UNIVERSITY OF ALABAMA
Department of Physics and Astronomy

PH 102-2 Exam I

INSTRUCTIONS
1. **Answer all questions below.** All problems have equal weight.
2. Clearly mark the answer you choose using the tick boxes.
3. **There will be no partial credit given.**
4. You are allowed 2 sides of a standard 8.5x11 in piece of paper with notes/formulas and a calculator.

1. A spherical surface surrounds a point charge q. Describe what happens to the total flux through the surface if the charge is moved outside the surface

☐ The flux is increased.

☐ The flux is decreased.

☐ The flux remains constant.

☐ The flux goes to zero.

2. A spherical conducting object A with a charge of $+Q$ is lowered through a hole into a metal container B that is initially uncharged. When A is at the center of B, but not touching it, what is the charge on the inner surface of B?

☐ $+Q$

☐ $-Q$

☐ 0

☐ cannot be determined

3. An electron is released a short distance above the surface of the Earth. A second electron directly below it exerts an electrostatic force on the first electron just great enough to cancel the gravitational force on it. How far below the first electron is the second?

☐ 5.1 m

☐ 7.5 m

☐ 10.2 m

☐ 2.5 m

4. A point charge q is located at the center of a spherical shell of radius a that has a charge $-q$ uniformly distributed on its surface. Find the electric field for a point a distance $r > a$ from the center of the shell (*i.e.,* outside the sphere).

☐ $E = \frac{k_e q}{r^2}$

☐ $E = \frac{k_e q}{4\pi r^2}$

☐ $E = 0$

☐ $E = \frac{k_e q^2}{r^2}$

5. Each of the electrons in a particle beam has a kinetic energy of 1.50×10^{-17} J. What is the magnitude of the uniform electric field (pointing in the direction of the electrons' movement) that will stop these electrons in a distance of 11.0 cm?

☐ 852 N/C

☐ 253 N/C

☐ 179 N/C

☐ 1024 N/C

6. Calculate the speed of a proton that is accelerated from rest through a potential difference of $130\,\text{V}$.

□ $3.21 \times 10^4\,\text{m/s}$

□ $7.9 \times 10^4\,\text{m/s}$

□ $6.76 \times 10^6\,\text{m/s}$

□ $1.58 \times 10^5\,\text{m/s}$

7. A parallel-plate capacitor is disconnected from a battery, and the plates are pulled a small distance further apart. Which quantities increase, which decrease, and which stay the same?

□ C, Q decrease, ΔV increases, energy stays the same

□ C decreases, Q stays the same, ΔV and energy increase

□ $\Delta V, Q$ decrease, energy stays the same, C increases

□ energy decreases, C, Q stay the same, ΔV increases
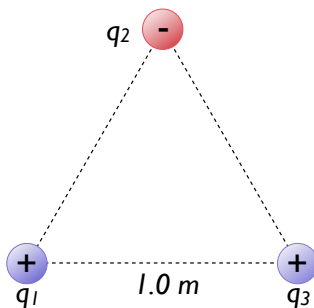
8. Three charges are arranged in an equilateral triangle, as shown at left. All three charges have the same *magnitude* of charge, $|q_1| = |q_2| = |q_3| = 10^{-9}\,\text{C}$ (note that q_2 is negative though). What is the **total potential energy** of this system of charges? Take the zero of potential energy to be when all charges are infinitely far apart.

□ $-9.0\,\text{nJ}$

□ $-7.1\,\text{nJ}$

□ $+4.6\,\text{nJ}$

□ $+8.6\,\text{nJ}$

9. What is the equivalent capacitance for the five capacitors at right?

□ $3.6\,\mu\text{F}$

□ $2.0\,\mu\text{F}$

□ $9.0\,\mu\text{F}$

□ $8.3\,\mu\text{F}$
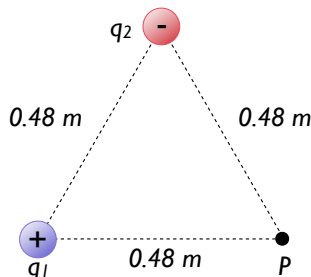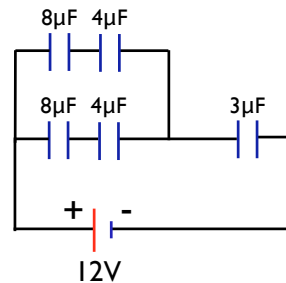
10. Two charges of $q_1 = 1.0\,\mu\text{C}$ and $q_2 = -2.1\,\mu\text{C}$ are $0.48\,\text{m}$ apart at two vertices of an equilateral triangle, as shown at left. What is the total electric potential at point P, the third vertex? Take the zero of electric potential to be infinitely far away.

□ $18700\,\text{V}$

□ $-39300\,\text{V}$

□ $-20600\,\text{V}$

□ $11423\,\text{V}$

11. Referring to the circuit below, which of the following must be true? In both circuits, we attempt to measure a resistor R by separately measuring the current and voltage and using Ohm's law. Assume both meters have internal resistance.

□ Circuit **a** overestimates R, circuit **b** underestimates it.

□ Circuit **a** underestimates R, circuit **b** overestimates it.

□ Both circuits overestimate R.

□ Both circuits underestimate R.
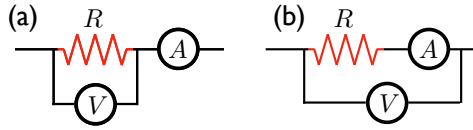
12. Two resistors, A and B, are separately connected across identical batteries. The resistance of A is twice that of B. Which resistor dissipates more power?

□ resistor A

□ resistor B

□ both resistors dissipate the same power

□ more information is needed.

13. If the current carried by a conductor is doubled, what happens to the electron drift velocity?

□ it is halved

□ it remains the same

□ it is doubled

□ it quadruples

□ it decreases by four times

14. How many 103 W lightbulbs can you use in a 125 V circuit without tripping a 15 A circuit breaker? (The bulbs are connected in parallel, which means that the potential difference across each lightbulb is 125 V.)

□ 3

□ 5

□ 10

□ 18

15. In a certain stereo system, each speaker has a resistance of $2.00\,\Omega$. The system is rated at $55.0\,\text{W}$ in each channel. What is the current drawn by each speaker?

□ 10.5 A

□ 3.12 A

□ 5.24 A

□ 11.3 A

16. Car batteries are often rated in ampere-hours. This unit by itself designates the amount of which of the following that can be drawn from the battery?

□ charge

□ power

□ energy

□ current

17. In the circuit diagram below, the resistors represent light bulbs. In these three circuits, all the batteries are identical and have negligible internal resistance, and all the light bulbs are identical. Rank all 5 light bulbs (A, B, C, D, E) in order of brightness from brightest to dimmest.

□ $A = B = C > D = E$

□ $A = D = E > B = C$

□ $A > B = C = D = E$

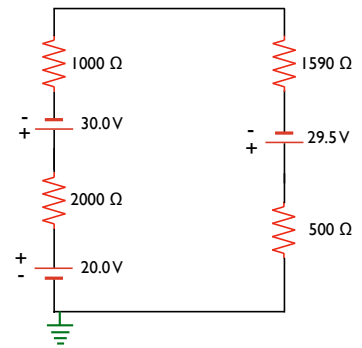□ $A > B = C > D = E$

□ $A > D = E > B = C$

□ $D = E > A > B = C$
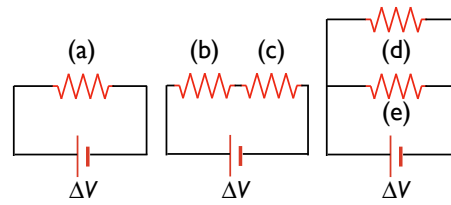
18. A series RC circuit has $R = 10.0\,\text{M}\Omega$, $C = 2.0\,\mu\text{F}$, and $\Delta V = 31$ V. Find the charge on the capacitor $10\,\text{s}$ after the switch is closed and the voltage is applied.

□ $19.1\,\mu\text{C}$

□ $56.9\,\mu\text{C}$

□ $24.4\,\mu\text{C}$

□ $2.7\,\mu\text{C}$

19. Find the current in the circuit at right.

□ $3.8\,\text{mA}$

□ $15.6\,\text{mA}$

□ $4.7\,\text{mA}$

□ $87.1\,\text{mA}$

20. A battery having an ideal voltage of 11.00 V delivers $117\,\text{mA}$ when connected to a $67.0\,\Omega$ load. What is the internal resistance of the battery?

□ $9\,\Omega$

□ $83\,\Omega$

□ $27\,\Omega$

□ $54\,\Omega$

Cheat Sheet

Constants:

$$
\begin{aligned}
k_e &= 8.98755 \times 10^9 \,\text{N} \cdot \text{m}^2 \cdot \text{C}^{-2} \\
\epsilon_0 &= 8.85 \times 10^{12} \,\text{C}^2/\text{N} \cdot \text{m}^2 \\
e &= 1.60218 \times 10^{-19} \,\text{C} \\
c &= 2.99792 \times 10^8 \,\text{m/s} \\
m_{e^-} &= 9.10938 \times 10^{-31} \,\text{kg} \\
m_{p^+} &= 1.67262 \times 10^{-27} \,\text{kg} \\
m_{n^0} &= 1.67493 \times 10^{-27} \,\text{kg} \\
g &\approx 9.81 \,\text{m/s}^2
\end{aligned}
$$

Current:

$$
\begin{aligned}
I &= \frac{\Delta Q}{\Delta t} = nqAv_d \\
J &= \frac{I}{A} = nqv_d \\
v_d &= \frac{-e\tau}{m}E \quad \tau = \text{scattering time} \\
\varrho &= \frac{m}{ne^2\tau} \\
\Delta V &= \frac{\varrho l}{A}I = RI \\
R &= \frac{\Delta V}{I} = \frac{\varrho l}{A} \\
\mathscr{P} &= E \cdot \Delta t = I\Delta V = I^2 R = \frac{[\Delta V]^2}{R} \quad \text{power}
\end{aligned}
$$

Electric Force & Field

$$
\begin{aligned}
\vec{\mathbf{F}}_e &= q\vec{\mathbf{E}} \\
\vec{\mathbf{E}} &= k_e \frac{q}{r^2}\hat{\mathbf{r}} \\
\Phi_E &= |\vec{\mathbf{E}}|A\cos\theta_{EA} = \frac{Q_{\text{inside}}}{\epsilon_0} \quad \text{Gauss} \\
\Delta PE &= -W = -q|\vec{\mathbf{E}}||\Delta\vec{\mathbf{x}}|\cos\theta = -qE_x\Delta x \\
& \quad \uparrow \text{ constant E field}
\end{aligned}
$$

Capacitors:

$$
\begin{aligned}
Q_{\text{capacitor}} &= C\Delta V \\
C_{\text{parallel plate}} &= \frac{\epsilon_0 A}{d} \\
E_{\text{capacitor}} &= \frac{1}{2}Q\Delta V = \frac{Q^2}{2C} \\
C_{\text{eq, par}} &= C_1 + C_2 \\
C_{\text{eq, series}} &= \frac{C_1 C_2}{C_1 + C_2} \\
C_{\text{with dielectric}} &= \kappa C_{\text{without}}
\end{aligned}
$$

Quadratic formula:

$$
0 = ax^2 + bx^2 + c \implies x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}
$$

Basic Equations:

$$
\begin{aligned}
\vec{\mathbf{F}}_{\text{net}} &= m\vec{\mathbf{a}} \ \text{Newton's Second Law} \\
\vec{\mathbf{F}}_{\text{centr}} &= -\frac{mv^2}{r}\hat{\mathbf{r}} \ \text{Centripetal} \\
\text{KE} &= \frac{1}{2}mv^2 \\
\text{KE}_{\text{initial}} + \text{PE}_{\text{initial}} &= \text{KE}_{\text{final}} + \text{PE}_{\text{final}}
\end{aligned}
$$

Electric Potential:

$$
\begin{aligned}
\Delta V &= V_B - V_A = \frac{\Delta \text{PE}}{q} \\
\Delta PE &= q\Delta V = -q|\vec{\mathbf{E}}||\Delta\vec{\mathbf{x}}|\cos\theta = -qE_x\Delta x \\
& \quad \uparrow \text{ constant E field} \\
V_{\text{point charge}} &= k_e \frac{q}{r} \\
PE_{\text{pair of point charges}} &= k_e \frac{q_1 q_2}{r_{12}} \\
PE_{\text{system}} &= \text{sum over unique pairs of charges} \\
PE_{\text{system}} &= \sum_{\text{pairs } ij} \frac{k_e q_i q_j}{r_{ij}} \\
-W &= \Delta \text{PE} = q(V_B - V_A)
\end{aligned}
$$

Resistors:

$$
\begin{aligned}
R_{\text{eq, series}} &= R_1 + R_2 \\
\frac{1}{R_{\text{eq, par}}} &= \frac{1}{R_1} + \frac{1}{R_2} \\
R_{\text{eq, par}} &= \frac{R_1 R_2}{R_1 + R_2}
\end{aligned}
$$

RC circuits

$$
\begin{aligned}
Q_C(t) &= Q_0\left[1 - e^{-t/\tau}\right] \quad \text{charging} \\
Q_C(t) &= Q_0 e^{-t/\tau} \quad \text{discharging} \\
Q(t) &= C\Delta V(t) \\
\tau &= RC
\end{aligned}
$$

Units

$$
\begin{aligned}
1\,\text{eV} &= 1.6 \times 10^{-19} \,\text{J} \\
1\,\text{J} &= 1\,\text{N} \cdot \text{m} = 1\,\text{kg} \cdot \text{m}^2/\text{s}^2 \\
1\,\text{N} &= 1\,\text{kg} \cdot \text{m/s}^2 \\
1\,\text{W} &= 1\,\text{J/s} = 1\,\text{kg} \cdot \text{m}^2/\text{s}^3 \\
1\,\text{F} &= 1\,\text{C/V} \\
1\,\text{C} &= 1\,\text{A/s} \\
1\,\text{N/C} &= 1\,\text{V/m}
\end{aligned}
$$