Circuits Mock Exam

10 MCQ 2 FRQ - 60 MINUTES

INSTRUCTIONS

DO NOT OPEN THIS TEST UNTIL YOU ARE TOLD TO BEGIN

- Use $g = 9.8$ N/kg throughout this contest.
- Test under standard conditions, which means that you must complete the test in 60 minutes in one sitting.
- This test contains 10 Multiple Choice Questions and 2 Free Response Questions.
- Correct answers will be awarded the points shown; leaving an answer blank will be awarded zero points. The amount of partial credit is up to your discretion as the grader. Our recommendation is to be more strict than necessary.
- A hand-held calculator may be used. Its memory must be cleared of data and programs. You may use only the basic functions found on a graphing calculator. Calculators may not be shared. Cell phones may not be used during the exam. You may not use tables, books, or formula collections.
- The number in **red** next to each question represents the amount of points the question is worth. There are a total of 40 points on this test.
- If you have any questions or clarifications, please contact us at tjhsstphysicsteam@gmail.com.

The creators of this exam are (in alphabetical order):

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Good luck and have fun! Turn the page to start the mock.

Fundamental Constants

$$e = 1.602 \times 10^{-19}\,\mathrm{C}$$
$$\epsilon_0 = 8.854 \times 10^{-12}\,\mathrm{N\,m^{-1}}$$
$$\pi = 3.141$$

10 MCQs

[2] **Problem 1.** What is the equivalent resistance of the following setup?

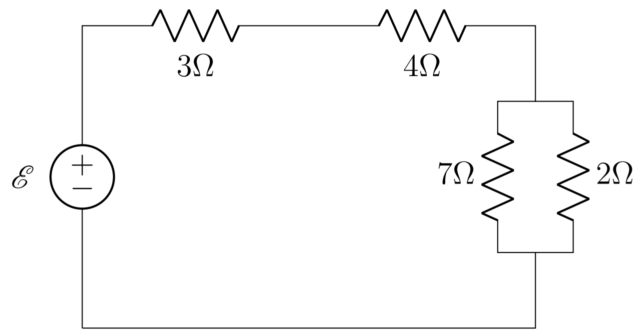


Figure 1: Resistors in a Circuit

A) 6.12Ω

B) 8.56Ω

C) 9.89Ω

D) 10.45Ω

E) 16.00Ω

[2] **Problem 2.** Suppose that circuits A and B are both DC circuits, each with an ideal battery of voltage V. Circuit A contains two resistors, each of resistance R, added in parallel, while circuit B contains two resistors of resistance R added in series. If P is the power dissipated as heat by the entire circuit, what is the ratio of P_A/P_B? Suppose that the wires have negligible resistance.

A) 1/16

B) 1/4

C) 1/2

D) 1

E) 2

F) 4

G) 16

[2] **Problem 3.** When an RC circuit with resistance R and capacitance C with resistor and capacitor *in series* is attached to a battery of voltage V, it takes time T to charge the capacitor to 50% of it's maximum charge. In an RC circuit with a battery of voltage $2V$ and with the resistor and capacitor *in parallel*, how long will it take for the capacitor to gain the same charge as the capacitor in the first circuit?

A) The capacitor will appear to charge instantly

B) $\frac{1}{2}T$

C) T

D) $2T$

E) The charge on the capacitor will never reach this amount

[2] **Problem 4.** A capacitor with capacitance C is charged using a battery of voltage V_0. The capacitor is then disconnected from the battery, and a dielectric is inserted into the capacitor, which effectively doubles its capacitance. How much work was done on the system when inserting the dielectric?

A) $-\frac{1}{2}CV_0^2$

B) $-\frac{1}{4}CV_0^2$

C) 0

D) $\frac{1}{4}CV_0^2$

E) $\frac{1}{2}CV_0^2$

[2] **Problem 5.** A spherical conducting shell has some ”self-capacitance”, which is the ratio between the charge it carries and the electric potential at its surface. In a shell with radius $R = 3$cm. What is the work done in charging the capacitor to a charge $q = 1.5 * 10^{-7}$C? Hint: First find the self-capacitance of a general sphere with radius r by finding the ratio $Q/\Delta V = Q/V$ (since potential is zero at infinite distance away) and use your capacitance and the given radius to evaluate the total potential energy.

A) $1.12 * 10^{-5}$ J

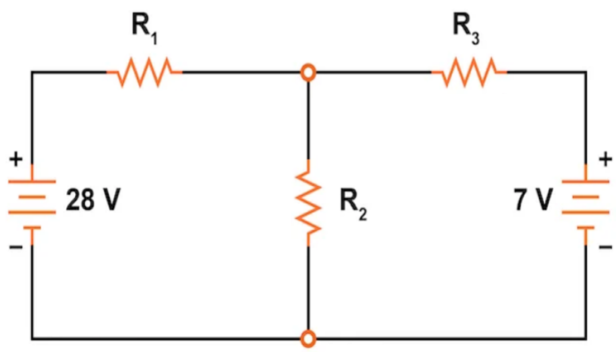
B) $3.37 * 10^{-3}$ J

C) $7.59 * 10^{-2}$ J

D) $9.65 * 10^{2}$ J

E) $5.33 * 10^{3}$ J

[2] **Problem 6.** The DC circuit shown below has resistances $R_1 = 4\Omega$, $R_2 = 4\Omega$, and $R_3 = 5\Omega$. What is the absolute value of the potential difference across resistor R_2?



A) 5 V

B) 8 V

C) 12 V

D) 18 V

E) 24 V

[2] **Problem 7.** A cylindrical metal wire with a diameter of 3 mm and length 0.2 m conducts a current of 12 A. The wire is made of a uniform material and the electric field inside the wire is $2.75 * 10^{-2}$ N/C. Calculate the resistivity of the material.

A) $1.35 * 10^{-9}\ \Omega \cdot m$

B) $4.05 * 10^{-9}\ \Omega \cdot m$

C) $5.40 * 10^{-9}\ \Omega \cdot m$

D) $1.62 * 10^{-8}\ \Omega \cdot m$

E) $4.82 * 10^{-7}\ \Omega \cdot m$

F) $3.44 * 10^{-6}\ \Omega \cdot m$

[2] **Problem 8.** Two conducting wires, both with the same density of electrons $8.49 * 10^{28}$ m^{-3} and a resistance of $4.5 * 10^{-2}\ \Omega$ maintain a potential difference of $9V$. However, one of the wires has a circular cross-section with diameter 5 mm, while the other has a square cross-section with a side length of 5 mm. What is the absolute value of the difference in electron drift velocities between the two wires, assuming that electrons are the only charge carriers in both wires? See the reference sheet for the charge of an electron.

Hint: The *charge density* in a conductor is equal to $q * n$, where q is the charge of the charge carriers and n is the density of the charge carriers.

A) $3.84 * 10^{-5}$ m/s

B) $1.61 * 10^{-4}$ m/s

C) $5.89 * 10^{-4}$ m/s

D) $7.50 * 10^{-4}$ m/s

E) $2.90 * 10^{-3}$ m/s

[2] **Problem 9.** Eric has stolen Aarush's phone! To Aarush's dismay, Eric used up all the battery playing Brawl Stars. Aarush, who now yearns to play Brawl Stars himself, begins to charge his phone with a very short 3.1 cm USB-C cable that carries a current of 19.6 A with a thick internal wire of diameter 18.7 mm. Assuming the phone begins to charge when electrons reach the phone after physically drifting from the adapter to the phone, how long would it take for the phone to start charging after Aarush plugs it in?

Use $8.49 * 10^{28}$ electrons/m^3 as the density of free electrons in copper.

A) 13.6 minutes

B) 31.2 minutes

C) 37.8 minutes

D) 72.1 minutes

E) 98.5 minutes

[2] **Problem 10.** When electric field is constant, which of the following is current density inversely proportional to?

A) Electric Potential

B) Current

C) Resistance

D) Resistivity

E) Voltage

F) None of the above

Free Response Questions

[10] **Problem 1.** *In the following parts, each item should be considered independently of the previous items.*

Consider a setup as shown in Fig 2.

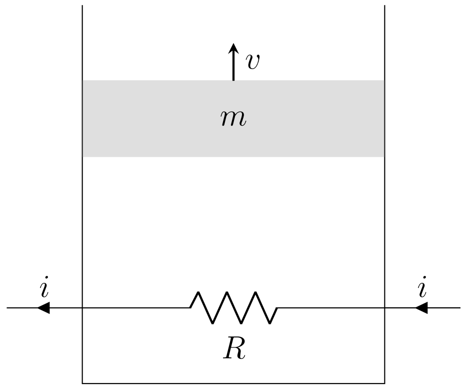


Figure 2: FRQ 1

A resistor with resistance R and current i runs through a thermally insulated container with an ideal gas inside, and a piston of mass m at the top. The piston then begins to move upwards with a speed v.

A) What should v be such that the energy of the system stays constant? Neglect changes in the energy of the gas.

B) The resistor is replaced with two resistors in parallel of resistance R, each with a current i running through them. Find v again.

C) Now assume as the gas has an internal energy proportional to T - that is,

$$E_{\text{int,gas}} = \alpha T$$

where α is a constant. Find the rate of change of temperature $\mathrm{d}T/\mathrm{d}t$ as a function of i, R, m, v, and any other constants.

[10] **Problem 2.** An initially uncharged capacitor is fully charged by an emf $\mathscr{E}$ in series with a resistor R (see Fig 3)

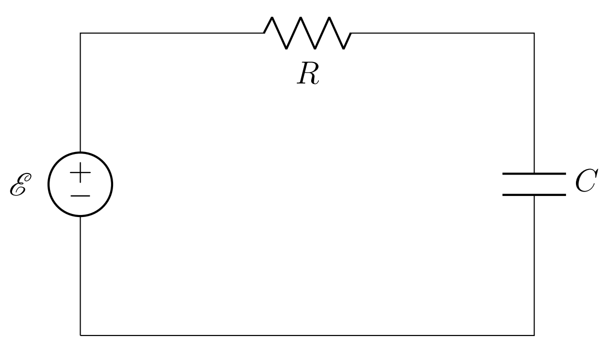


Figure 3: An RC circuit

A) After a very long time, the capacitor is charged to a charge q. What is the energy in the capacitor at this point?

B) Show the same result as above by directly integrating i^2R over the charging time.

C) At what time is the rate of heat dissipation in the resistor the same as the rate of energy storage in the capacitor.