THE UNIVERSITY OF BRITISH COLUMBIA

Physics 108

Sessional Examination

12:00 noon — 21 April 2005

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

FULL NAME: ______________________ STUDENT # : ______________

SIGNATURE: ______________________

This Examination paper consists of 13 pages (including this one). Make sure you have all 13.

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:

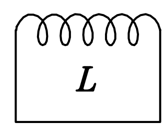
Q1	/50	**Q4**	/10
Q2	/10	**Q5**	/10
Q3	/10	**Q6**	/10
TOTAL			/100

NAMES OF INSTRUCTORS: Jess H. Brewer

Q1 "QUICKIES" [50 marks — 5 each]

(*a*) Given only the value of the speed of light, $c = 2.99792458 \times 10^8$ m/s, and that of the permeability of free space, $\mu_0 = 4\pi \times 10^{-7}$ N/A^2, show how to *calculate* the value of the *permittivity of free space*, ϵ_0, in units of C^2/N-m^2.

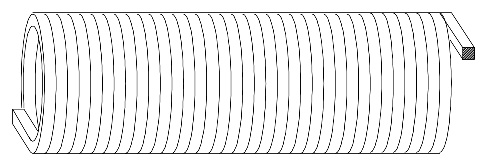
(*b*) The current I in any *shorted* coil will exhibit *thermal fluctuations.* If a 1 H coil is in thermal equilibrium at a temperature of 300 K, what is the *root mean square current* $I_{rms} = \sqrt{\langle I^2 \rangle}$ flowing through the coil?



YOUR FULL NAME:

(*c*) To which of the laws represented by Maxwell's Equations did Maxwell himself actually make a direct contribution, and *what was* his contribution?

(*d*) A long straight solenoid of inductance L and resistance R is made by tightly wrapping one layer of copper conductor (square cross section, width w) around a circular spindle of radius r and length ℓ. If all the dimensions are increased by a factor of 2 (*i.e.* the picture shown is unchanged but the scale is doubled), the *time constant* of the coil is ...



[encircle the best answer]

... halved. ... doubled. ... quartered. ... quadrupled. ... unchanged.

(Note: partial credit is possible only if you *explain* your answer.)

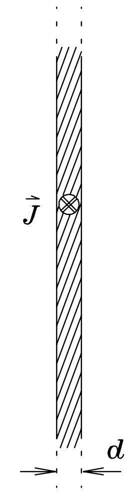
YOUR FULL NAME:

(e) Some tropical fish have bright red scales without any red pigments. Explain briefly how this is possible.

(f) A proton is *initially* at rest in a uniform magnetic field out of the page, as shown. A uniform electric field is then applied in the $+y$ direction, perpendicular to the magnetic field. Describe the subsequent motion of the proton *qualitatively*, using a simple *sketch* and a few words. (Remember, a *uniform* field is the same everywhere in space.)

YOUR FULL NAME:

(*g*) A semi-infinite flat sheet of conductor with thickness d is viewed "edge-on" at right. The sheet carries a uniform current density $\vec{\boldsymbol{J}}$ into the page. Calculate the *magnetic field* $\vec{\boldsymbol{B}}$ *outside* the sheet as a function of $\vec{\boldsymbol{J}}$ and d. Explain each step of your reasoning.



(*h*) An uncharged spherical conducting ball is suspended by an *insulating thread*. A positive point charge is moved near the ball and held fixed. The ball will . . .

i) . . . be attracted to the point charge and swing toward it.

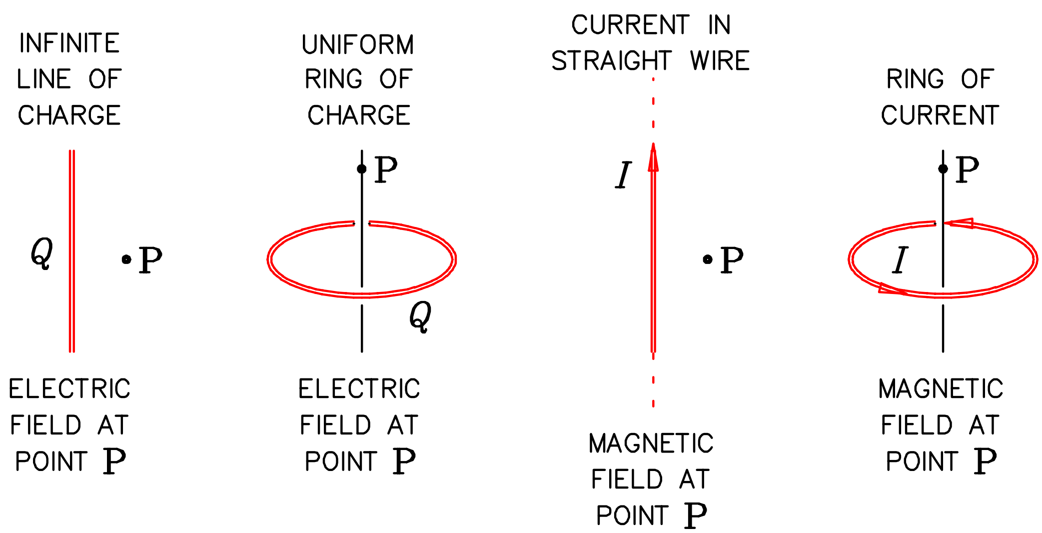
ii) . . . be repelled from the point charge and swing away from it.

iii) . . . not be affected by the point charge.

[Indicate the best completion of the sentence.]
(Note: partial credit is possible only if you *explain* your answer.)

YOUR FULL NAME:

(*i*) Shown below are four types of calculation problems and four "Laws" of Electricity and Magnetism. Match up (with connecting lines) each problem with the Law best suited to solving it.



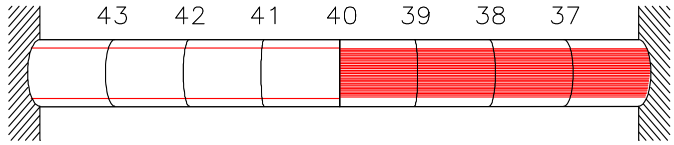
Coulomb's Law   Ampère's Law   Law of Biot & Savart   Gauss' Law

(*j*) An AC power supply produces an oscillating voltage of 15 V amplitude at 60 Hz. It is driving a circuit consisting of a 30 Ω resistor in series with a 0.2345 F capacitor and a 30 μH inductance. Show that the circuit is being driven *on resonance* and then find calculate the *maximum* current flowing through the resistor.

YOUR FULL NAME:

Q2 Rationally Calibrated Thermometer [10 marks]

A thermometer using thermal expansion of a liquid in a bulb is calibrated in *inverse electron volts* (eV^{-1}). It is pictured at right with the bulb (not shown) in thermal equilibrium with a large heat reservoir.



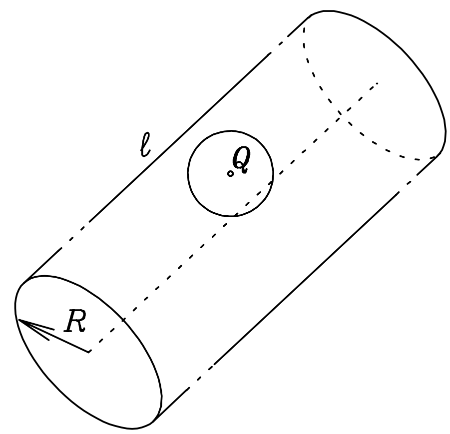
(*a*) [3 marks] In what sense is this a "rational" thermometer calibration?

(*b*) [3 marks] Which end is the bulb on? [Explanation required!]

(*c*) [4 marks] What is the temperature of the reservoir in degrees Kelvin?

Q3 Charge in a Spherical Cavity in a Cylindrical Conductor [10 marks]

A positive charge Q is held fixed at the centre of a hollow spherical cavity in a long, *solid* cylindrical conductor of radius R and length $\ell \gg R$. The cavity is *not* centred on the axis of the cylinder, but it is far from the ends of the cylinder. The conductor itself has zero net charge.



Describe the electric field as a function of position …

(a) [3 marks] …in the conductor;

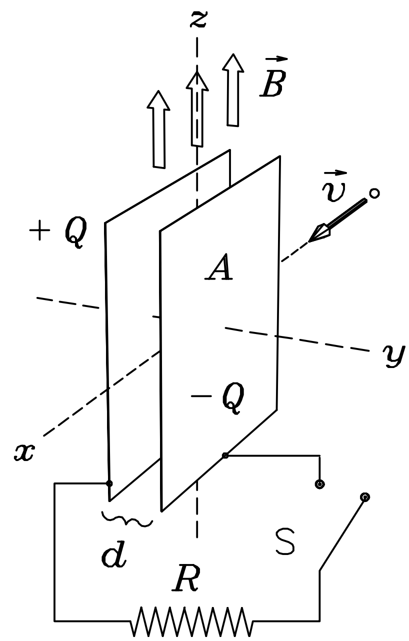
(b) [3 marks] …inside the spherical cavity;

(c) [4 marks] …outside the conductor ($r > R$, where r is the perpendicular distance from the cylinder's axis), far fom either end of the cylinder.

Be as complete as possible, with formulae and/or in words, and *explain your reasoning*.

YOUR FULL NAME:

Q4 Velocity Selector [10 marks]



A beam of protons with velocity $v = 10^6$ m/s is directed along the $+x$ axis between a pair of square metal plates of area $A = 1$ m^2 separated by a distance $d = 1$ cm. The plates have an initial charge of $Q = 10^{-6}$ C (the left plate has $+Q$ and the right plate has $-Q$). A uniform magnetic field $B = 0.01$ T is applied in the $+z$ direction. At $t = 0$ the switch S is closed, allowing the charge to flow off the plates through an $R = 100$ MΩ resistor. Assume that the magnetic field acts only in the space between the plates, and neglect "edge effects" on the electric field near the edges of the plates.

(*a*) [3 marks] For what value of the electric field E between the plates will the protons pass straight through without any deflection?

(*b*) [2 marks] How long will one proton spend inside the velocity selector at that E field?

(*c*) [5 marks] Calculate the *time* at which the protons will pass undeflected between the plates.

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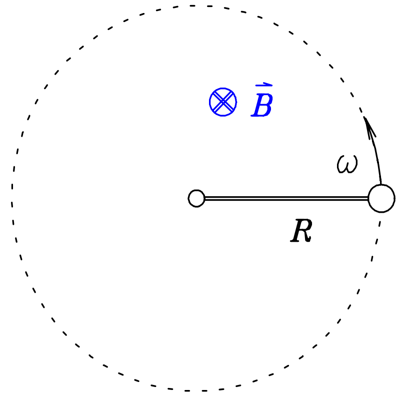
Q5 Spinerator [10 marks]



A small metal ball is whirling around in a circle on the end of an $R = 40$ cm long wire attached to a fixed, electrically insulated pivot. The angular frequency of rotation is $\omega = 30\ \mathrm{s}^{-1}$. There is a uniform magnetic field $B = 0.15$ T into the page as shown, normal to the plane of rotation. *What is the voltage difference between the metal ball and the central pivot?* Be sure to indicate which end is positive and which negative.

Q6 Understanding Gratings [10 marks]

A "diffraction grating" is produced by making N parallel scratches on a flat, transparent plate, so that the distance between any two adjacent scratches is d and the effective width of the "slit" formed by one scratch is a. Light shines on the grating normal to its surface and passes through it to make an interference pattern on a distant screen; ϑ is the angle between the incident light and the direction to a given position on the screen.

(a) [2 marks] What is the *meaning* of the formula $d \sin \vartheta_m = m\lambda$?

(b) [2 marks] What is the *meaning* of the formula $a \sin \vartheta_1 = \lambda$?

(c) [2 marks] What is the *meaning* of the formula $d \sin \Delta\vartheta = \lambda/N$?

(d) [2 marks] What is the advantage of large N?

(e) [2 marks] How many *minima* are there between any two adjacent principal maxima?

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(spare page for scratch work)

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

Exchange Rate (26 Mar 2005)	\$1.00 CAD	=	¥87.3086 JPY (Japanese Yen)
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
Permittivity of free space	$\epsilon_\circ$	=	0.8854×10^{-11} C^2/N-m^2 [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	=	$4\pi \times 10^{-7} = 1.2566 \times 10^{-6}$ N/A^2 [H/m]
constant in Biot-Savart Law	$k_M = \dfrac{\mu_0}{4\pi}$	=	10^{-7} T-m/A [H/m]
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
Boltzmann constant	k_{B}	=	1.3807×10^{-23} J/K
electron volt	1 eV	=	1.602×10^{-19} J $=$ $k_{\mathrm{B}} \times 11,600$ K
Atmospheric pressure:	1 atm	=	760 torr $=$ 1.013×10^5 pascal [N/m^2]

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