THE UNIVERSITY OF BRITISH COLUMBIA

Physics 108

Second Midterm Examination

Friday 12 March 2004

TIME: 50 MINUTES

FULL NAME: ______________________ STUDENT # : ______________

SIGNATURE: ______________________

This Examination paper consists of 9 pages (including this one). Make sure you have all 9.

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!

MARKING:

Q1	/60
Q2	/20
Q3	/20
TOTAL	/100

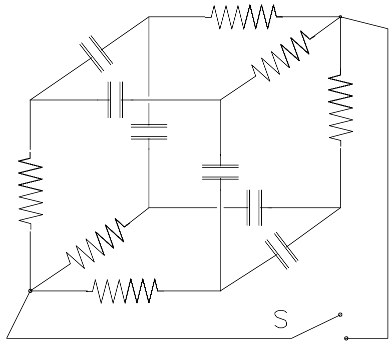
NAME OF INSTRUCTOR: Jess H. Brewer

Q1 QUICKIES [10 marks each — 60 total]

(*a*) An electric field of 100 V/m acts between two parallel capacitor plates separated by an air gap. Without altering the charge on either plate, we now completely fill the space between the plates with strontium titanate, whose dielectric constant is $\kappa = 310$. What is then the electric field between the plates?

(*b*) Two resistors have a net resistance of 16 Ω when connected in series and 3 Ω when connected in parallel. What are their individual resistances?

(*c*) Six identical capacitors of capacitance $C = 1$ F and six identical resistors of resistance $R = 1\ \Omega$ are arranged in a cube as shown. Before it is closed at $t = 0$, there is a potential of 1 V across the switch S.

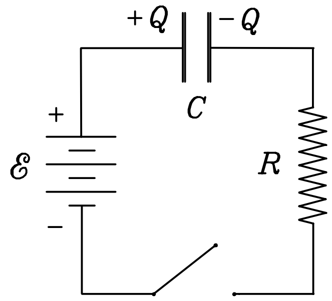


i) [4 marks] What is the net charge stored in the circuit before the switch is closed?

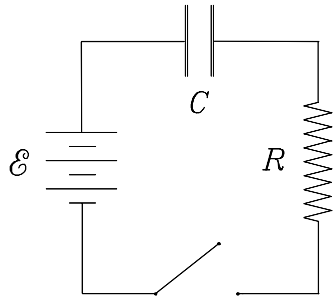
ii) [4 marks] How long will it take for the net charge on any capacitor to drop to $1/e$ of its initial value? [$e \equiv 2.71828\cdots$]

iii) [2 marks] Would there be an unique answer to the previous question if one of the capacitors had a different capacitance from the others? *Explain.*

(d) Describe *in detail* what happens when the switch is closed at $t = 0$ in each of the following circuits, where in each case $C = 0.1$ F, $R = 10\ \Omega$ and $\mathcal{E} = 10$ V.



The capacitor is initially charged to $Q = 1$ C.

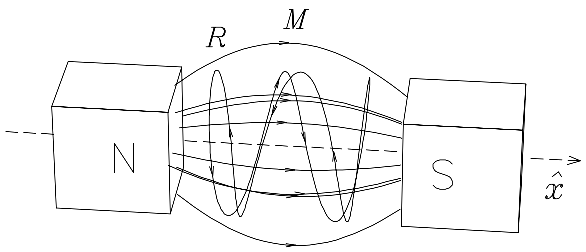


The capacitor is initially *un*charged.

YOUR FULL NAME:

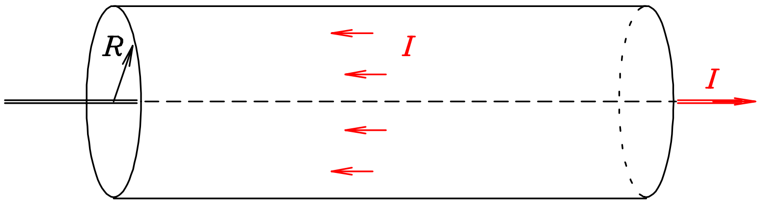
(*e*) A velocity selector has a magnetic field $\vec{\boldsymbol{B}}$ perpendicular to an electric field of 30,000 V/m. Charged particles with velocity $v = 2.0 \times 10^5$ m/s move through the device undeflected. What is the strength of $\vec{\boldsymbol{B}}$ [in Tesla]?

(*f*) A proton is trapped in a magnetic mirror system as shown. In its spiralling motion, the proton's total kinetic energy and the magnetic flux encircled by its orbit both remain constant. *Explain why* the total kinetic energy of the proton remains constant.



Q2 Coaxial Cable [20 marks]

A net current of $I = 100$ A flows down a long, thin central wire and back along a long, thin-walled cylindrical outer conductor of radius $R = 1$ cm, as shown. The returning current density is uniformly distributed over the outer conducting shell.



(a) [5 marks] In what *direction* is the vector magnetic field $\vec{\boldsymbol{B}}$ in various regions? (Indicate on the sketch and/or in words.)

(b) [10 marks] Find a complete expression for the magnetic field strength B as a function of r (the distance from the central axis), I and R.

(c) [5 marks] *Plot* $B(r)$ from $r = 0$ to $r = 2R$, labelling your axes clearly (including the vertical scale in Tesla and the horizontal scale in metres).

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Q3 Athletic Potential [20 marks]

A sprinter on the UBC track team runs at a speed of 7 m/s while holding a 6 m long pole vault pole horizontal at right angles to her direction of motion.[1] The pole has a fine copper wire down the center from one end to the other. If the Earth's magnetic field at the location of the runner has a magnitude of 0.5×10^{-4} T and makes an angle of 40° with the horizontal, *what is the potential difference* [in volts] between one end of the pole and the other?

[1]This is not the usual orientation in which a pole vaulter would hold the pole during a "run up," but this sprinter is performing a Physics experiment, so unconventional behaviour is expected!

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(extra work space)

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 $\sqrt{2}$.

Exchange Rate (11 Mar 2004)	1.00 EUR (Euro)	=	\$1.62248 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 $= 4.1357 \times 10^{-15}$ 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
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 $= 1.013 \times 10^5$ pascal [N/m^2]

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