THE UNIVERSITY OF BRITISH COLUMBIA

Physics 108

Sessional Examination

08:30 AM — 23 April 2004 — LSK 460

TIME: $2\frac{1}{2}$ HOURS

FULL NAME: ____________________ STUDENT # : ____________

SIGNATURE: ____________________

This Examination paper consists of 14 pages (including this one). Make sure you have all 14.

INSTRUCTIONS:

Write your name on every sheet.

One 1-page Summary Sheet is allowed.

Try every question — *easy* ones first! A *diagram* is usually a good start.

Read carefully!

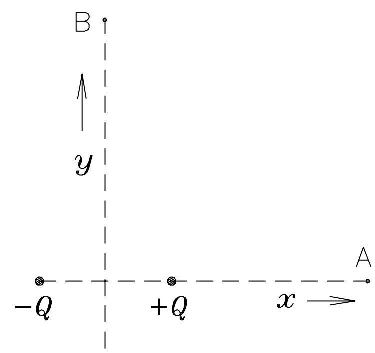
MARKING:

Q1	/60		
Q2	/10	**Q4**	/10
Q3	/10	**Q5**	/10
TOTAL			/100

NAMES OF INSTRUCTORS: Jess H. Brewer & Erich W. Vogt

Q1 "QUICKIES" [60 marks — 6 each]

(*a*) *i*) On the drawing, *sketch in the electric field vectors* at points A and B.



ii) If you take the electrostatic potential to be zero infinitely far from the charges, is the *potential* at point A positive, negative or zero? (Underline your answer.)

iii) What about the potential at point B? (Positive, negative or zero?)

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(*b*) An electron is moving with a finite constant velocity $\boldsymbol{v}$ in a region where there is a uniform, constant electric field $\boldsymbol{E}$ as well as a uniform, constant magnetic field $\boldsymbol{B}$. Of the three vectors $\boldsymbol{v}$, $\boldsymbol{E}$ and $\boldsymbol{B}$, which *pairs* of vectors must be *perpendicular*?

i) The electric field and the velocity.

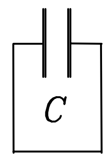
ii) The velocity and the magnetic field.

iii) The electric field and the magnetic field.

iv) All the vectors are mutually perpendicular.

v) No two vectors are necessarily perpendicular to each other.

(*c*) The charge Q on any *shorted* capacitor will exhibit thermal fluctuations. If a 1 F capacitor is in thermal equilibrium at a temperature of 300 K, what is its *root mean square charge* $Q_{rms} = \sqrt{\langle Q^2 \rangle}$?



(*d*) An infinitely long straight wire passes over another such wire at right angles without touching the other wire, thus forming a rather exotic capacitor. The resultant capacitance is [underline the correct answer]

(*a*) zero. (*b*) nonzero but finite. (*c*) infinite.

(*e*) Suppose that you want to make a plastic camera lens with a *nonreflective coating* of a transparent material (*e.g.* diamond) whose index of refraction is *higher* than that of the lens. *What is the optimum thickness* of the coating? *Explain.*

(*f*) The temperature T of an isolated system

i) increases as the energy U of the system increases.

ii) increases as the entropy S of the system increases.

iii) decreases as the entropy S of the system increases.

iv) does not depend on the magnitude of either U or S.

v) increases as the rate of change dS/dU increases.

(Indicate any true statements; *explain* your reasoning briefly to ensure at least part credit.)

(*g*) A loop of limp wire lies in a heap on a frictionless horizontal surface. What happens when a current is passed through the loop?

i) The wire spreads out into a circular loop.

ii) The wire clumps up into an even tighter tangle.

iii) Nothing happens.

Explain your reasoning briefly to ensure at least part credit.

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(*h*) A length of wire carrying a current can be made into a single circular loop or a two-turn circular coil of half the diameter. If B_1 is the resultant magnetic field strength at the centre of the single loop, what is the *ratio* of B_1 to B_2, the field at the centre of the double loop? (*i*) 1. (*ii*) 2. (*iii*) 1/2. (*iv*) 4. (*v*) 1/4.
Explain your reasoning briefly to ensure at least part credit.

(*i*) A uniform current density flows down a long, straight copper tube. Which of the following statements is true?

i) There is a magnetic field inside the tube, but none outside.
ii) There is a magnetic field ouside the tube, but none inside.
iii) There is a magnetic field both inside and outside the tube.
iv) There is no magnetic field either inside or outside the tube.

Explain your reasoning briefly to ensure at least part credit.

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(j) Match up the names on the left and the principles on the right with the equations in the middle. (For each match, draw a connecting line.)

Lorentz Force

Gauss' Law for Magnetostatics

Gauss' Law for Electrostatics

Ampère's Law

Faraday's Law

$$\oiint_{\mathcal{S}} \vec{\boldsymbol{D}} \cdot d\vec{\boldsymbol{A}} = Q_{\rm encl}$$

$$\vec{\boldsymbol{F}} = q \left(\vec{\boldsymbol{E}} + \vec{\boldsymbol{v}} \times \vec{\boldsymbol{B}} \right)$$

$$\oint_{\mathcal{C}} \vec{\boldsymbol{E}} \cdot d\vec{\boldsymbol{\ell}} = -\frac{\partial}{\partial t} \iint_{\mathcal{S}} \vec{\boldsymbol{B}} \cdot d\vec{\boldsymbol{A}}$$

$$\oiint_{\mathcal{S}} \vec{\boldsymbol{B}} \cdot d\vec{\boldsymbol{A}} = 0$$

$$\oint_{\mathcal{C}} \vec{\boldsymbol{H}} \cdot d\vec{\boldsymbol{\ell}} = I_{\rm encl} + \frac{\partial}{\partial t} \iint_{\mathcal{S}} \vec{\boldsymbol{D}} \cdot d\vec{\boldsymbol{A}}$$

A charged particle generally follows a curved path in a magnetic field.

"Lines of force" are continuous (unbroken) except where they begin and end on *charges*.

The "circulation" of magnetic field "lines" around an *open* surface is proportional to the net electric current flowing through that surface.

There are (apparently) no "magnetic monopoles."

Changing an electric field generates a magnetic field.

Changing a magnetic field generates an electric field.

Moving charges generate magnetic fields.

Definitions: $\vec{\boldsymbol{D}} \equiv \epsilon \vec{\boldsymbol{E}}$ $\quad \epsilon \equiv \kappa \epsilon_0$ $\quad \kappa =$ dielectric constant.

$\vec{\boldsymbol{B}} \equiv \mu \vec{\boldsymbol{H}}$ $\quad \mu = \mu_0 (1 + \chi_m)$ $\quad \chi_m =$ magnetic susceptibility.

(In vacuum, $\kappa = 1$ and $\chi_m = 0$.)

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Q2 ELECTRON SPIN IN THERMAL EQUILIBRIUM [10 marks]

An electron in a magnetic field $B = 1$ T is in thermal equilibrium with a heat reservoir at temperature τ. The electron's magnetic moment μ_{B} points in the direction opposite to its spin.

(a) [3 marks] For what τ is the electron spin sure to be "up" (along the magnetic field)?

(b) [3 marks] For what τ is its spin sure to be "down" (opposite to the magnetic field)?

(c) [4 marks] For what τ is the electron spin equally likely to be "up" or "down"?

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Q3 *LCR* **CIRCUITS** [10 marks]

You are given the following components from which to build a circuit:

- A switch, initially open.
- Two 1 F capacitors, both initially charged to capacity at 1 V.
- Two 2 Ω resistors.
- Two 1 H inductances.

(*a*) [5 marks] Using any combination of these 7 components, draw a circuit that will *oscillate* at *exactly* 0.5 s^{-1} after the switch is closed.

(continued on next page)

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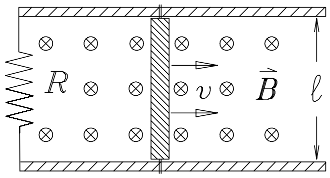
LCR **CIRCUITS** *(continued from previous page)*

(*b*) [5 marks] If all 7 components are connected in series, describe *in quantitative detail* what happens after the switch is closed at $t = 0$.

Q4 RAIL GUN IN REVERSE [10 marks]



A vertical bar of length $\ell = 50$ cm is pulled to the right at a constant speed $v = 4.20$ m/s through a constant, uniform magnetic field $B = 0.675$ T normal to the plane of the circuit. Assuming that the resistance of the bar and rails is negligible compared to that of the resistor ($R = 12\ \Omega$), find the *power* dissipated in the resistor.

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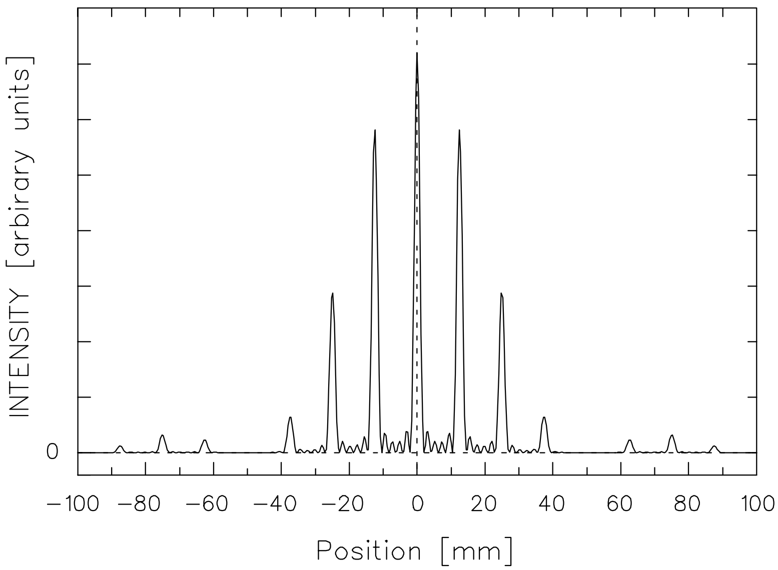
Q5 GRATING [10 marks]



A grating is uniformly illuminated with infrared light of wavelength $\lambda = 1\ \mu$m incident normal to the plane of the grating, producing the interference pattern shown at left on a screen 1 m away.

Make a detailed sketch of the grating itself, showing all dimensions.

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(spare page for scratch work)

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Constants and Conversion Factors. (You may not need all of these!)

Note: your answers may be expressed in terms of irrational numbers like π or $\sqrt{2}$.

Universal Gravitational Constant	G	$=$	6.672×10^{-11} m^3 kg^{-1} s^{-2}
Mass of the Earth	M_E	$=$	5.974×10^{24} kg
Mean radius of the Earth	R_E	$=$	6367 km
Planck's constant	h	$=$	6.6262×10^{-34} J-s $= 4.1357 \times 10^{-15}$ eV-s
Permittivity of free space	ϵ_0	$=$	0.8854×10^{-11} C^2/N-m^2 [or F/m]
constant in Coulomb's Law	$k_E = \dfrac{1}{4\pi\epsilon_0}$	$=$	8.988×10^9 N-m^2/C^2
Permeability of free space	μ_0	$=$	1.2566×10^{-6} N/A^2 [or H/m]
constant in Biot-Savart Law	$k_M = \dfrac{\mu_0}{4\pi}$	$=$	10^{-7} T-m/A
Electric charge of a proton	e	$=$	1.602×10^{-19} C
Speed of light in vacuum	c	$=$	2.99792458×10^8 m/s
Avogadro's number	N_0	$=$	6.022×10^{23} molecules per mole
Proton rest mass	M_p	$=$	1.673×10^{-27} kg
Neutron rest mass	M_n	$=$	1.675×10^{-27} kg
Electron rest mass	m_e	$=$	9.11×10^{-31} kg
Bohr magneton (electron's magnetic moment)	μ_B	$=$	9.274×10^{-24} J/T [1 T $\equiv 10^4$ G]
Boltzmann constant	k_B	$=$	1.3807×10^{-23} J/K
electron volt	1 eV	$=$	1.602×10^{-19} J $=$ $k_B \times 11,600$ K
Atmospheric pressure:	1 atm	$=$	760 torr $=$ 1.013×10^5 pascal [N/m^2]

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