THE UNIVERSITY OF BRITISH COLUMBIA

Science 1 Physics

Sessional Examination

9 April 2001

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

FULL NAME: ______________________ STUDENT # : ______________

SIGNATURE: ______________________

This Examination paper consists of 12 pages (including this one). Make sure you have all 12.

INSTRUCTIONS:

Write your name on every sheet.

No memory aids allowed.

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

MARKING:

Q1	/40	**Q4**	/12
Q2	/12	**Q5**	/12
Q3	/12	**Q6**	/12
TOTAL			/100

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

Q1 "QUICKIES" [40 marks — 5 each]

(*a*) A 50 kg woman is standing still on the Moon. Approximately what net force does she exert on the Moon?

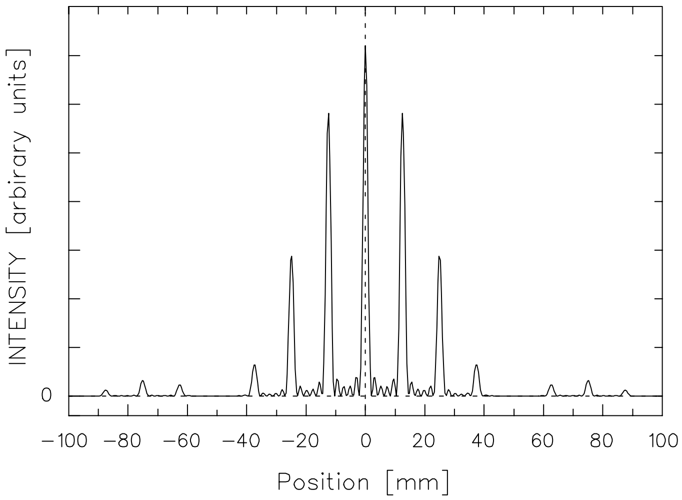
(*i*) 50 kg (*ii*) 500 N (*iii*) 20 N (*iv*) 0 N

(*b*) Two large meteors made of pure carbon collide just outside the Earth's atmosphere and produce a huge number of "buckyballs" (C_{60} molecules) that then fall gently into the atmosphere and settle toward the ground. One buckyball has a mass of 1.1956×10^{-24} kg. After the buckyballs have had plenty of time to reach thermal equilibrium, assuming perfectly still air at 300 K, at what *altitude* above sea level will the concentration of buckyballs (per cubic meter of air) be exactly $1/e$ of their concentration at sea level? (Here e is the base of the natural logarithm.)

(c) Some butterflies have bright blue wings without any blue pigments. Explain briefly how this is possible.

(d) A velocity selector has a magnetic field $\vec{\boldsymbol{B}}$ perpendicular to an electric field of 10,000 V/m. We find that charged particles with velocity $v = 2.0 \times 10^4$ m/s perpendicular to both $\vec{\boldsymbol{E}}$ and $\vec{\boldsymbol{B}}$ pass through the device undeflected. What is the strength of $\vec{\boldsymbol{B}}$ [in Tesla]? *Explain.*

(*e*) A diffraction grating is uniformly illuminated, producing the interference pattern shown at right on a distant screen.



i) How many slits are illuminated?

ii) What is the *ratio* of the *width* of each slit to the *spacing* between adjacent slits?

(*f*) If $\epsilon_\circ$ and $\mu_\circ$ are respectively the permittivity and the permeability of free space, what is the value [including *units*] of the quantity $(\mu_\circ\epsilon_\circ)^{-1/2}$ and *what does it represent*?

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(g) Suppose you have a superconducting coil, a capacitor and a 1000 Ω resistor. First you charge up the capacitor and put it in series with the coil; this circuit oscillates at a frequency of $f = (1/2\pi)$ kHz. Next you charge up the same capacitor and discharge it through the resistor. (No coil in the circuit this time.) It takes 0.1 s for the charge on the capacitor to drop to $1/e$ of its original value. What was the inductance of the coil?

(h) An electron is trapped between two parallel flat plates 5 nm apart. What is the *lowest kinetic energy* it can have?

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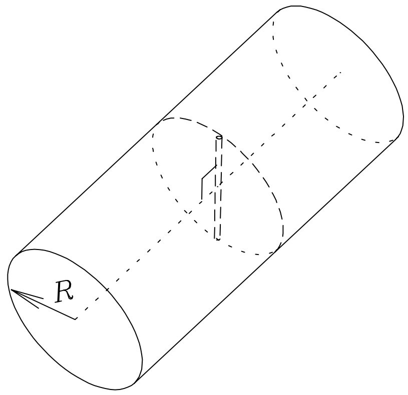
Q2 Cylinder of Charge [12 marks]



A long solid insulating cylinder of radius R is uniformly charged with a positive charge density ρ [charge per unit volume]. A small hole is drilled straight through the cylinder at right angles to its axis, as shown. Assume that the hole is very far from the ends of the cylinder.

(a) [6 marks] Show that the electric field in the hole is proportional to the distance from the cylinder axis.

(b) [6 marks] Show that a negatively charged particle dropped straight into the hole will execute simple harmonic motion as long as it doesn't hit the sides of the hole.

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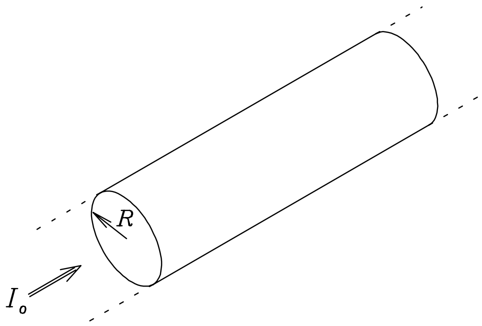
Q3 Field of a Wire [12 marks] A wire (*i.e.* a long, straight, solid cylindrical conductor) of radius R carries a steady current $I_\circ$ that is uniformly distributed over the cross-sectional area of the wire.



Calculate the magnetic field $\vec{\boldsymbol{B}}$ at a distance r from the centre of the wire in both regions: $r \geq R$ and $r < R$. *Sketch* $B(r)$ from $r = 0$ to $r = 4R$.

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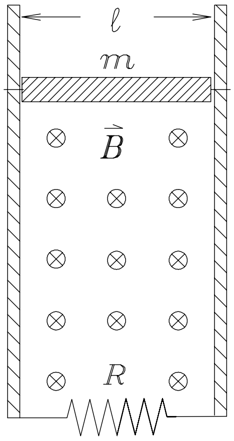
Q4 Falling Bar [12 marks]



A horizontal bar of mass m is free to slide without friction down the vertical rails of a conducting frame, as shown. The combined resistance of the bar and the frame is negligible compared to R, the resistance placed in series with this circuit. What is the *terminal speed* of the bar as it falls under the influence of gravity (at the surface of the Earth) through a uniform horizontal magnetic field $\vec{\boldsymbol{B}}$ directed perpendicular to the plane of the frame? (Give your answer in terms of m, B, ℓ, R, g and other fundamental constants.)

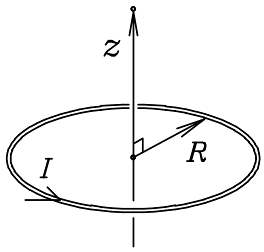
Q5 Relativistic Reflection [12 marks]

A rocket moves at constant speed u toward a stationary mirror. When the rocket is a distance d from the mirror (as measured by an observer at rest with respect to the mirror) a light pulse is emitted from the rocket toward the mirror and is subsequently reflected back to the rocket. What is the *total travel time of the light pulse* as measured by

(a) [6 marks] an observer in the rest frame of the mirror?

(b) [6 marks] an observer in the rest frame of the rocket?

Q6 Current Ring [12 marks]



An electric current I is circulating as shown around a superconducting ring of radius R. What is the magnetic field on axis a distance z up from the centre of the ring, in terms of the parameters given?

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

Universal Gravitational Constant	G	$= 6.672 \times 10^{-11}\ \mathrm{m^3\ kg^{-1}\ s^{-2}}$
Mass of the Earth	M_E	$= 5.974 \times 10^{24}$ kg
Mass of the Moon	M_M	$= 7.348 \times 10^{22}$ kg
Mean radius of the Earth	R_E	$= 6367$ km
Mean radius of the Moon	R_M	$= 3476$ km
Planck's constant	h	$= 6.6262 \times 10^{-34}$ J-s $= 4.1357 \times 10^{-15}$ eV-s
Permittivity of free space	$\epsilon_\circ$	$= 0.8854 \times 10^{-11}\ \mathrm{C^2/N\text{-}m^2}$ [or F/m]
constant in Coulomb's Law	$k_E = \dfrac{1}{4\pi\epsilon_\circ}$	$= 8.988 \times 10^{9}\ \mathrm{N\text{-}m^2/C^2}$
Permeability of free space	$\mu_\circ$	$= 1.2566 \times 10^{-6}\ \mathrm{N/A^2}$ [or 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	$= 1.602 \times 10^{-19}$ C
Speed of light in vacuum	c	$= 2.997 \times 10^{8}$ m/s
Avogadro's number	$N_\circ$	$= 6.022 \times 10^{23}$ molecules per mole
Proton rest mass	M_p	$= 1.673 \times 10^{-27}$ kg
Neutron rest mass	M_n	$= 1.675 \times 10^{-27}$ kg
Electron rest mass	m_e	$= 9.11 \times 10^{-31}$ kg
Boltzmann constant	k_B	$= 1.3807 \times 10^{-23}$ J/K
electron volt		$1\ \mathrm{eV} = 1.602 \times 10^{-19}\ \mathrm{J} = k_\mathrm{B} \times 11,600\ \mathrm{K}$

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