THE UNIVERSITY OF BRITISH COLUMBIA

Science 1 Physics
Sessional Examination
11 April 2000

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

FULL NAME: ______________________ STUDENT # : ______________

SIGNATURE: ______________________

This Examination paper consists of 14 pages (including this one). Make sure you have all 14.

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	**Q5**	/10
Q2	/10	**Q6**	/10
Q3	/10	**Q7**	/10
Q4	/10	**TOT**	/100

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

Q1 "QUICKIES" [40 marks — 5 each]

(a) To which of the laws represented by Maxwell's Equations did Maxwell actually make a direct contribution? *Explain.*

(b) What is the difference between *phase velocity* and *group velocity*? *Explain.*

(c) How do tropical fish and birds achieve brilliant colours without using pigments? *Explain.*

YOUR FULL NAME:

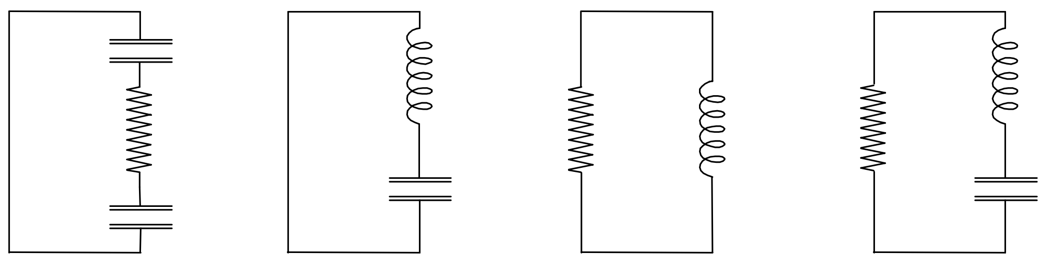
(*d*) A certain whimsical physicist is fond of saying, "Particles hate to be confined!" What is he talking about? *Explain.*

(*e*) In a hydrogen atom, the electrostatic force between the proton and electron is 2.3×10^{39} times greater than the gravitational force. If we can adjust the distance between the two particles, at what separation will the electrostatic and gravitational forces between them be equal? *Explain.*

YOUR FULL NAME:

(*f*) A dielectric is inserted between the plates of a capacitor, which is then charged. The dielectric is later removed. What qualitative effect (if any) does the removal of the dielectric have on the electrostatic energy stored in the capacitor? *Explain*.

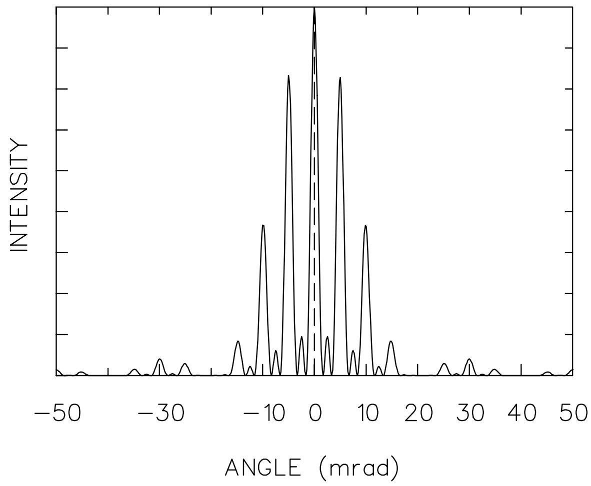
(*g*) Encircle any of the following circuits in which the *current* might exhibit *simple exponential decay* without any oscillations.



YOUR FULL NAME:

(*h*) 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?

Q2 DHM [10 marks]

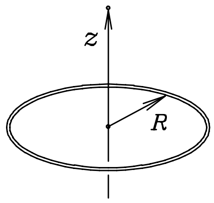
A 1 kg mass attached to an ideal massless spring experiences a viscous drag force $F_d = -bv$ where $b = 10$ N-s/m and v is the velocity of the mass.

(a) [3 marks] Write down the differential equation governing the motion of the mass, in terms of the mass m, the spring constant k and the drag coefficient b.

(b) [4 marks] Solve this differential equation to find a general form for the position x of the mass as a function of time t, again in terms of the above constants. (If you don't remember how to solve this kind of DE, try a good guess.)

(c) [3 marks] For what *range of values* of the *spring constant* k will the mass *oscillate* when the spring is stretched and released?

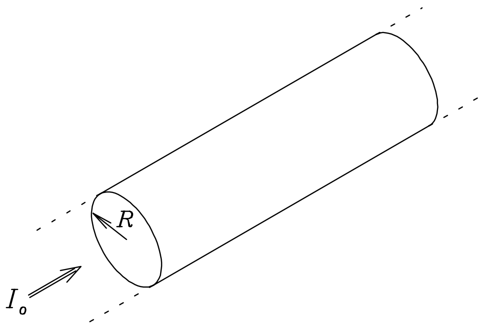
Q3 Charged Ring [10 marks]



A net charge Q is uniformly distributed around the perimeter of a circular ring of radius R. What is the *difference* in *electrostatic potential* between a point at the geometrical centre of the ring and a point on its axis a distance z from the centre?

YOUR FULL NAME:

Q4 Do $\vec{\boldsymbol{B}}$ [10 marks]

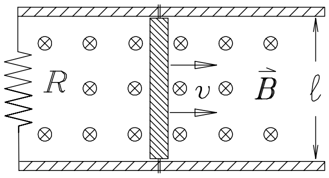


A wire (*i.e.* a long, straight, solid cylindrical conductor) of radius R carries a steady current $I_\circ$ that is uniformly distributed over the cross-sectional area of the wire.

Calculate the magnetic field $\vec{\boldsymbol{B}}$ at a distance r from the centre of the wire in both regions: $r \geq R$ and $r < R$.

YOUR FULL NAME:

Q5 Rail Gun in Reverse [10 marks]



A vertical bar of length $\ell = 50$ cm is pulled to the right at a constant speed $v = 4.20$ m/s through a constant, uniform magnetic field $B = 0.675$ T normal to the plane of the circuit. Assuming that the resistance of the bar and rails is negligible compared to that of the resistor ($R = 12\ \Omega$), find the *power* dissipated in the resistor.

YOUR FULL NAME:

Q6 Double Slit Plus [10 marks]

A double-slit interference experiment is performed in vacuum. Then a thin glass plate with index of refraction $n = 1.56$ is placed in front of one slit. The fifth interference maximum now appears at the angle where the second interference maximum previously appeared. If the incident light has a wavelength of 480 nm, *how thick is the plate?*

YOUR FULL NAME:

Q7 YOUR CHOICE [10 marks] Answer **ONE** of the following questions:

Q7.1 Hot Charge — Answer EITHER this question OR the one on the next page!

In the middle of a large space habitat (where gravity can be neglected), a large flat sheet of insulating material is given a uniform positive charge of 10^{-12} C/m^2. A small glass bead containing a *single excess electron* (which we will assume is "stuck" in the bead) is placed next to the charged sheet and allowed to reach thermal equilibrium with the ambient air at $T = 300$ K. Assume that the air is perfectly still (no air currents).

(*a*) [4 marks] If $P(h)$ is the *probability* of finding the bead a distance h away from the plate, how does this probability vary with h?

(*b*) [6 marks] At what h is $P(h) = P(0)/e$? (Here e is the base of the natural logarithm.)

YOUR FULL NAME:

Q7.2 Star Dreck — Answer EITHER this question **OR** the one on the previous page!

Captain Picard places the starship *Enterprise* in a circular orbit about a 1-Solar-mass neutron star (radius approximately 9 km) at what seems a safe distance of 1000 km from its centre.

(a) [3 marks] What is the centripetal acceleration g of the centre of gravity of the *Enterprise*?

(b) [3 marks] Show that the *rate of change* of the centripetal acceleration with the distance r from the centre of the star is given by $\dfrac{dg}{dr} = -2\,\dfrac{g}{r}$.

(c) [4 marks] If Picard's head is 1.8 m further from the star than his feet, what is the "tidal" difference between the gravitational acceleration of his head and that of his feet? Comment.

YOUR FULL NAME:

YOUR FULL NAME:

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

Universal Gravitational Constant	G	$=$	6.672×10^{-11} m^3 kg^{-1} s^{-2}
Acceleration due to gravity	$g_\circ$	$=$	9.81 m-s^{-2} (at Earth's surface)
Mass of the Sun	$M_\odot$	$=$	1.989×10^{30} kg
Planck's constant	h	$=$	6.6262×10^{-34} J-s $= 4.1357 \times 10^{-15}$ 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
Boltzmann constant	k_B	$=$	1.3807×10^{-23} J/K

YOUR FULL NAME: