Energy Systems – winter 2005 – midterm exam

This is a CLOSED BOOK, take-home exam, due Thus.3. Feb.2005 at 1:00 (in class).
You may refer to your homework and your fall portfolio, but nothing else.
Do not discuss the exam with anyone or get help from anyone.
This is designed as a 2-hour exam, so you should be able to finish it in 3 hours.
Do take a break midway through the exam.
Do not use calculators or computers, for numerical solutions, graphing, or anything else.

Always * show your work clearly, * use words to explain your reasoning, and circle your answer (or underline).

(print) (sign your name)

I affirm that I worked this exam without help from anyone, and without using a calculator or computer, texts, or any other resources except my own homework and fall portfolio.

Use the best problem-solving techniques you have learned in homework and class.
Do your rough work on a scratch sheet if necessary, and turn in NEAT exam-quality work.

Possibly useless data and constants:

water: c = 4190 J/kg·K, L_v = 2260 kJ/kg, L_f = 333 kJ/kg, density = 10^3 kg/m^3

Electric force constant $k = \frac{1}{4\pi\varepsilon_0} \approx 9\times10^9 \frac{N\cdot m^2}{C^2}$ speed of light c = 3 x 10^8 m/s

Metric ton = 10^3 kg

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……Please leave the section below for your prof's grading notes……

Section A: Electricity

Section B: Magnetism

Section C: Calculus

Section D: Seminar questions

Section E: ESwinmid on InQsit (research and possibly seminar) will be available Wednesday noon, and is due Thursday before class.

Section A: Electricity

1 First recall these fundamental relationships:
(a) What is the electric force on a charge q in a field E?

(b) What is the fundamental relationship between electric field and potential?

(c) What is the potential V of a point charge Q?

(d) How much current I can a voltage V drive through a resistor R?

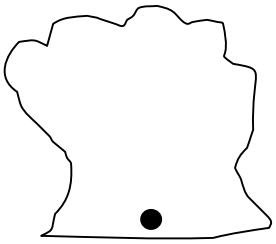
(e) What is the fundamental relationship between current and charge ?

(f) How much power P does it take to drive current I with voltage V?

(g) What is the fundamental relationship between work and power?

2 A thundercloud forms above Mount Rainier. The bottom of the cloud is 3 km above the mountain. Precipitation can establish a charge separation in the cloud. **Consider the effect on the Earth if 20 coulombs of charge builds up on the bottom of the cloud.** (Approximate the charge as a point charge. Ignore any other effects.)

SHOW YOUR WORK and fill in your answers, with units.



(a) **Label** dimensions and quantities on the diagram (which is not to scale).
Draw some representative electric field lines _____ and equipotential lines - - - - - between the cloud and the Earth, including one just above the Earth's surface.

(b) What is the potential difference between the cloud and ground? (Don't worry about sign)

(c) Estimate the strength of the **electric field** at the top of the mountain.
(Can you ignore Earth's usual E_0= 150 V/m field?)

(d) If 10% of the cloud's charge discharges in 0.1 milliseconds, how much **current** will flow?

(e) How much **power** is carried by a 10^4 A lightning strike traveling through a potential difference of 10^8 volts?

(f) How much **work** is done by the lightning strike in (e), if it lasts 0.1 ms and is 100% efficient?

(g) How much glacier ice (m) could this 0.1 ms lightning strike melt?
Estimate the effect on the water level of the Nisqually river.

(h) You witness the lightning strike from a cross country ski cabin to which you drove your VW van. More clouds are rolling in, and the thunderstorm threatens to worsen. Will you feel safer from a lightning strike in the cabin or in your vehicle? Why?

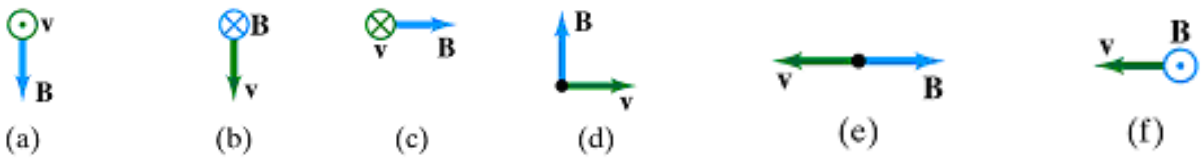
Section B: Magnetism

What is the magnetic force F on a charge q moving with velocity **v** in a magnetic field **B**?

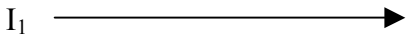
F=

Describe how you can find the direction of the magnetic force.

Draw the force on each charge:



Based on your investigations with your Electromagnetism Kit, and our work in class, **draw the direction of the magnetic field** around a current-carrying wire.

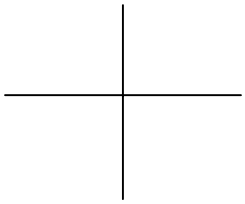


Now draw a second current I_2 below the first current I_1.
What is the **direction of the magnetic force** on I_2?
Draw and **describe** how you figured this out.

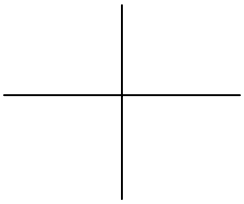
Section C: Calculus

1. Differentiate each function and **integrate** if indicated**. Sketch** functions f(x), g(x), h(x), and their integrals and derivatives, as indicated. **Label intercept values.**

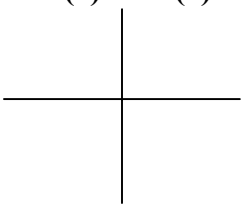
$f(x)=x^3$



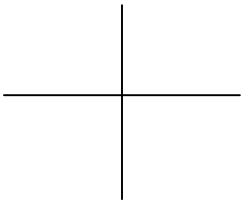
$g(x)=e^{-3x}$



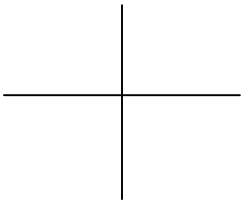
h(x) = sin(x)



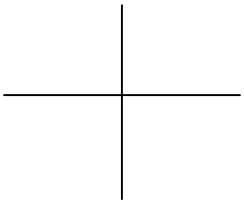
df/dx=



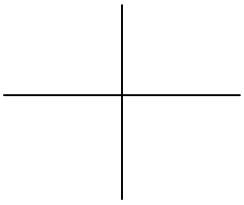
dg/dx=



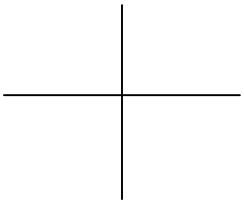
Sketch dh/dx



$\int f\,dx =$



$\int g\,dx =$



2. **Evaluate, simplify**, and circle or underline your answer.

$x(t) = 4t^3 + t^2 + a$ dx/dt = $\int x\,dt =$

$y(t) = \ln t^4$ dy/dt =

$z(x) = x^3\,(x^2 + 1)$ dz/dx =

$v(x) = x^3 / (x^2 + 1)$ dv/dx =

Section D: Seminar: Solar physics and Tesla

If Tesla's device produced sparks 5 meters long, and air ionizes in a field of 3 million V/m, what voltage must his device have produced?

If a CME travels at 1 million miles per hour, how long does it take to reach Earth (in days)? (Recall that we are 93 million miles from the Sun, or about 150 million km.)

The 2 May 1994 event dumped 4600 GW-hr of electricity into Earth's upper atmosphere. How much energy is that (in Joules)? (Hint: giga = 10^9)

If $R_{sun} = 100\ R_{Earth}$, then find the ratio of their volumes, V_{sun}/V_{earth}. (Do it the easy way!)

If m=5 millions tons of mass is converted to energy ($E=mc^2$) each second, calculate the power (P) produced by the Sun.

If the Sun's mass is $M=2x10^{30}$ kg, and it keeps losing dm/dt = 5 million tons per second, how long (T) can the Sun last (in years)?

Section E: Go online to InQsit and do the ESwinmid quiz by the end of the day, Friday 4.Feb.

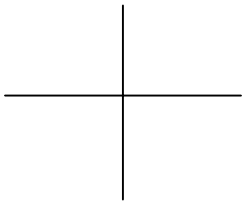
EXTRA problems not used – candidates for final?

Describe each quantity and its units in Ohm's law, V=IR.
V=
I=
R=

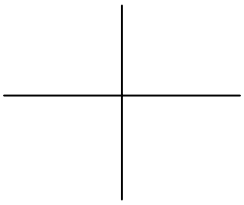
Recall the definition of current density J in terms of I: J=
Recall the definition of R in terms of resistivity ρ: R=
Combine these with E=V/L to find the Ohm's law relation between E, J, and ρ:

Differentiate each function and **integrate** if indicated**. Sketch** functions f(x), g(x), h(x), and their integrals and derivatives. **Label** intercept values.

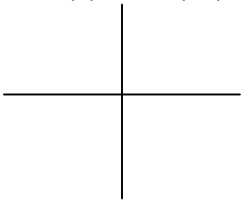
$f(x)=x^3$



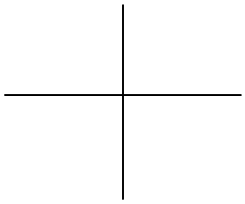
$g(x)=e^{-3x}$



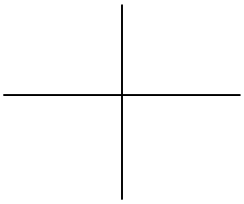
h(x) = sin(2x)



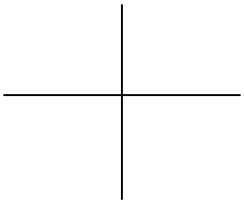
df/dx=



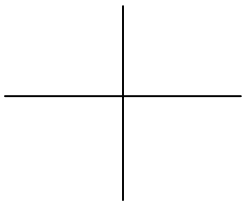
dg/dx=



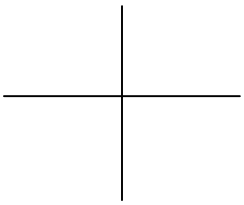
dh/dx=



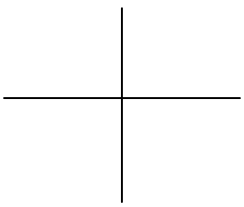
$\int f\,dx =$



$\int g\,dx =$



$\int h\,dx =$



$x(t) = 4t^3 + t^2 + a$

dx/dt=

$\int x\,dt =$

$y(t) = \ln t^4$ $dy/dt=$

$z(x) = x^3 (x^2 + 1)$ $dz/dt=$

$v(x) = x^3 / (x^2 + 1)$ $dv/dt =$

$x(\theta) = \cos (3\theta)$ $dx/d\theta =$ $\int x\, d\theta =$

$y(\theta) = \cos^2(3\theta)$ $dy/d\theta =$