Introduction to Physics II — Exam 1
11:30-1:00 Tuesday March 10

You may use a 3"x5" card of notes, both sides. You may have a calculator. NO PHONES. **There is no acceptable reason for your work to look exactly like someone else's work.** "Someone else" includes other people, the textbook, anything on the web, and handed out solutions.

Present clear and complete solutions

Start solutions with definitions (e.g. $\vec{v} \equiv \frac{d\vec{r}}{dt}$), theorems (e.g. Newton's laws), and commonly used equations (e.g. constant acceleration equations).

Any physics/engineering/math major should be able to understand what you did just by reading your solution. A diagram and words help. A correct final answer without a reasonably organized justification will earn no credit.

Leave some values and integrals uncalculated

Do all derivatives.

Do simple integrals: $\int \mathrm{a}z^n dz$, $\int \mathrm{a}e^x dx$, $\int \mathrm{a}(\cos\theta)d\theta$, $\int \mathrm{a}(\sin\phi)d\phi$, and $\int \mathrm{a}\ln(g)dg$.

Don't do other integrals. Setup them up, and leave unevaluated. Include limits, move constants out, and simplify.

$$E_z = \frac{\mathrm{kq}}{2\ell}\int_a^{2b} \frac{z}{(z^2 - \mathrm{b}^2)^{3/2}} dz \qquad \text{is perfect}$$

$$E_z = \int \frac{\mathrm{kq}}{2\ell(z^2 - \mathrm{b}^2)} \frac{z}{\sqrt{(z^2 - \mathrm{b}^2)}} dz \qquad \text{is not}$$

Do simple calculations. Multiply, divide, subtract and add integers. Calculate sine and cosine of 0, integer multiples of $\frac{\pi}{6}$ (that is $\frac{\pi}{6}, \frac{\pi}{3}, \frac{\pi}{2}, \frac{2\pi}{3}, \ldots$), and integer multiples of $\frac{\pi}{4}$ ($\frac{\pi}{4}, \frac{\pi}{2}, \frac{3\pi}{4}, \ldots$).

Don't do other calculations. Write an expression for your calculation. Include all values in the right units.

$$v_f = \left[(10\mathrm{m/s})^2 + (\frac{300\mathrm{N/m}}{0.3\mathrm{kg}})(12 \times 10^{-2}\mathrm{m})^2\right]^{1/2} \qquad \text{is perfect}$$

$$\frac{1}{2}(0.3)v_f^2 = \frac{1}{2}(0.3)(10)^2 + \frac{1}{2}(300\mathrm{nC})(12\mathrm{cm})^2 \qquad \text{is not}$$

CONSTANTS AND EQUATIONS

$$\epsilon_0 = 9 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$$
$$m_{\text{electron}} = 9.1 \times 10^{-31}\mathrm{kg} \quad m_{\text{proton}} = 1.67 \times 10^{-27}\mathrm{kg}$$
$$N_A = 6 \times 10^{23}\ \text{atoms/mol}$$

$$E_{\text{dipole}} = k\frac{2\vec{p}}{r^3}\ \text{along axis} \qquad E_{\text{dipole}} = -k\frac{\vec{p}}{r^3}\ \text{bisecting plane}$$

$$E_{\text{line}} = k\frac{Q}{y\sqrt{y^2 + (L/2)^2}},\ \text{along} \perp \text{bisector} \qquad E_{\text{inf line}} = k\frac{2\lambda}{r}$$

$$E_{\text{ring}} = k\frac{zQ}{(z^2 + R^2)^{3/2}} \qquad E_{\text{disk}} = \frac{\sigma}{2\epsilon_0}\left[1 - \frac{z}{\sqrt{z^2 + R^2}}\right]$$

$$E_{\text{plane}} = \sigma/2\epsilon_0$$

Make-up exams will be arranged if you can provide (1) advance notice (an email or voicemail 15 minutes ahead of time is fine) **and** (2) an approved and documentable excuse. If you cannot do both of these, you cannot make up the exam.

Include units on your final answer. Magnitude and direction, or components, are expected for all vector quantities.

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1. Earth carries a net charge of -5×10^5C.
   (a) Are there more protons or electrons on Earth?
   (b) How many more?

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2. Sphere A, with radius 3 cm, has an initial charge of $+20\mu$C. Sphere B is identical to A, except it's neutral. The two spheres briefly touch, then separated by 8cm. The spheres now have equal charges, uniformly distributed on the surface.

   (a) Calculate the magnitude of the electrostatic force on Sphere A.
   (b) Are the spheres insulators or conductors? Justify your answer.

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3. A -4.0 C charge experiences an electrostatic force of $+12\hat{\jmath}$N. Calculate the force would a proton experience in this same field.

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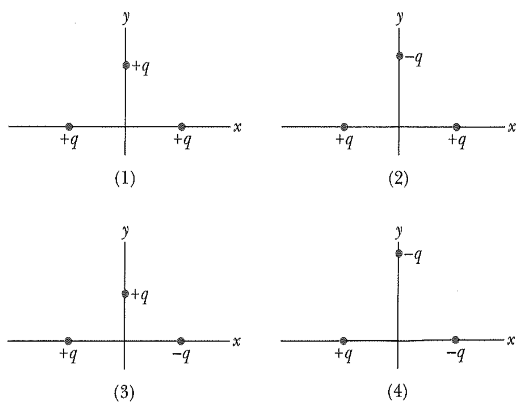
4. Sketch the direction of the electrostatic force on the top charge.



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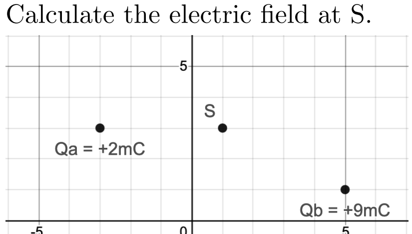
5. Calculate the electric field at S.



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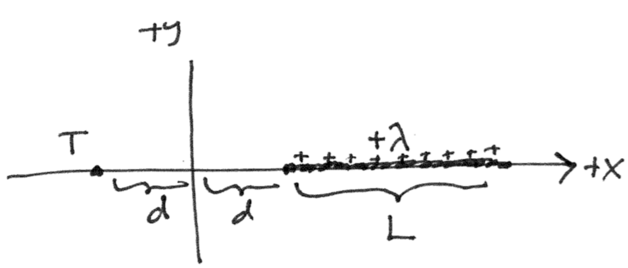
6. Derive an expression for the electric field at point T.



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7. A flat surface of area 0.90m^2 lies in the yz plane. An electric field with a magnitude of 34 N/C is present, such that the electric flux through this surface is 27.7 $\text{N}\cdot\text{m}^2/\text{C}$.

   (a) Determine the direction of the electric field. Provide an angle.
   (b) Sketch this situation. Include the area, $\vec{A}$, $\vec{E}$, and the angle you calculated in (a).

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8. A -11 mC point charge sits in the center of a cube of side length 9 cm. Calculate the electric flux through one face of the cube. (Hint: use symmetry. Don't do the integral.)

Answer 2 of the following:

9. Determine the electric field required to accelerate protons to one-hundredth the speed of light ($0.01c$, where $c = 3 \times 10^8$ m/s) in a distance of 7m.

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10. Explain how a neutral object (either an insulator or a conductor, you decide) can be attracted to a charged object. Include a useful and well-labelled diagram. Refer to the diagram in your explanation.

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11. A dipole has an electric field of

$$E = \frac{2kqa}{(a^2 + y^2)^{3/2}}$$

   at points in a plane that perpendicularly bisects the line between the charges.

   (a) Sketch a dipole. Label the charges and the distance a.
   (b) Determine an expression for this field for points far away from the dipole. (Let me know what limit you're taking.)

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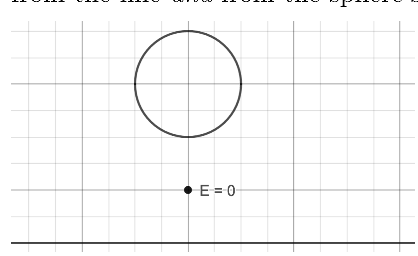
12. A uniformly charged sphere of radius R is near an infinite line charge with linear charge density λ. $\vec{E}$ is zero at a point midway between the two (R away from the line *and* from the sphere's surface).



   Determine the sphere's charge Q. Give this in terms of λ and R.
