Physics 132-2 Test 2

I pledge that I have neither given nor received unauthorized assistance during the completion of this work.

Name ______________________________ Signature ______________________________

Questions (5 for 8 pts. apiece) Answer in complete, well-written sentences WITHIN the spaces provided.

1. Use Newton's law of universal gravitation to show that the magnitude of the acceleration due to gravity on an object of mass m at a height h above the surface of the earth is given by the following expression

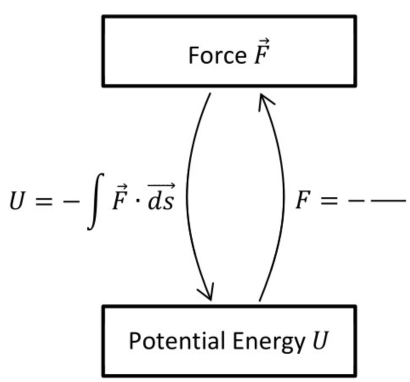
$$\frac{GM_e}{(R+h)^2}$$

where G is the gravitational constant, M_e is the mass of the Earth, and R is the radius of the Earth. Hint: Because of the spherical symmetry of the Earth you can treat the mass of the Earth as if it were all concentrated at a point at the Earth's center. Explain.

2. For non-uniform forces (that is, forces that change with position), the work done by a force is given by

$$W = -\int \vec{F} \cdot d\vec{s}$$

which reduces to $W = \int F ds$ in one dimension. The diagram below shows the resulting general relationship between force $\vec{F}$ and potential energy U. Complete the equation on the right showing how to find the force if you know the potential energy U. Explain you reasoning.



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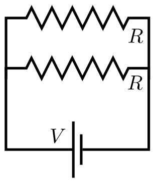
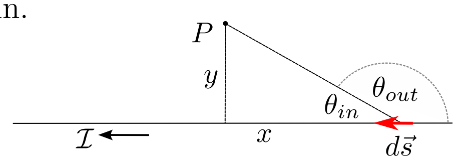
3. Consider the circuit shown below. How would you connect an ammeter to measure the total current in the circuit? A sketch might be helpful. Explain.



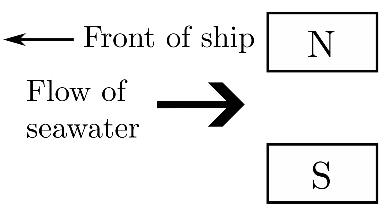
4. In calculating the magnetic field due to a nearby line of current of length L like the one shown in the figure, you encounter the integral shown below

$$|\vec{B}| = \oint \frac{\mu_o \mathcal{I}}{4\pi} \frac{y}{(x^2 + y^2)^{(3/2)}} dx$$

where $\mathcal{I}$ is the current and the point P is over the midpoint of the line of current. What is the direction of the field at point P? Explain.

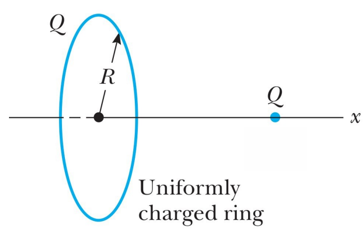


5. Consider the following idea for a novel propulsion for a ship or submarine. In this 'magnetohydrodynamic drive' seawater flows between the poles of a magnet as shown below and an electric field drives a current through the seawater. The magnetic force on this current propels the water towards the rear of the ship pushing the ship forward. What should be the direction of the applied electric field in the region between the poles of the magnet? Explain.



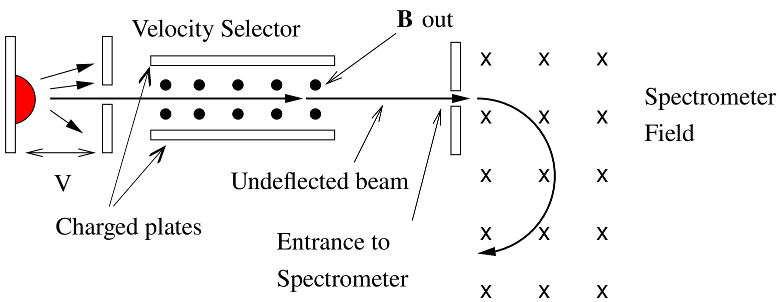
Problems (3). Clearly show all reasoning for full credit. Use a separate sheet to show your work.

1. 15 pts. The x axis is the symmetry axis of a stationary, uniformly charged ring of radius R and charge Q (see figure). A particle with charge Q and mass M is located on this axis. Starting from the electric potential of a point charge, what is the electric potential along the x-axis in terms of x, Q, R, M, and any other constants?

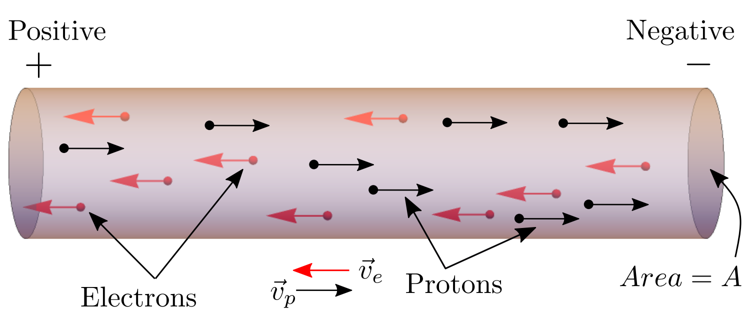


Problems (3). Clearly show all reasoning for full credit. Use a separate sheet to show your work.

2. 20 pts. Many mass spectrometers have an additional device to insure the velocity of the particles entering the magnetic field of the spectrometer is the desired value. This 'velocity selector' consists of an electric field and a second magnetic field oriented perpendicular to the $\vec{E}$ field (see figure below). These two fields are set so that only particles with the desired velocity are undeflected as they move through the device. Negative ^{14}C ions with charge $q = -e$ are accelerated across the electric potential $V = 10^6\ V$ and enter the velocity selector. The magnetic field of the velocity selector is 0.5 T. To pick out the ^{14}C ions, what should be the value of the electric field in the velocity selector and how should it be oriented?



3. 25 pts. In a fusion experiment a magnetic 'bottle' holds a gas of hydrogen atoms with an initial density $\rho = 2.8 \times 10^{21}\ atoms/m^3$. After reaching a high temperature the hydrogen gas within this volume becomes partially ionized meaning that each proton spends part of its time bound to an electron and part of the time alone. An applied electric field causes the bare protons to drift in a cylindrical region of cross sectional area $A = 1.2 \times 10^{-3}\ m^2$ at $v_p = 25\ m/s$ while the electrons drift in the opposite direction at $v_e = 88\ m/s$ (see figure). The net current has magnitude $|\mathcal{I}| = 21\ A$. What fraction of the gas is ionized?



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Physics 132-02 Equations Test 2

$$\vec{F}_G = -G\frac{m_1 m_2}{r_{12}^2}\hat{r} \qquad \vec{F}_C = k_e\frac{q_1 q_2}{r_{12}^2}\hat{r} \qquad \vec{E} \equiv \frac{\vec{F}}{q_0} \qquad \vec{E} = k_e\sum_i \frac{q_i}{r_i^2}\hat{r}_i \qquad \vec{E} = k_e\int \frac{dq}{r^2}\hat{r} \quad k_e = \frac{1}{4\pi\epsilon_0}$$

$$\vec{E}_{dipole} = k_e\frac{q(2a)}{(x^2+a^2)^{3/2}}\hat{j} \quad \vec{E}_{ring} = k_e\frac{qx}{(x^2+R^2)^{3/2}}\hat{i} \quad \vec{E}_{plane} = 2\pi k_e\eta\hat{k} = \frac{\eta}{2\epsilon_0}\hat{k}$$

$$\vec{E}_{disk} = 2\pi k_e\eta\left[1-\frac{z}{\sqrt{z^2+R^2}}\right]\hat{k} = \frac{\eta}{2\epsilon_0}\left[1-\frac{z}{\sqrt{z^2+R^2}}\right]\hat{k}$$

$$W \equiv \int \vec{F}\cdot d\vec{s} \quad \Delta V \equiv \frac{\Delta PE}{q_0} = -\int_A^B \vec{E}\cdot d\vec{s} \quad V = k_e\frac{q}{r} \quad V = k_e\sum_i \frac{q_i}{r_i}$$

$$V = k_e\int\frac{dq}{r} \quad V = Ed \quad I = \frac{dQ}{dt} \quad Q = \int I dt \quad V = IR \quad P = IV \quad R_{equiv} = \sum R_i$$

The algebraic sum of the potential changes across all the elements of a closed loop is zero.

$$I = nqv_dA$$

$$\vec{F}_B = q\vec{v}\times\vec{B} \quad |\vec{F}_B| = |qvB\sin\alpha| \quad \vec{B} = k_m\int\frac{Id\vec{s}\times\hat{r}}{r^2} \quad k_m = \frac{\mu_0}{4\pi} \quad \vec{B}_{ring} = \frac{\mu_o IR^2}{2}\frac{1}{(x^2+R^2)^{3/2}}\hat{i}$$

$$KE_0 + PE_0 = KE_1 + PE_1 \quad KE = \frac{1}{2}mv^2 \quad PE = qV$$

$$\vec{F} = m\vec{a} \qquad |\vec{F}_{cent}| = m\frac{v^2}{r} \qquad x = \frac{a}{2}t^2 + v_0t + x_0 \qquad v = at + v_0$$

$$\frac{dx^n}{dx} = nx^{n-1} \qquad \frac{df(u)}{dx} = \frac{df}{du}\frac{du}{dx} \qquad \frac{d}{dx}f(x)\cdot g(x) = f\frac{dg}{dx} + g\frac{df}{dx}$$

$$\langle x\rangle = \frac{1}{N}\sum_i x_i \quad \sigma = \sqrt{\frac{\sum_i (x_i - \langle x\rangle)^2}{N-1}} \quad A = 4\pi r^2 \quad V = Ah \quad V = \frac{4}{3}\pi r^3$$

$$\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z \quad \vec{A}\times\vec{B} = |\vec{A}||\vec{B}||\sin\alpha| \to rhr$$

$$\ln(ab) = \ln a + \ln b \quad \ln\left(\frac{a}{b}\right) = \ln a - \ln b \quad \ln x^n = n\ln x \quad x = e^{\ln x} = \ln(e^x)$$

$$\frac{df(x)}{dx} = \lim_{\Delta x\to 0}\frac{f(x+\Delta x)-f(x)}{\Delta x} \quad \int_a^b f(x)dx = \lim_{\Delta x\to 0}\sum_{n=1}^N f(x)\Delta x \quad \frac{d\ln x}{dx} = \frac{1}{x}$$

$$\int\frac{1}{x}dx = \ln x \quad \int x^n dx = \frac{x^{n+1}}{n+1} \quad \int e^{ax}dx = \frac{e^{ax}}{a} \quad \int\frac{1}{\sqrt{x^2+a^2}}dx = \ln\left[x+\sqrt{x^2+a^2}\right]$$

$$\int \frac{x}{\sqrt{x^2+a^2}}dx = \sqrt{x^2+a^2} \quad \int \frac{x^2}{\sqrt{x^2+a^2}}dx = \frac{1}{2}x\sqrt{x^2+a^2} - \frac{1}{2}a^2 \ln\left[x+\sqrt{x^2+a^2}\right]$$

$$\int \frac{x^3}{\sqrt{x^2+a^2}}dx = \frac{1}{3}(-2a^2+x^2)\sqrt{x^2+a^2} \quad \int \frac{1}{(x^2+a^2)^{3/2}}dx = \frac{x}{a^2\sqrt{x^2+a^2}}$$

$$\int \frac{x}{(x^2+a^2)^{3/2}}dx = \frac{-1}{\sqrt{x^2+a^2}} \quad \int \frac{1}{x^2+a^2}dx = \frac{1}{a}\tan^{-1}\left(\frac{x}{a}\right)$$

Physics 132-3 Constants

$T_{boiling}$ (N_2)	$77\ K$	$T_{freezing}$ (N_2)	$63\ K$
$T_{boiling}$ (water)	$373\ K$ or 100°C	$T_{freezing}$ (water)	$273\ K$ or 0°C
L_v(water)	$2.26 \times 10^6\ J/kg$	L_f (water)	$3.33 \times 10^5\ J/kg$
L_v(N_2)	$2.01 \times 10^5\ J/kg$	c (copper)	$3.87 \times 10^2\ J/kg -^\circ$ C
c (water)	$4.19 \times 10^3\ J/kg - K$	c (steam)	$0.69\ J/kg - K$
c (iron)	$4.5 \times 10^2\ J/kg - k$	c (aluminum)	$9.0 \times 10^2\ J/kg - K$
ρ (water)	$1.0 \times 10^3 kg/m^3$	P_{atm}	$1.01 \times 10^5\ N/m^2$
R	$8.31 J/K - mole$	g	$9.8\ m/s^2$
$0\ K$	-273° C	Speed of light (c)	$3.0 \times 10^8\ m/s$
proton/neutron mass	$1.67 \times 10^{-27}\ kg$	k_B	$1.38 \times 10^{-23}\ J/K$
Gravitation constant	$6.67 \times 10^{-11}\ N - m^2/kg^2$	1.0 eV	$1.6 \times 10^{-19}\ J$
e electronic charge	$1.6 \times 10^{-19}\ C$	Electron mass	$9.11 \times 10^{-31}\ kg$
Permittivity constant (ϵ_0)	$8.85 \times 10^{-12} \frac{kg^2}{N-m^2}$	$1\ u$	$1.67 \times 10^{-27}\ kg$
Permeability constant (μ_0)	$4\pi \times 10^{-7}\ Tm/A$	Earth-Sun distance	$1.5 \times 10^{11}\ m$
$k_e = 1/4\pi\epsilon_0$	$8.99 \times 10^9\ N - m^2/C^2$	Earth's mass	$5.97 \times 10^{24}\ kg$
$k_m = \mu_o/4\pi$	$10^{-7}\ Tm/A$	Earth's radius	$6.37 \times 10^6\ m$

hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
* *Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

The Periodic Chart.