THE UNIVERSITY OF BRITISH COLUMBIA

Science 1 Physics

Spring Midterm

29 February 2000

TIME: 50 MINUTES

FULL NAME: ______________________ STUDENT # : ______________

SIGNATURE: ______________________

This Examination paper consists of 7 pages (including this one). Make sure you have all 7.

INSTRUCTIONS:

Write your name on every sheet.

No "memory aids" allowed. Physical constants *etc.* are provided on the last page.

MARKING:

Q1	/20
Q2	/20
Q3	/30
Q4	/30
TOTAL	/100

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

Q1 Plane Wave [20 marks]

A plane electromagnetic wave is traveling in the positive x direction at speed $c = 2.997 \times 10^8$ m/s. If we take a "snapshot" of the wave at $t = 0$, we find that the electric field E is $+0.7071$ volts per meter (V/m) at $x = 0$ and increases in the region from $x = 0$ to $x = 1$ m, where it reaches its maximum value of $+1.0$ V/m. Write down a formula for the electric field $E(x, t)$ as a function of position x and time t, giving quantitative values for each of the symbols in the formula.

(A sketch may be helpful.)

YOUR FULL NAME:

Q2 Particle in a Box [20 marks]

In 1924, Louis Victor Pierre Raymond duc de Broglie suggested that if light behaves like particles then perhaps electrons behave like waves, with a universal relationship between momentum p and wavelength λ given by $p\lambda = h$ (where h is Planck's constant).

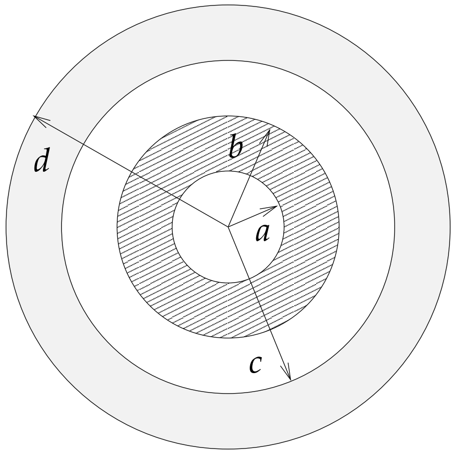
(a) [10 marks] An electron is confined to a one-dimensional box of length $L = 1$ nm. Taking de Broglie's hypothesis into account, what is the *lowest kinetic energy* it can have? (Express your answer in *electron volts*.)

(b) [6 marks] What happens to the electron's energy if L shrinks by a factor of ten?

(c) [4 marks] What sort of objects are about this size?

YOUR FULL NAME:

Q3 Concentric Spherical Shells [30 marks]



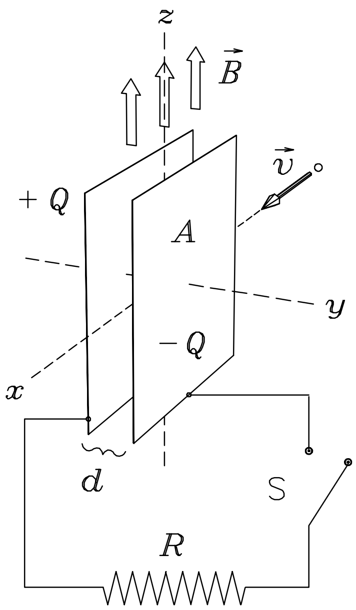
A hollow conducting sphere has an inner radius a and an outer radius b. It is enclosed within a concentric hollow sphere of inner radius c and outer radius d, made of an insulating material with dielectric constant κ.

A charge Q is placed on the conductor.

Express the *electric field* $\vec{\boldsymbol{E}}$ as a function of radius r (and other constants) in each of the four regions: $r < a$, $a < r < b$, $b < r < c$, $c < r < d$ and $r > d$.

YOUR FULL NAME:

Q4 Velocity Selector [30 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.

Assuming that the magnetic field acts only in the space between the plates, and neglecting "edge effects" on the electric field between the plates, calculate the *time* at which the protons will pass *undeflected* between the plates.

(extra work space)

YOUR FULL NAME:

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

Speed of sound in air (typical)	c_{sound}	$\approx$	340 m/s
Planck's constant	h	$=$	6.6262×10^{-34} J-s $= 4.1357 \times 10^{-15}$ eV-s
Planck's constant / 2π	$\hbar \equiv \dfrac{h}{2\pi}$	$=$	1.0546×10^{-34} J-s $= 0.6582 \times 10^{-15}$ eV-s
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
Proton rest mass	M_p	$=$	1.67×10^{-27} kg
Electron rest mass	m_e	$=$	9.11×10^{-31} kg
electron volt	1 eV $= 1.602 \times 10^{-19}$ J $= 1.602 \times 10^{-12}$ erg $= k_{\text{B}} \times 11,600$ K		

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