THE UNIVERSITY OF BRITISH COLUMBIA

Science 1 Physics
Spring Midterm
1 March 2001

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 page.

No memory aids allowed.

(Formulae can be "purchased" for 5 marks each.)

MARKING:

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

NAMES OF INSTRUCTORS: Jess H. Brewer & Domingo Louis-Martinez

Q1 QUICKIES [60 marks — 10 each]

(a) Encircle all the *true* completions of the sentence: 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.

(b) A target is placed in a uniform magnetic field $\vec{\boldsymbol{B}} = B\hat{z}$. You want to hit it with a beam of positive particles of charge q and momentum p, using a "beam weapon" that you can place wherever you want, as long as it is not closer to the target than a distance $r = p/qB$. Along which direction(s) can you "aim" the beam and hit the target?
[Encircle all correct answers.]

$+\hat{x}$ $-\hat{x}$ $+\hat{y}$ $-\hat{y}$ $+\hat{z}$ $-\hat{z}$

(c) Explain *in words* (no mathematical symbols or equations) why the *flux** of any conserved quantity emitted *isotropically* at a constant rate from some source must always drop off as the inverse square of the distance from the centre of the source.
(**flux:* the flow of "stuff" per unit time per unit area normal to the flow)

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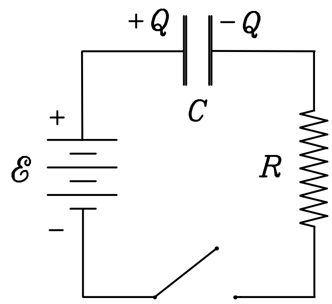
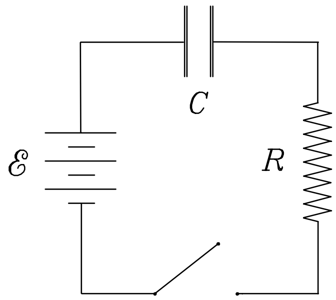
(*d*) A cube 1 m on a side completely surrounds an electric dipole consisting of a positive electric charge of 1 C located 10 cm away from an equal-magnitude negative charge. What is the average value, taken over the whole surface of the cube, of the electric field normal to the surface? Explain your answer.

(*e*) The capacitor in the circuit shown is initially charged to $Q = C\mathcal{E}$ where $\mathcal{E}$ is the voltage on the battery. Describe in detail what happens when the switch is closed.



(f) The initially *un*charged capacitor ($C = 1$ F) is in series with a battery whose voltage is $\mathcal{E} = 10$ V and a resistor ($R = 100\ \Omega$). Describe in detail what happens when the switch is closed.



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Q2 Two-State System [20 marks]

A simple organism has only two possible microstates: "asleep" with zero energy or "awake" with energy ε. It is in thermal equilibrium with its environment at temperature $\tau \equiv k_{\mathrm{B}}T$.

(*a*) For what τ is the organism $1/e$ times as likely to be awake as to be asleep? ($e = 2.718\cdots$)

(*b*) For what τ does it have an equal probability of being asleep or awake?

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In the space below, *sketch*

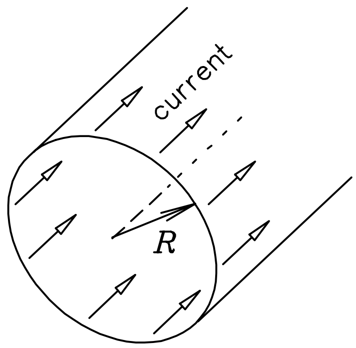
(c) The probability of being awake as a function of temperature τ for a fixed microstate energy ε.

(d) The probability of being awake as a function of the microstate energy ε for a given temperature τ.

(Include axis labels and vertical scales on your sketches.)

Q3 Ampère's Law [20 marks]

A net current of $I = 1$ A flows down a long, empty, thin-walled metal pipe of radius $R = 10$ cm. If the current density is uniformly distributed over the conducting shell, what is the *direction* of the vector magnetic field $\vec{\boldsymbol{B}}$ at any point? (Indicate on the sketch and/or in words.)



Find expressions for the magnetic field strength B as a function of r, the distance from the central axis. Then *plot* $B(r)$ from $r = 0$ to $r = 3R$, labelling your axes clearly (including the vertical scale in Tesla).

Table 1 — **Constants and Conversion Factors.** (You may not need all of these!)

Exchange Rate (17 Dec 1999)	\$1.00 CDN	=	2,8205 Zloty (Poland)
Permittivity of free space	$\epsilon_\circ = \dfrac{10^7}{4\pi c^2}$	=	0.8854×10^{-11} F/m
constant in Coulomb's Law	$k_E = \dfrac{1}{4\pi\epsilon_\circ}$	=	8.988×10^{9} V-m/C
Permeability of free space	$\mu_\circ$	=	1.2566×10^{-6} H/m
constant in Biot-Savart Law	$k_M = \dfrac{\mu_\circ}{4\pi}$	=	10^{-7} T-m/A
Electric charge of a proton	e	=	1.602×10^{-19} C
Speed of light in vacuum	c	=	2.997×10^{8} m/s
Boltzmann constant	$k_{\rm B}$	=	1.3807×10^{-23} J/K
electron volt	$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J} = 1.602 \times 10^{-12} \text{ erg} = k_{\rm B} \times 11,600 \text{ K}$		
Atmospheric pressure:	$1 \text{ atm} = 760 \text{ torr} = 1.013 \times 10^5 \text{ pascal (N/m}^2)$		

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