Carleton UNIVERSITY

Deferred Final Exam
EXAMINATION
Summer 2012

DURATION: 3 HOURS No. of Students: **2**

Department Name & Course Number: **Physics 1004A**
Course Instructor(s) **Dr. Andrew Robinson**

AUTHORIZED MEMORANDA

Pen, pencil, calculator

Students MUST count the number of pages in this examination question paper before beginning to write, and report any discrepancy to a proctor. This question paper has 12 pages including the cover page.

This examination question paper may not be taken from the examination room.

In addition to this question paper, students require:	**an examination booklet**	**no**
	a Scantron sheet	**no**

Please print your name and student number in the boxes below:

Family Name	First Name	Student Number

This exam is out of 60 marks and consists of two parts:

Section A: 10 multiple choice questions, each worth one mark. Please circle the correct answer on the paper.

Section B: Answer 5 out of the 6 questions and tick the check boxes provided to indicate your choice of the questions to be marked. Each question is worth 10 marks. Write your answers under the questions. You may use the other side of the sheet if you require more space. Useful formulae are provided on the last two pages of the examination paper. These two sheets may be removed from the paper.

	Section A	
☐	**B1**	
☐	**B2**	
☐	**B3**	
☐	**B4**	
☐	**B5**	
☐	**B6**	
	Total	

Section A

Answer all questions. Each question is worth 1 mark. Please circle your answer in the box.

A1

A 12.0 N force with a fixed orientation does work on a particle, as the particle moved through a displacement **d** = (2.00 m)**i** - (4.00 m)**j** + (3.00 m)**k**. The change in the particle's kinetic energy is +30.0 J. What is the angle between the force vector and the displacement vector?

(A) 12.1°	(B) 16.8°	(C) 21.9°	(D) 46.1°	(E) 62.3°

A2

A 3.0 kg particle is moving in simple harmonic motion in one dimension and moves according to the equation:

$$x = (5.0\ \mathrm{m})\cos\left[\left(\frac{\pi}{3}\ \mathrm{rad/s}\right)\mathrm{t} - \left(\frac{\pi}{4}\ \mathrm{rad}\right)\right]$$

where t is measured in seconds. At what value of x is the potential energy of the particle exactly half of the mechanical energy?

(A) 0.1 m	(B) 2.8 m	(C) 3.5 m	(D) 4.6 m	(E) 4.9 m

A3

The linear density of a string is 16 g/cm. A transverse wave on the string is described by the equation

$$y = (0.021\,\mathrm{m})\sin\left[(2.0\,\mathrm{m}^{-1})x + (32\,\mathrm{s}^{-1})t\right]$$

Calculate the tension in the string

(A) 0.35 N	(B) 2.6 N	(C) 24 N	(D) 410 N	(E) 830 N

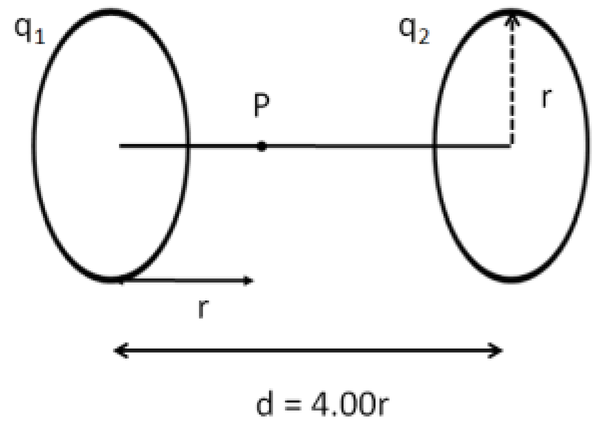
A4

If a metal conductor has a charge -1.45×10^{-7} C, how many excess electrons are there on it?

(A) 1.44×10^{-3}	(B) 2.40×10^{8}	(C) 9.05×10^{11}	(D) 8.31×10^{13}	(E) 1.05×10^{18}

A5

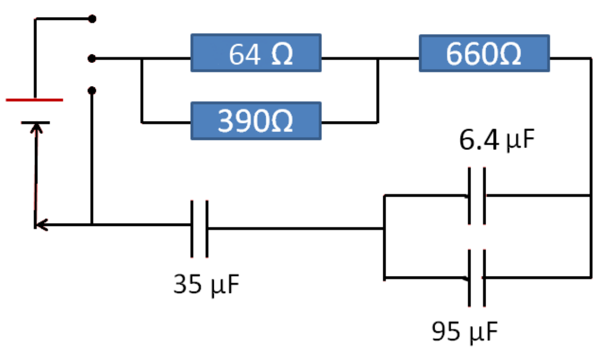
The figure shows two parallel non-conducting rings with their central axes along a common line. Ring 1 has a uniform charge q_1 and ring 2 has a uniform charge q_2. Both disks have a radius R, and the separation between the disks is 4R. The net electric field is zero at point P, which is R away from disk 1 and 3R from disk 2. What is the charge ratio q_1/q_2?



(A) 0.268	(B) 0.333	(C) 0.500	(D) 0.750	(E) 1.00

A6

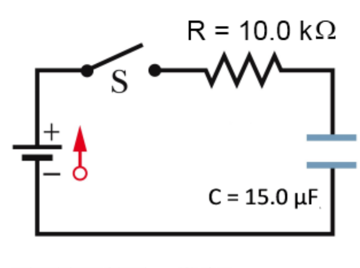
What is the time constant of this RC circuit?



(A) 26 μs	(B) 19 ms	(C) 1.2 s	(D) 11 s	(E) 230 s

A7

The switch S in the circuit pictured on the right is closed at t = 0 and the uncharged capacitor (C = 15.0 μF) starts to charge. At what point does the potential across the resistor (R = 10.0 kΩ) equal that of the capacitor?



(A) 525 μs	(B) 950 μs	(C) 0.100 ms	(D) 0.208 ms	(E) 0.350 ms

A8

A solenoid of length 15 cm, and with 45 turns, has a current of 1.25 amps flowing in it. What is the magnitude of the magnetic field inside the solenoid?

(A) 1.0×10^{-5} T	(B) 1.2×10^{-4} T	(C) 3.8×10^{-3} T	(D) 7.0×10^{-3} T	(E) 9.5×10^{-2} T

A9

A coil is connected in series with a 10.0 kΩ resistor. An ideal 50.0V battery is connected across the two devices, and the current reaches 2.00 mA after 5.00 milliseconds. Find the inductance of the coil.

(A) 97.9 H	(B) 108 H	(C) 979 H	(D) 2.61×10^{3} H	(E) 2.61×10^{6} H

A10

In an oscillating LC circuit with L = 65 mH and C = 4.0μF. The current is initially a maximum. How long will it take before the capacitor is fully charged for the first time?

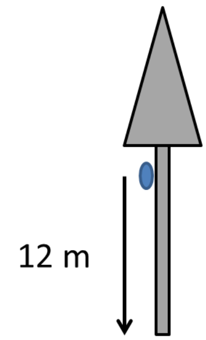
(A) 7.1×10^{-7} s	(B) 2.6×10^{-6} s	(C) 4.0×10^{-5} s	(D) 6.4×10^{-4} s	(E) 8.0×10^{-4} s

Section B

Answer **5** questions out of **6**. Use the check boxes on the front page to indicate which questions you want marked. If the check boxes are not filled in, the first five questions encountered will be marked. All questions are worth 10 marks. **Show all work**. Equations not on the formula sheet must be derived from first principles. The appropriate number of significant figures must be used in the final answer.

Section B questions continue on the next page.

B1



A 28 kg bear slides 12 m down a tree, from rest, moving with a speed of 5.6 m/s just before hitting the ground.

(a) What is the change in gravitational potential energy of the bear? *(3 marks)*

(b) What is the kinetic energy of the bear just as it hits the ground? *(3 marks)*

(c) What is the magnitude of the average friction force operating on the bear as it slides down the tree? *(4 marks)*

B2

Two long, charged, thin-walled, concentric, cylindrical shells have radii of 3.0 cm and 6.0 cm. The charge per unit length is 5.0×10^{-6} C/m^2 on the inner cylinder, and -7.0×10^{-6} C/m^2 on the outer cylinder.

(a) Calculate the magnitude and direction of the electric field at radial distance r = 4.0 cm *(5 marks)*

(b) Calculate the magnitude and direction of the electric field at radial distance r = 8.0 cm *(5 marks)*

B3

The electric potential in a region of space is given by the equation:

$$V = (2.0\ \text{V/m}^2)x^2 + (1.5\ \text{V/m})x - (3.0\ \text{V/m})y + (4.0\ \text{V/m}^2)z^2$$

(a) Find the equation for the electric field in this region of space *(7 marks)*

(b) Find the electric field at the point (3.0 m, 2.0 m, 1.5 m). *(3marks)*

B4

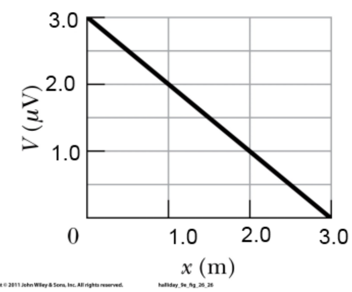
A 2.0 μF capacitor and a 4.0 μF capacitor are connected in parallel across a 240 V potential difference. The 4.0 μF capacitor has a parallel plate configuration, with a surface area of 110 cm^2, and a dielectric material (paper) between the plates with $\kappa = 3.5$

(a) Calculate the total charge stored on the capacitors *(3 marks)*

(b) Calculate the total energy stored in the capacitors *(3 marks)*

(c) Calculate the spacing between the plates in the 4.0 μF capacitor. *(4 marks)*

B5 The figure shows a graph of electrical potential V(x) along a copper wire carrying a uniform current. At x = 0, the potential is 3.0 μV, and at x = 3.00 m, the potential is zero. The wire has a radius of 2.00 mm. The resistivity of copper is $1.69 \times 10^{-8}\ \Omega.m$



(a) Calculate the resistance of a length of 10.0 m of the copper wire *(4 marks)*
(b) Calculate the current in the wire *(6 marks)*

B6

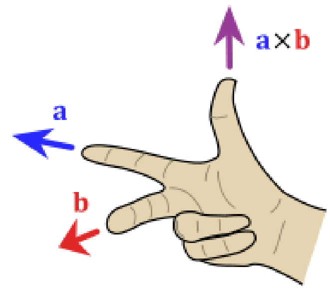
A proton (mass 1.67×10^{-27} kg) is travelling through uniform magnetic and electric fields. The electric field is (4.00 V/m)**k** and the magnetic field is **B** = (-2.50 mT)**i**. If the velocity of the proton is (3450 m/s)**k** , then, using unit vector notation, calculate

(a) The electric force on the proton *(3marks)*

(b) The magnetic force on the proton *(4 marks)*

(c) The net acceleration on the proton *(3 marks)*

Physical Constants and conversion factors



$G = 6.67\times10^{-11}\ \mathrm{Nm^2kg^{-2}}$; $g = 9.81\mathrm{m/s^2}$; $N_A = 6.02\times10^{23}\ \mathrm{mol^{-1}}$
$c = 3.00\times10^{8}\ \mathrm{m/s}$; $m_e = 9.31\times10^{-31}\ \mathrm{kg}$; $1\,\mathrm{calorie} = 4.185\,\mathrm{J}$;
$k_B = 1.38\times10^{-23}\ \mathrm{J/K}$; $R = 8.314\ \mathrm{J/mol.K}$ $\mathrm{e} = 1.602\times10^{-19}\ \mathrm{C}$;
$k = 8.99\times10^{9}\ \mathrm{N.m^2}/C^2$; $\varepsilon_0 = 8.85\times10^{-12}\ C^2/\mathrm{N.m^2}$;
$1\ \mathrm{eV} = 1.60\times10^{-19}\mathrm{J}$ $\mu_0 = 4\pi\times10^{-7}\ \mathrm{T.m/A}$;

Mathematics, Statistics and Geometry

$$If\ ax^2 + bx + c = 0\ then\ x = \frac{-b\pm\sqrt{b^2-4ac}}{2a};\ \frac{d}{dx}(x^n) = nx^{n-1};\ \frac{d}{dx}(\sin ax) = a\cos ax;$$

$$\frac{d}{dx}(a\cos x) = -a\sin ax;\quad \int x^n dx = \frac{x^{n+1}}{n+1} + C;\ \int \sin ax = -\frac{1}{a}\cos ax + C;\ \int \cos ax = \frac{1}{a}\sin ax + C$$

$$\vec a\cdot\vec b = a_x b_x + a_y b_y + a_z b_z = ab\cos\theta;\ \left|\vec a\times\vec b\right| = ab\sin\theta;\ \frac{dx}{dt} = \frac{dx}{du}\frac{du}{dt}$$

$$\vec c = \vec a\times\vec b = (a_y b_z - b_y a_z)\mathbf{i} + (a_z b_x - b_z a_x)\mathbf{j} + (a_x b_y - b_x a_y)\mathbf{k}$$

$$\mathrm{A} = \pi \mathrm{r}^2;\ \mathrm{C} = 2\pi \mathrm{r}\ \ \mathrm{V_{sphere}} = \frac{4}{3}\pi r^3;\ \mathrm{A_{sphere}} = 4\pi \mathrm{r}^2;\qquad (1+x)^n \approx 1+nx\ \text{ if }\ x \ll 1$$

$$\sigma_f = \sqrt{\left(\frac{\partial f}{\partial x}\sigma_x\right)^2 + \left(\frac{\partial f}{\partial y}\sigma_y\right)^2 + \left(\frac{\partial f}{\partial z}\sigma_z^2\right)^2 + \ldots}\quad;\ \sigma = \frac{H-L}{\sqrt{N}};\quad \sigma_x = \frac{H-L}{N}$$

Physics

$$v = \frac{dx}{dt};\ a = \frac{dv}{dt} = \frac{d^2x}{dt^2};\ \ \vec x = \vec x_0 + \vec v_0 t + \frac{1}{2}\vec a t^2;\ \vec v = \vec v_o + \vec a t;\ \vec v_{av} = \frac{\vec v_0 + \vec v}{2};\ v^2 = v_0^2 + 2a(x - x_0);$$

$$\vec F_{net} = m\vec a;\ \text{ Hooke's Law}: \vec F = \text{-}k\vec x\quad;\ \text{work W} = \vec F\cdot\vec d\quad; W = \int_{r_A}^{r_B}\vec F(\vec r)\cdot d\vec r;\ \mathrm{K} = \frac{1}{2}mv^2;\quad W = \Delta K;$$

$$\overline{P} = \frac{\Delta W}{\Delta t};\quad P = \frac{dW}{dt};\ P = \vec F\cdot\vec v\quad \Delta U = -W;\ \Delta U_g = mg\Delta y;\ U_E = \frac{1}{2}kx^2\quad; E = K + U;$$

$$\Delta U = -\int_{x_i}^{x_f} F(x)dx;\ F = -\frac{dU}{dx};\ \ W = \Delta E_{mec} + \Delta E_{th};\ \vec F = -\left(\frac{GMm}{r^2}\right)\hat r;\quad U(r) = -\frac{GMm}{r};$$

$$x(t) = x_m\cos(\omega t + \phi);\ v(t) = -\omega x_m\sin(\omega t + \phi);\ a = \frac{dv}{dt} = -\omega^2 x_m\cos(\omega t + \phi) = -\omega^2 x(t)$$

$$x(t) = Ae^{-\alpha t}\sin(\omega' t + \phi);\ \omega = 2\pi f;\ T = \frac{1}{f};\ v = f\lambda = \frac{\lambda}{T} = \frac{\omega}{k};\ \omega = \sqrt{\frac{k}{m}};\ \omega = \sqrt{\frac{g}{L}};\ E = \frac{1}{2}kx_m^2;$$

$$y(x,t) = y_m\sin(kx - \omega t);\ k = \frac{2\pi}{\lambda};\ v = \sqrt{\frac{\tau}{\mu}};\ P = \frac{\mu\omega^2 A^2 v}{2};\ \frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2};\ \vec F = k\frac{q_1 q_2}{r^2}\hat r;\ i = \frac{dq}{dt};$$

$$n_{electrons} = \frac{q_{total}}{e}; \; \vec{E} = \frac{\vec{F}}{q}; \; \vec{E} = k\frac{q}{r^2}\hat{r}; \; \vec{p} = q\vec{d}; \; E = \frac{1}{2\pi\varepsilon_0}\frac{p}{z^3}; \; E_{total} = \frac{1}{4\pi\varepsilon_0}\frac{qz}{\left(z^2+R^2\right)^{\frac{3}{2}}}$$

$$E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{z}{\sqrt{(z^2+R^2)}}\right]; E = \frac{\sigma}{2\varepsilon_0}; \; \vec{\tau} = \vec{p}\times\vec{E}; U = -\vec{p}.\vec{E}; \; \Phi = \sum \vec{E}.\Delta\vec{A}; \; \Phi = \oint \vec{E}.d\vec{A};$$

$$\varepsilon_0\Phi = q_{enc}; \; \varepsilon_0\oint \vec{E}.d\vec{A} = q_{enc}; \; E = \frac{\sigma}{\varepsilon_0}; \quad \sigma = \frac{q}{A}; \; E = \frac{\lambda}{2\pi\varepsilon_0 r}; \quad \lambda = \frac{q}{L} \; E = \frac{\sigma}{2\varepsilon_0}; \; E_{\parallel} = \frac{2\sigma_1}{\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

$$V = \frac{U}{q}; \; \Delta V = \frac{\Delta U}{q} = \frac{-W}{q}; \; W = q_0\int_i^f \vec{E}.d\vec{s}; \; \Delta V = -\int_i^f \vec{E}.d\vec{s}; \; V(r) = \frac{q}{4\pi\varepsilon_0 r}; \; V = \frac{1}{4\pi\varepsilon_0}\sum \frac{q_i}{r_i};$$

$$V_{dipole} = \frac{1}{4\pi\varepsilon_0}\left[\frac{p\cos\theta}{r^2}\right]; \; E_s = -\frac{\partial V}{\partial s}; \quad U = W = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}; \quad C = \frac{q}{V}; \quad C = \frac{\varepsilon_0 A}{d};$$

$$C_{cyl} = 2\pi\varepsilon_0\frac{L}{\ln(b/a)}; \; C_{sp} = 4\pi\varepsilon_0\frac{ab}{b-a}; \; C_{iso} = 4\pi\varepsilon_0 R; \; C_{eq,p} = C_1 + C_2 + \ldots \; \frac{1}{C_{eq,s}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$$

$$U = \frac{q^2}{2C} = \frac{1}{2}CV^2; \; u = \frac{1}{2}\varepsilon_0 E^2; \; \varepsilon_0\oint \kappa\vec{E}.d\vec{A} = q_{enc}; \; i = \frac{dq}{dt} = \int \vec{J}\cdot d\vec{A}; \quad \vec{J} = ne\vec{v}_{drift};$$

$$R = \frac{V}{i}; R = \frac{\rho L}{A}; \quad \rho - \rho_0 = \rho_0\alpha(T - T_0); \quad P = iV = i^2 R = \frac{V^2}{R}; \; R_{eq,s} = R_1 + R_2 + \ldots$$

$$\frac{1}{R_{eq,p}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots \; q = C\xi(1 - e^{\frac{-t}{RC}}); \quad \tau = RC; \; i = \frac{dq}{dt} = \pm\left(\frac{\xi}{R}\right)e^{\frac{-t}{RC}}; \; \vec{F}_B = q\vec{v}\times\vec{B}; \quad |q|vB = \frac{mv^2}{r}$$

$$\vec{F}_B = i\vec{L}\times\vec{B}; \quad d\vec{F}_B = id\vec{L}\times\vec{B}; \; \vec{\tau} = \vec{\mu}\times\vec{B}; \quad \mu = NiA; \quad U(\theta) = -\vec{\mu}\cdot\vec{B}; \; d\vec{B} = \frac{\mu_0}{4\pi}\frac{id\vec{s}\times\hat{r}}{r^2};$$

$$B_{lsw} = \frac{\mu_0 i}{2\pi R}; \quad B_{arc} = \frac{\mu_0 i\phi}{4\pi R}; \quad F_{ba} = \frac{\mu_0 L i_a i_b}{2\pi d}; \; \oint \vec{B}\cdot d\vec{s} = \mu_0 i_{enc}; B_{sol} = \mu_0 in; \quad B_{tor} = \frac{\mu_0 iN}{2\pi}\frac{1}{r};$$

$$\vec{B}(z) = \frac{\mu_0}{2\pi}\frac{\vec{\mu}}{z^3}; \; \Phi_B = \int \vec{B}.d\vec{A}; \; \xi = -\frac{d\Phi_B}{dt}; \quad \xi = -N\frac{d\Phi_B}{dt}; \; \xi = \oint \vec{E}.d\vec{s} \; L = \frac{N\Phi_B}{i}; \; \xi_L = -L\frac{di}{dt};$$

$$i = \frac{\xi}{R}\left(1 - e^{\frac{t}{\tau_L}}\right); \tau_L = \frac{L}{R}; \; i = i_0 e^{\frac{-t}{\tau_L}}; \; U_B = \frac{1}{2}Li^2; \; u_B = \frac{B^2}{2\mu_0}; \; \xi_2 = -M\frac{di_1}{dt} \text{ and } \xi_1 = -M\frac{di_2}{dt};$$

$$L\frac{d^2q}{dt^2} + \frac{1}{C}q = 0; \; q = Q\cos(\omega t + \phi); \; \omega = \frac{1}{\sqrt{LC}};$$

$$i = -\omega Q\sin(\omega t + \phi); \; L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{1}{C}q = 0; \quad q = Qe^{\frac{-Rt}{2L}}\cos(\omega' t + \phi); \; \omega' = \sqrt{\omega^2 - \left(\frac{R}{2L}\right)^2}$$

$$V_C = IX_C, \phi = -\pi/2; \quad V_L = IX_L, \phi = +\pi/2;$$

$$I = \frac{\xi_m}{Z} = \frac{\xi_m}{\sqrt{R^2 + (\omega_d L - 1/\omega_d C)^2}}; \quad Z = \sqrt{R^2 + (X_L - X_C)^2}; \; \tan\phi = \frac{X_L - X_C}{R};$$

$$P_{avg} = I_{rms}^2 R = \xi_{rms} I_{rms}\cos\phi; \quad I_{rms} = I/\sqrt{2}; \quad V_{rms} = V/\sqrt{2}; \quad \xi_{rms} = \xi/\sqrt{2};$$

$$V_s = V_p\frac{N_s}{N_P}; \quad I_s = I_p\frac{N_p}{N_s}; \; R_{eq} = \left(\frac{N_p}{N_s}\right)^2 R;$$