THE UNIVERSITY OF BRITISH COLUMBIA

Physics 108

First Midterm Examination

Friday 4 February 2005

TIME: 50 MINUTES

FULL NAME: ______________________ STUDENT # : ______________

SIGNATURE: ______________________________

This Examination paper consists of 8 pages (including this one). Make sure you have all 8.

INSTRUCTIONS:

Write your name on every sheet.

Calculator and 1-page Summary Sheet allowed.

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

Read carefully!

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

MARKING:

Q1	/60
Q2	/40
TOTAL	/100

NAME OF INSTRUCTOR: Jess H. Brewer

Q1 QUICKIES [10 marks each — 60 total]

(a) Under what circumstances would the *entropy* of a system *decrease* with the *addition of energy*, and what could you say about the *temperature* of such a system?

(b) Charges of $+2Q$ and $-Q$ are located in the plane of the page as shown. *Sketch the region* in the same plane (if any) where the resultant *electric field* is *zero*.

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(*c*) In broad general terms, explain why the thermal distribution of particle speeds is **not** the same in a **1**-dimensional ideal gas as it is in a **3**-dimensional ideal gas of the same particles at the same temperature.

(*d*) A positive point charge Q is fixed at an arbitrary location (*not* on the axis) inside an uncharged, thin-walled copper tube whose length L is much larger than its radius R. The charge is not located near either end. Define r as the perpendicular distance from the axis of the tube. Match up **all** the left and right side phrases that make up *true* sentences:

	is zero.
The electric field inside the tube ($r < R$)	is a complicated function of the charge's position.
The electric field outside the tube ($r > R$)	has a magnitude $E \approx Q/2\pi\epsilon_\circ Lr$ except near the ends.
	is in the $\hat{\boldsymbol{r}}$ direction.

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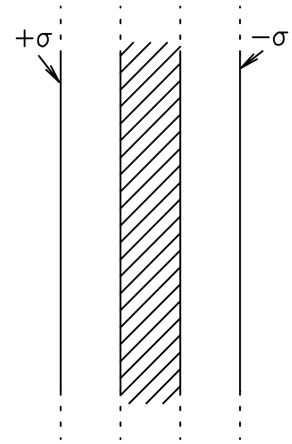

(*e*) The diagram shows an edge-on view of an electrically neutral, semi-infinite, flat conducting slab with a parallel sheet of uniformly distributed positive charge (charge per unit area $+\sigma_\circ$) on the left and a parallel sheet of uniformly distributed negative charge (charge per unit area $-\sigma_\circ$) on the right. What is the direction and magnitude of the electric field …

i) …to the left of the positive sheet of charge?

ii) …between the positive sheet of charge and the slab?

iii) …inside the slab?

iv) …between the slab and the negative sheet of charge?

v) …to the right of the negative sheet of charge?

(*f*) Referring to the previous diagram, calculate the induced surface charge σ per unit area on each side of the slab, in terms of $\sigma_\circ$.

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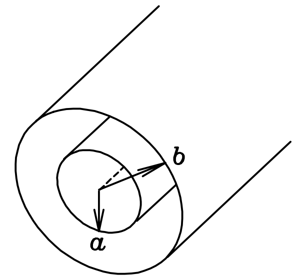
Q2 CHARGED COAXIAL CONDUCTORS [40 marks]



A long copper cylinder of radius a is surrounded by a coaxial copper tube whose inner radius is b, as shown. The inner cylinder carries a uniform charge per unit length (λ) and the outer shell has an equal and opposite charge per unit length ($-\lambda$) so that the system as a whole is electrically neutral.

(a) [5 marks] If r is the distance from the axis, what is the electric field for $r < a$? Explain.

(b) [5 marks] What is the electric field $\vec{\boldsymbol{E}}(r)$ for $r > b$? Explain.

(c) [10 marks] What is the electric field $\vec{\boldsymbol{E}}(r)$ between the two cylinders ($a < r < b$)?

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Now consider the case where $a = 1$ m, $b = 1.01$ m and $\lambda = +10^{-10}$ C/m. Since $(b - a) \ll a$, you can treat the electric field between the cylinders as approximately constant in magnitude. The 1 cm gap between the inner cylinder and the outer tube is evacuated except for 100 tiny beads, each of which contains a single excess electron fixed at its centre so that its net charge is $-e$. The beads stick to the copper surfaces, but are occasionally shaken loose by thermal motion. The whole system is in thermal equilibrium at 300 K.

(*d*) [5 marks] What is the difference $\varepsilon = U(b) - U(a)$ between the electrostatic potential energy $U(b)$ of a bead stuck to the surface of the outer shell and that of a bead stuck to the surface of the inner cylinder, $U(a)$?

(*e*) [15 marks] *On average,* how many beads are stuck to each surface?

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(extra work space)

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

Exchange Rate (30 Jan 2005)	1.00 EUR (Euro)	=	\$1.61649 CAD
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 [or F/m]
constant in Coulomb's Law	$k_E = \frac{1}{4\pi\epsilon_0}$	=	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	$k_M = \frac{\mu_0}{4\pi}$	=	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
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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