

Energy Systems – winter 2005 – final

This is a CLOSED BOOK, take-home exam, due Thus.3. Mar.2005 at 1:00 in class.

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.

You may use your fall + winter portfolio, and nothing else (including texts or solutions).

Do not use calculators or computers, for numerical solutions, graphing, or anything else.

Do not discuss the exam with anyone or get help from anyone.

(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 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.

*Show your work clearly, *use words to explain your reasoning, and circle or underline your answer.



Courtesy of Nick Kim @ <http://www.nearingzero.net/faq.html>

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

Section A: Qualitative EM

Section B: Quantitative EM

Section C: Calculus

Section D: Energy transformations

Section A. **Qualitative questions about electromagnetism:**

- In electrostatics, conductors have:
 - Zero electric field inside
 - All excess charges on the surface
 - A constant potential along the surface
 - All of the above
- The electrostatic field of a flat charged plate (infinite in spatial extent)
 - increases with distance from the plate
 - decreases with distance
 - is independent of distance
- The magnetic field of a long straight current-carrying wire
 - increases with distance from the wire
 - decreases with distance
 - is independent of distance

4. What can you say about the **spatial dependence** of each case below? (Assume fields are static in time)
- | | Constant? | Zero? | Variable? |
|--|-----------|-------|-----------|
|--|-----------|-------|-----------|

E field along the surface of a conductor

Potential V along the surface of a conductor

E field due to an infinite sheet of charge

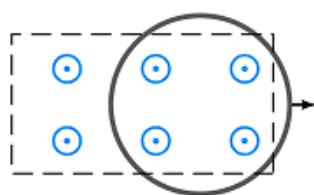
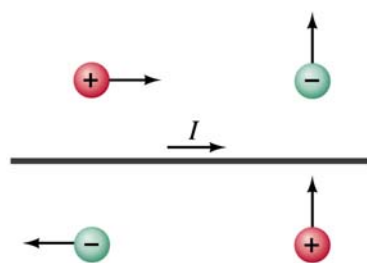
Potential V due to an infinite sheet of charge

Magnetic field of a long straight current

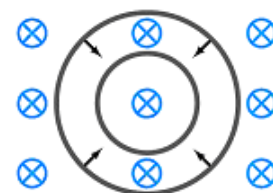
Magnetic field inside a tightly wound solenoid

Magnetic field outside a tightly wound solenoid

5. Sketch the **direction** of the **force** on each charge and the **current** in each loop. Explain your reasoning.



(c)
Pulling the loop to the right
out of a magnetic field
that points out of the page



(d)
Shrinking a loop in a
magnetic field pointing
into the page

Section **B. Quantitative questions about electromagnetism:**

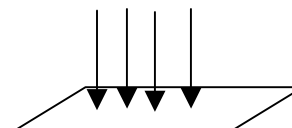
1. Recall your e/m experiment. Use (i) words, (ii) drawings, and (iii) equations to:

(a) describe the effect of the **electric** field on the **motion** and **energy** of the electrons

(b) describe the effect of the **magnetic** field on the **motion** and **energy** of the electrons

2. Solar magnetic field (carried by a coronal mass ejection - CME) increased the magnetic flux through a loop of power lines in Canada. The resultant voltage spike knocked out power to millions in March 1989. (a) Say the CME carries a weak magnetic field, about 10^{-8} T. **How strong would a current** in a long straight wire have to be to create this field at a distance of 2 km (about the size of the CME)?

(b) If the incoming magnetic field is oriented as drawn, **what is the direction** of the current induced in the power grid loop in Canada? **Explain.**



(c) If the CME carries 10^{-8} T through the loop in about 10^{-5} seconds, **find the emf** induced in a square loop of power lines of size 10 km on each side.

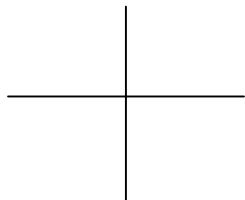
(d) If the resistance of the wires is 5 ohms, **how much current** would this emf drive?

(e) **How much power** would that dissipate through the wires?

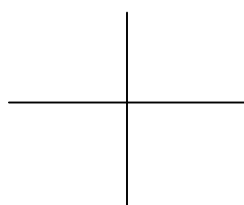
Section C: Calculus

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

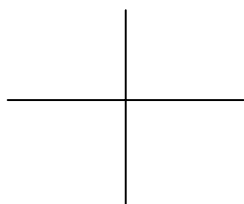
$$f(x) = x^2$$



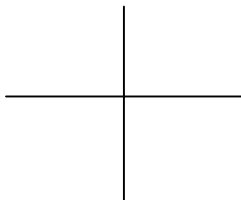
$$df/dx =$$



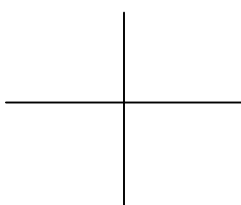
$$\int f \, dx =$$



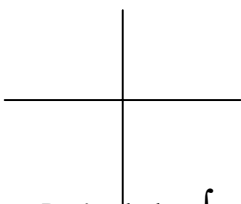
$$g(x) = 3e^{-x^2}$$



$$dg/dx =$$

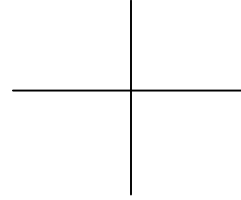


$$\int g \, dx$$

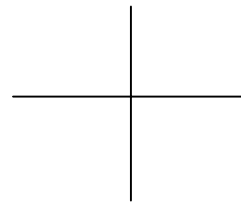


Don't calculate $\int g \, dx$,
but do sketch it.

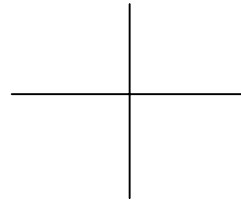
$$h(x) = 2 \sin(2x)$$



$$dh/dx =$$



$$\int h \, dx =$$



2. Evaluate, simplify, and circle or underline your answer. Show your reasoning.

$$f(t) = t + \frac{1}{t} \quad df/dt =$$

$$\int f \, dt =$$

$$\frac{d}{dx}(e^{2x} \cos^3(ax)) =$$

$$\text{Simplify } \ln(y^2 e^{x^3}) =$$

Section D. Energy transformations

Write down a simple, relevant equation for each process below. **Explain** your equation in ordinary language. **Define** each term. (No need to solve equations or plug in numbers.)

(a) The Sun's core burns nuclear fuel.

(b) The power radiated by the Sun depends on its size and temperature.

(c) Charged particles from the solar wind get deflected by the Earth's magnetic field.

(d) A lake warms up by absorbing radiation from the Sun.

(f) Water flows over Niagara Falls, and speeds up as it falls.

(g) The falling water turns a turbine and creates electrical power.

(e) Solar magnetic field carried by coronal mass ejections comes through a loop of power lines in Canada. (The resultant voltage spike knocks out power all night.)

(h) Describe another energy transformation of interest to you.