
- [x] $R \ln(2)$
- [ ] only calculable with more information given.
- [ ] $2R$
- [ ] $R \ln(1/2)$

3. The figure shows equipotential lines. Which vector best represents the electric field at point $x$ on the 20-V equipotential line?




Toward lower potential

- [x] A
- [ ] B
- [ ] C
- [ ] D
- [ ] None of the above

4. A parallel plate capacitor with air between the plates is charged to a potential $V$. While it is still connected to the battery a dielectric with dielectric constant of 4 is placed between the plates of the capacitor. What happens to the energy stored in the capacitor?

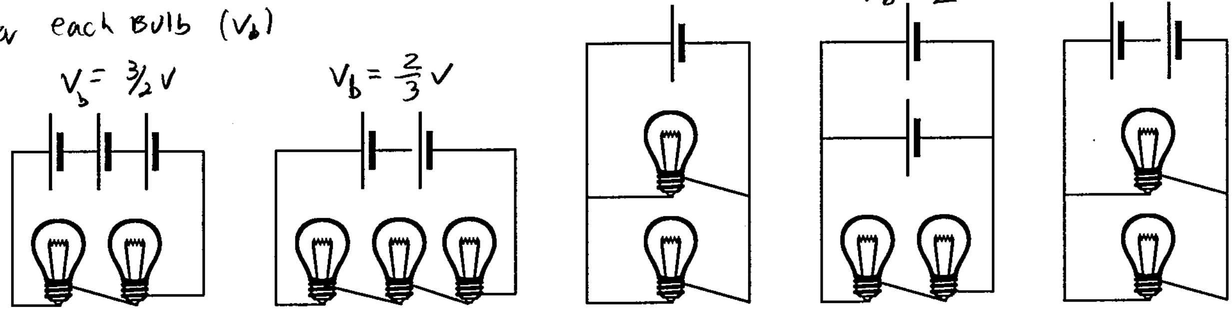
$U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{\varepsilon_0 KA}{d}V^2$

$K \to 4K$

- [ ] It decreases by a factor of 16
- [ ] It decreases by a factor of 4
- [ ] It increases by a factor of 2
- [x] It increases by a factor of 4
- [ ] It increases by a factor of 16

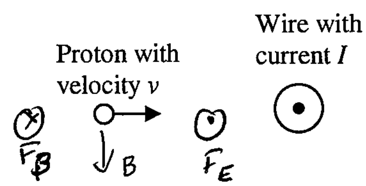
5. In the diagrams below, all light bulbs are identical and all batteries are identical. In which circuit will the bulbs be dimmest?

For each bulb ($V_b$)




☐ ☐ ☐ ☒ ☐

6. A wire is carrying a current directly out of the page as shown. A proton is traveling directly toward the wire. What direction should an electric field point so that it is possible that the proton feels no net force?




| ⊗ | ⊙ | ↓ | ↑ | → | ← |
|---|---|---|---|---|---|
| ☐ | ☒ | ☐ | ☐ | ☐ | ☐ |

7. The sound level of a dog's bark is 50 dB. The intensity of a rock concert is 10,000 times that of the dog's bark. What is the sound level of the rock concert?

☐ 10,050 dB
☒ 90 dB
☐ 54 dB
☐ 500,000 dB
☐ 2000 dB

$\beta = 10\log\frac{I}{I_0}$

$50 = \log\left(\frac{I}{I_0}\right)^{10}$

$I_0 10^{50} = I^{10}$

$I_0 10^5 = I$

$I' = 10^4 I = 10^9 I_0 \Rightarrow \beta = 10\log\frac{I'}{I_0} = 90\text{ dB}$

8. A sinusoidal wave is traveling along the x axis at a speed of 5.0 m/s with an amplitude of $A$. An observer at the origin notices that at $t$=0 seconds, the wave has a maximum, then it has another maximum 10 seconds later. What function below best describes this wave

☐ $y = A\sin(\pi x/25 - \pi t/5)$
☐ $y = A\sin(\pi x/50 - 10\pi t)$
☐ $y = A\sin(\pi x/50 - \pi t/5)$
☒ $y = A\cos(\pi x/25 - \pi t/5)$
☐ $y = A\cos(\pi x/50 - 10\pi t)$
☐ $y = A\cos(\pi x/50 - \pi t/5)$

$f = \frac{1}{10}\text{ s}$

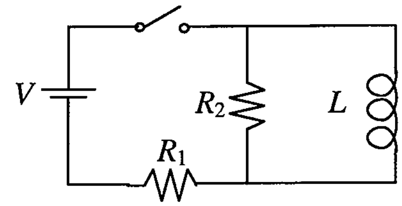
$v = 5\text{ m/s}$

$\lambda = \frac{v}{f} = 50\text{ m}$

$y = A\cos(kx - \omega t)$

$k = \frac{2\pi}{\lambda} \quad \omega = 2\pi f$

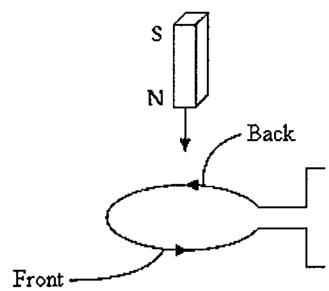
9. In the circuit shown $R_1 = R_2$. What is the voltage across $R_1$, $R_2$, and $L$ when the switch is initially closed?

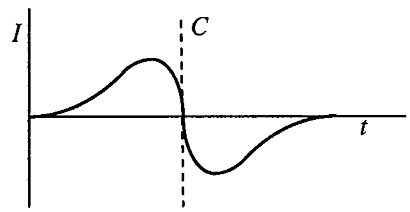



| | $L$ | $R_1$ | $R_2$ |
|---|---|---|---|
| ☐ | $V$ | $\frac{1}{2}V$ | $\frac{1}{2}V$ |
| ☐ | $V$ | 0 | $V$ |
| ☐ | $V$ | 0 | 0 |
| ☐ | 0 | $\frac{1}{2}V$ | $\frac{1}{2}V$ |
| ☐ | 0 | $V$ | 0 |
| ☒ | $\frac{1}{2}V$ | $\frac{1}{2}V$ | $\frac{1}{2}V$ |

$I_L = 0$ ⇒ all current in 1st loop. Use Loop rule

10. A bar magnet is dropped through a loop of copper wire as shown. If the positive direction of the induced current $I$ in the loop is as shown by the arrows on the loop, the variation of $I$ with time as the bar magnet falls through the loop is illustrated qualitatively by which of the following graphs? The time when the midpoint of the magnet passes through the loop is indicated by $C$.

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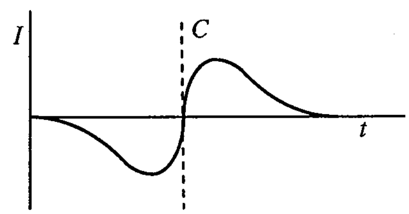


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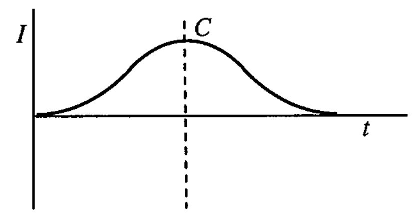


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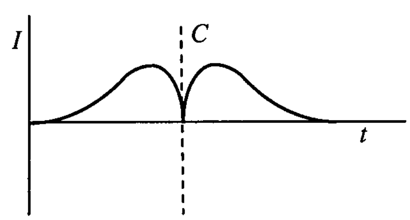


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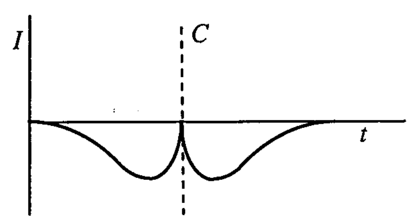
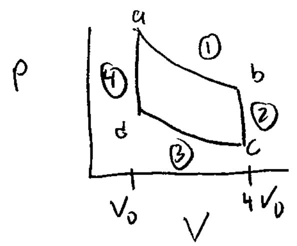



☐

11. A heat engine follows a four step process using 0.345 moles of a diatomic ideal gas. (1) Starting at a high temperature of 633 °C the gas expands isothermally to four times its volume. (2) It then cools isochorically to one third of the original temperature. (3) The gas is then compressed isothermally back to its original volume. (4) Finally, the temperature is increased isochorically to the original pressure and temperature.

a) Draw a P-V diagram of this process.
b) Draw a chart showing the work, change in internal energy, and heat transfer during each of the four steps of this process?
c) What is the efficiency of this engine?
d) If this were a Carnot cycle operating between these high and low temperatures, what would be its efficiency?

a)




$T_c = \frac{1}{3} T_b = \frac{1}{3}(906\,K) = 302\,K$

b) $W_{a\to b} = \int P\,dV = \int \frac{nRT_b\,dv}{V} = nRT \ln\frac{V_f}{V_i} = (.345\text{ mole})(8.314)(906\,K)\ln 4$

$= 3603\text{ J}$

$W_{c\to d} = nRT_c \ln\left(\frac{1}{4}\right) = (.345\text{ mol})(8.314)(302\,K)\ln\frac{1}{4} = -1201\text{ J}$

$\Delta U_{b\to c} = N_F \frac{1}{2} nR(T_c - T_b) = \frac{5}{2}(.345\text{ mol})(8.314)(302 - 906\,K) = -4331\text{ J}$

$\Delta U_{d\to a} = N_F \frac{1}{2} nR(T_a - T_d) = \frac{5}{2}(.345\text{ mol})(8.314)(906 - 302\,K) = 4331\text{ J}$

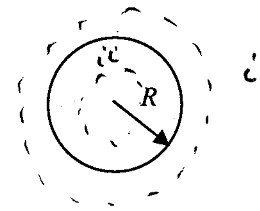
(in Joules)

| | Q | W | ΔU |
|---|---|---|---|
| ① | 3603 | 3603 | 0 |
| ② | -4331 | 0 | -4331 |
| ③ | -1201 | -1201 | 0 |
| ④ | 4331 | 0 | 4331 |

c) $\varepsilon = 1 - \frac{|Q_L|}{|Q_H|} = 1 - \frac{(4331 + 1201)}{(4331 + 3603)} = \boxed{.30}$

d) $\varepsilon_c = 1 - \frac{T_L}{T_H} = 1 - \frac{302}{906} = \boxed{.67}$

12. A solid nonconducting spherical object with a charge density given by $\rho = Ar^2$ has a radius of $R$ and a total charge of $+Q$.




a) Find the constant $A$ by integrating the charge density over the volume of the inner sphere and setting the integral equal to $+Q$.

b) Find the electric field in the regions (i) $r > R$, and, (ii) $r < R$. Show all of your work.

c) Plot the electric field as a function of radius from the center of the sphere.

a) $V = \frac{4}{3}\pi r^3 \quad dV = 4\pi r^2 dr$

$$Q = \int_0^R \rho\, dV = \int_0^R Ar^2\, 4\pi r^2 dr = 4\pi A \int_0^R r^4 dr = \frac{4\pi A R^5}{5}$$

$$\Rightarrow \boxed{A = \frac{5Q}{4\pi R^5}}$$

b) Use Gauss's Law

i) $\oint E \cdot dA = Q_{enc}/\varepsilon_0$

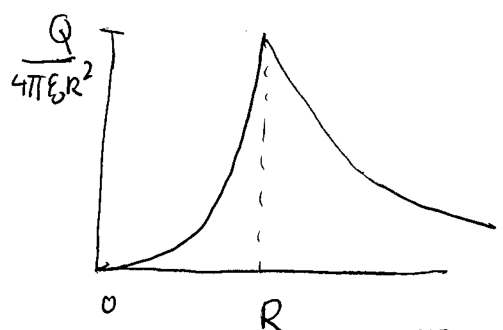
$$4\pi r^2 E = \frac{Q}{\varepsilon_0} \Rightarrow \boxed{E = \frac{Q}{4\pi\varepsilon_0 r^2}}$$

ii) $\varepsilon_0 \oint E \cdot dA = Q_{enc} = \int_0^r \rho\, dV = \int_0^r 4\pi r^2 A r^2 dr = A 4\pi \int_0^r r^4 dr$

$$\varepsilon_0 4\pi r^2 E = A 4\pi\, r^5/5$$

$$E = \frac{Ar^3}{5\varepsilon_0} = \frac{Q r^3}{4\pi\varepsilon_0 R^5}$$

c)




This part proportional to $r^3$

This proportional to $\frac{1}{r^2}$

13.

a) Use Ampere's law or the Biot-Savart law to find the magnetic field a distance $R$ from an infinitely long wire carrying a current $I$. Show all of your calculations.

b) Three very long wires are oriented perpendicular to the plane of this paper. Each has a current as shown in the figure. If $I_1 = I_2 = 9.0$ A, what value of $I_3$ will give a magnetic field with only an **i** ($x$) component at point $P$?

c) A fourth wire is placed parallel to the other three wires at point $P$. The fourth wire has a current of 16 A. If the magnetic force on the fourth wire just balances the gravitational force on that wire, what is the linear mass density of the wire and what is the direction of the 16 A current?

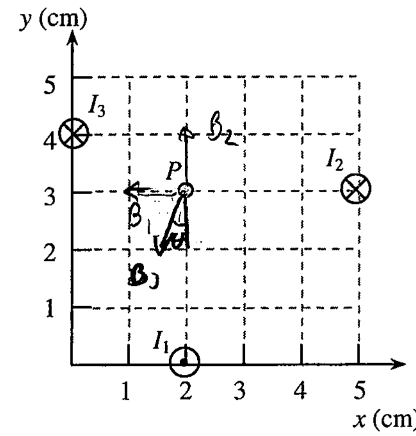
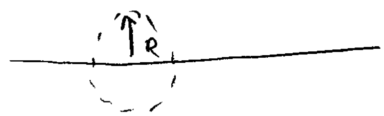



Figure for (b) and (c)

a) Use Ampere's law




$\oint B \cdot dL = \mu_0 I$

$2\pi R B = \mu_0 I \Rightarrow B = \dfrac{\mu_0 I}{2\pi R}$

b) magnitude of $B_1 = B_2 = \dfrac{\mu_0 I}{2\pi r} = \dfrac{(4\pi \times 10^{-7} \frac{T \cdot m}{A})(9.0\,A)}{2\pi(.03\,m)} = 6 \times 10^{-5}\,T$

$\vec{B}_1 = -6 \times 10^{-5}\,T\,\hat{i} \qquad \vec{B}_2 = -6.0 \times 10^{-5}\,T\,\hat{j}$

To get no magnetic field in the $\hat{j}$ direction $B_{3y} = -B_2$

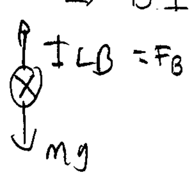
$B_{3y} = B_3 \cos\theta = \dfrac{\mu_0 I_3}{2\pi\sqrt{.01^2 + .02^2}\,m} \cos 26.6^\circ \qquad \theta = \tan^{-1}\frac{1}{2} = 26.6^\circ$

$I_3 = \dfrac{2\pi B_1 \; .0224\,m}{\mu_0 \cos 26.6^\circ} = \boxed{7.5\,A}$

c) $B_{3x} = B_3 \sin\theta = B_{3y} \dfrac{\sin 26.6}{\cos 26.6} = B_1 \tan 26.6^\circ = 3 \times 10^{-5}\,T$

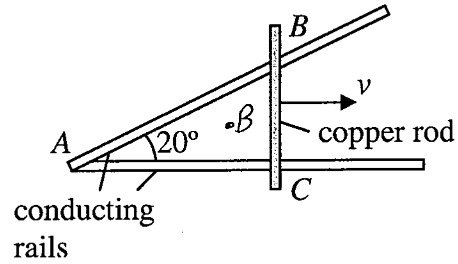
So $B_{TOTAL}$ at $P = B_{3x} + B_1 = -9 \times 10^{-5}\,T$

$\Sigma F = 0 \Rightarrow BIL = mg \qquad \dfrac{m}{L} = \dfrac{BI}{g} = \dfrac{(9 \times 10^{-5})(10\,A)}{9.8} = \boxed{1.5 \times 10^{-4}\,\frac{kg}{m}}$




into page so $\vec{F}_B$ is up

14. A copper rod is sliding on two conducting rails that make an angle of 20° with respect to each other as shown in the drawing. The rod is moving to the right with a constant speed of $v$=0.25 m/s and passes point $A$ at time, $t$=0. A 0.64 T uniform magnetic field is perpendicular to the plane of the paper and points out of the plane of the paper




a) Write an expression for the magnetic flux inside the triangular region as a function of time. (The area of a triangle is given by ½ times length times height).

b) Write an expression for the emf produced in the triangular region as a function of time.

c) What is the average emf produced in the first 4.0 seconds after the rod passes point $A$?

d) Which direction does the charge move in the copper rod, toward $B$ or toward $C$?

a) $\Phi = \int B \cdot dA = BA = \frac{1}{2} B L h$ $\quad L = vt \quad h = L\tan\theta \quad \tan\theta = \frac{h}{L}$

$\Phi = \frac{1}{2} B v^2 t^2 \tan\theta$

b) $\mathcal{E} = -\frac{d\Phi}{dt} = B v^2 t \tan\theta$

c) $\mathcal{E} = (.64T)(.25\ m/s)^2(4.0s)(\tan 20°) = \boxed{.058\ V}$ INSTANTANEOUS

$\mathcal{E}_{Ave} = \frac{\Delta\Phi}{\Delta t} = \frac{\Phi_f - \Phi_i}{\Delta t} = \frac{1}{2} \frac{Bv^2t^2\tan\theta}{t} = \boxed{.029\ V}$ Average

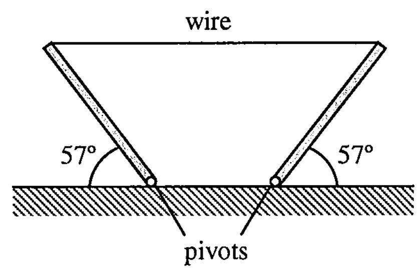
d) TOWARD C

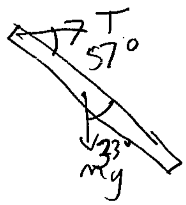
You can also do (a) as $A = \frac{1}{2}Lh = \frac{1}{2}v^2t^2\tan\theta$

$\Rightarrow dA = v^2 t \tan\theta\, dt$

so $\Phi = \int_0^t B \cdot dA = B\int_0^t v^2 t \tan\theta\, dt = \frac{Bv^2t^2\tan\theta}{2}$

15. A 5.00-m, 0.732-kg wire is used to support two uniform 235-N posts of equal length as shown in the figure. Assume the wire is essentially horizontal. A strong wind is blowing causing the wire to vibrate in its 8th harmonic (7th overtone). What is the wavelength and frequency of the sound this wire produces? (Hint: Use static equilibrium to determine the tension in the wire.)




$$\Sigma \tau = 0$$

$$\frac{L}{2} mg \sin 23° - T L \sin 57°$$

$$T = \frac{mg}{2} \frac{\sin 33°}{\sin 57°} = \frac{mg}{2} \tan 33° = \frac{235\,N}{2} \tan 33°$$

$$= 76\,N$$

$$\lambda = \frac{2L}{N} = \frac{2L}{8} = \frac{L}{4} = \frac{5.00\,m}{4} = \boxed{1.25\,m}$$

$$v = \lambda f$$

$$\Rightarrow f = \frac{v}{\lambda} = \sqrt{\frac{T}{m/L}}\,\frac{1}{\lambda} = \sqrt{\frac{76\,N}{.732/5\,m}}\,\frac{1}{1.25\,m} = \boxed{18.2\,Hz}$$