Introduction to Physics II — Exam 2
11:30-1:00 Tuesday April 10 2018

You may use a 3"x5" card of notes, both sides. No phones. No calculators. **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 usually 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 $\int \mathrm{a}\ln(g)dg$.

Leave other integrals unintegrated. Include the limits of integration, move constants out of the integral, 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: (1) multiply, divide, subtract and add integers and (2) 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 $\frac{\pi}{4}$ (that is $\frac{\pi}{4}, \frac{\pi}{2}, \frac{3\pi}{4}, \ldots$)

Leave other calculations uncalculated. Provide an expression that requires a single calculation from your calculator. This means using the correct units.

$$v_f = \left[(10\mathrm{m/s})^2 + (\frac{300\mathrm{N/m}}{0.3\mathrm{kg}})(12\times10^{-2}\mathrm{m})^2\right]^{1/2} \qquad \text{is perfect}$$

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

CONSTANTS AND EQUATIONS

$$k = 1/4\pi\epsilon_0 = 9\times10^9\ \mathrm{N\cdot m^2/C^2} \qquad e = 1.6\times10^{-19}\ \mathrm{C}$$
$$\epsilon_0 = 9\times10^{-12}\ \mathrm{C^2/N\cdot m^2} \qquad m_{\text{proton}} = 1.7\times10^{-27}\mathrm{kg}$$
$$g = 9.8\ \mathrm{m/s^2} \qquad m_{\text{electron}} = 9.1\times10^{-31}\mathrm{kg}$$
$$N_A = 6\times10^{23}\ \text{atoms/mol}$$

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.

1. For each of the following, (a) provide the symbol, (b) give the SI unit, and (c) identify it as a vector or scalar:

   electric flux, electric potential, electric potential difference, electric potential energy, electric potential energy difference, capacitance, dielectric constant, current, current density, resistance, emf, resistivity, conductivity.

   For example, force: $\vec{F}$, Newton (N), vector.

2. Given the electric flux for a closed surface, determine if there's a non-zero net charge inside the surface.

   If there's a non-zero net charge, calculate the net charge.

3. Write an equation and 1-2 sentences that describes Gauss's law.

4. Recognize if an electric field is appropriate for a charge distribution by considering symmetries.

   For a given charge distribution, determine whether it's best to find E using by using Gauss's law or by integrating over the charge.

5. Use Gauss's law to calculate the electric field of charge distributions such as

   (a) a point charge, spheres and spherical shells,
   (b) infinitely long lines, cylinders and cylindrical shells, and
   (c) an infinite plane of charge.

   Include a diagram of the charge distribution, the electric field, and the Gaussian surface.

6. Given a uniform electric field, calculate the electric potential difference between any two points.

   Do positive charges accelerate towards a lower potential or a higher potential? How about negative charges?

7. Calculate the change in potential energy when a charge moves in a potential field. Use this to describe changes in the motion of the charge (initial and final speeds, for example).

   Assume that only electrostatic forces are present.

8. Calculate the electric potential from

   (a) multiple point charges,
   (b) continuous lines or arcs of charge, and
   (c) combinations of point charges and continuous lines or arcs of charge.

9. Calculate the potential energy for a configuration of multiple point charges.

   What does it mean to have a positive potential energy? Negative potential energy?

10. Calculate the electric field from electric potential.

    Do this from a function for $V(x, y, z)$.

    Do this from a graph (equipotentials or $V(x)$).

    If $V = 0$, then is $\vec{E} = 0$? Similarly, if $\vec{E} = 0$ then is $V = 0$?

11. What is the electric field inside the solid part of a conductor? What is the electric field just outside the conductor? What is the potential at every point in a conductor? What is the potential just outside the conductor?

    Suppose the conductor is in an external electric field. What happens to $\vec{E}$ and V?

    Suppose the conductor has a net charge. Where is the net charge and what happens to $\vec{E}$ and V?

    Suppose the conductor has a cavity with a charge inside the cavity. What happens to charge of the conductor, and $\vec{E}$ and V?

12. What is a capacitor? What is capacitance?

    Use the definition of capacitance to calculate charge or voltage difference for a capacitor.

13. Derive the equation for the capacitance of a

    (a) parallel plate capacitor
    (b) cylindrical capacitor
    (c) spherical capacitor.

    Use these equations to calculate capacitance.

14. Calculate the energy density of an electric field. Calculate the energy in a volume containing an electric field.

15. Calculate how a dielectric affects the capacitance and energy stored in a capacitor.

    What is a dielectric? What is dielectric breakdown? What is dielectric strength?

16. In a circuit with one battery and several capacitors,

    (a) identify which capacitors have the same voltage, and which have the same charge.

    Calculate
    (b) equivalent capacitance
    (c) voltage, charge, and energy for each capacitor
    (d) charge moved by the battery
    (e) energy stored in the circuit

17. Calculate current and current density.

18. Calculate charge density, drift velocity, and mean time between collisions.

19. Calculate the electric field required to drive a particular current density (or the reverse), the resistivity, and the conductivity of a material or object.

20. Determine whether an object is ohmic.

    Calculate the resistance of an object.

    Calculate the voltage required to drive a particular current (or the reverse).