Physics 4B Winter 2018 Test 1

Name: _____

Jan 26, 2018

Please show your work! Answer as many questions as you can, in any order. Books, notes, and internet connected devices are not allowed. Use any blank space to answer questions, but please make sure it is clear which question your answer refers to.

When asked for an expression, give your answer only in terms of the variables given in the question and fundamental constants such as g, k, e, and so on.
DO NOT OPEN TEST BOOKLET UNTIL TOLD TO DO SO.

$g = 9.8\ \text{ms}^{-2}$
$k = 8.99 \times 10^9\ \text{Nm}^2\text{C}^{-2} = \frac{1}{4\pi\epsilon_0}$
$\epsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2\text{N}^{-1}\text{m}^{-2}$
$e = 1.60 \times 10^{-19}\ \text{C}$
$m_e = 9.11 \times 10^{-31}\ \text{kg}$
$m_p = 1.67 \times 10^{-27}\ \text{kg}$

$E = \frac{k\,q\,x}{(R^2+x^2)^{3/2}}$
$E = 2\pi k_e \sigma \left(1 - \frac{x}{\sqrt{R^2+x^2}}\right)$
$\mathbf{p} = q\mathbf{d}$

Trigonometric Identities

$\sin^2\theta + \cos^2\theta = 1$
$\sin(2\theta) = 2\sin(\theta)\cos(\theta)$
$\cos(2\theta) = \cos^2\theta - \sin^2\theta$
$\sin(\alpha \pm \beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$
$\cos(\alpha \pm \beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$
$\cos\alpha\cos\beta = \frac{1}{2}[\cos(\alpha-\beta) + \cos(\alpha+\beta)]$
$\sin\alpha\sin\beta = \frac{1}{2}[\cos(\alpha-\beta) - \cos(\alpha+\beta)]$
$\sin\alpha\cos\beta = \frac{1}{2}[\sin(\alpha+\beta) + \sin(\alpha-\beta)]$

$\sin\left(\theta + \frac{\pi}{2}\right) = \cos\theta$
$\cos\left(\theta + \frac{\pi}{2}\right) = -\sin\theta$
$\sec\theta := \frac{1}{\cos\theta}$
$\csc\theta := \frac{1}{\sin\theta}$
$\cot\theta := \frac{1}{\tan\theta}$

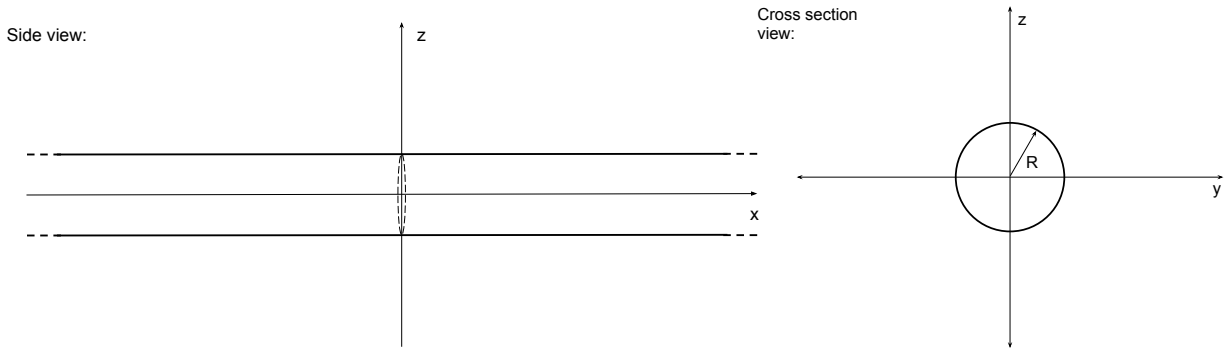
1. Consider a very, very long solid conducting cylinder of radius R. It carries a uniform charge per unit length (along the x-axis) of λ. The axis of the cylinder lies along the x-axis.

   (a) What is the electric field at distance r from the x-axis, where $r < R$? [2 pts]

   (b) What is the electric field at distance r from the x-axis, where $r > R$? [10 pts]

   (c) Define the zero of potential for this system to be a point a distance r_0 from the x-axis ($r_0 > R$), so that $V(r_0) = 0$. What is the electric potential on the on the x-axis? [6 pts]

   (d) Sketch and label the electric field lines and some equipotentials on the diagrams of the cylinder below. [4 pts]

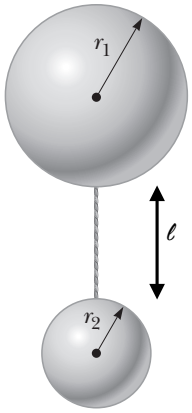


–Extra Workspace–

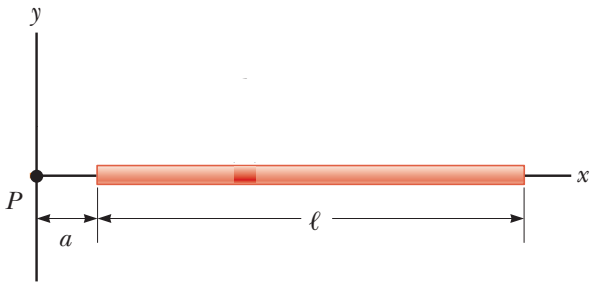
2. Two spheres made of the same conducting material have radii r_1 and r_2. They are connected by a light, conducting wire of length ℓ. A charge Q is placed on one of the conductors. Assume ℓ is sufficiently long so that the surface distribution of charge on each sphere is uniform.

   (a) Assuming $r_1 = r_2 = r$ so that the spheres are completely identical, find an expression for the tension in the wire. [3 pts]

   (b) Now suppose $r_1 \neq r_2$. Find an expression for tension in the wire in this case. [6 pts]



3. A rod of length ℓ lies along the x axis. It has a nonuniform charge density $\lambda = \alpha(x-a)$, where α is a positive constant. A point P is located along the long axis of the rod and a distance a from one end, as shown.



(a) Calculate the electric potential at P. [6 pts]

(b) Imagine a proton is placed at P and then released. What would its velocity be when it is infinitely far from the rod (assuming it interacts with nothing else)? Use the symbol m_p for the mass of the proton, and the symbols for any other fundamental constants as needed. [5 pts]

(c) Calculate the electric field at P. [6 pts]

–Extra Workspace–