

4. (7 points, suggested time 13 minutes)

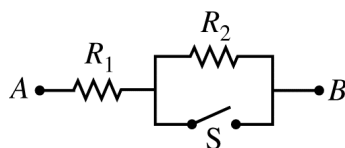
A motor is a device that when connected to a battery converts electrical energy into mechanical energy. The motor shown above is used to lift a block of mass M at constant speed from the ground to a height H above the ground in a time interval Δt . The motor has constant resistance and is connected in series with a resistor of resistance R_1 and a battery.

Mechanical power, the rate at which mechanical work is done on the block, increases if the potential difference (voltage drop) between the two terminals of the motor increases.

- (a) Determine an expression for the mechanical power in terms of M , H , Δt , and physical constants, as appropriate.
- (b) Without M or H being changed, the time interval Δt can be decreased by adding one resistor of resistance R_2 , where $R_2 > R_1$, to the circuit shown above. How should the resistor of resistance R_2 be added to the circuit to decrease Δt ?

☐ In parallel with the battery ☐ In parallel with R_1 ☐ In parallel with the motor ☐ In series with the battery, R_1 , and the motor

In a clear, coherent, paragraph-length response that may also contain figures and/or equations, justify why your selection would decrease Δt .



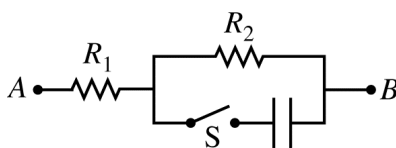
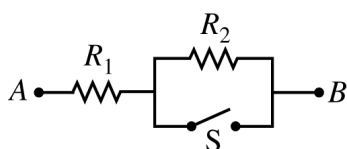
2. (12 points, suggested time 25 minutes)

Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2 , as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points A and B . The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2 .

- (a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2 .

Complete the Diagram

Describe the Experiment

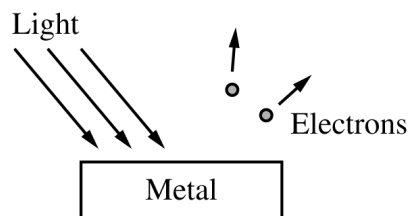


A second group of students is given a combination of circuit elements that is similar to the previous one but has an initially uncharged capacitor in series with the open switch, as shown above. The combination is placed in a circuit with a power supply so that the potential difference between A and B is maintained at 9 V. The students close the switch and immediately begin to record the current through point B . The initial current is 0.9 A, and after a long time the current is 0.3 A.

- (b)
- Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.
 - Calculate the values of R_1 and R_2 .
 - Determine the potential difference across the capacitor a long time after the switch is closed.

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

- (c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

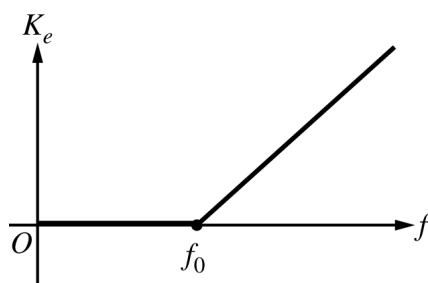


3. (12 points, suggested time 25 minutes)

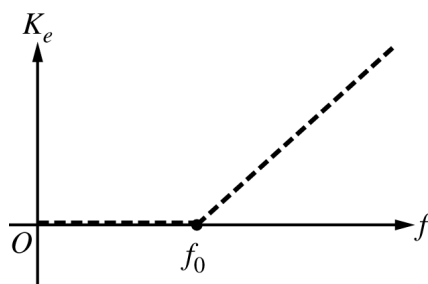
Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

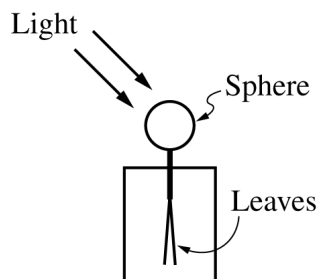
- i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \leq f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B . Also, explain the physical meaning of A , B , and f_0 .



- ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0 .
- iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



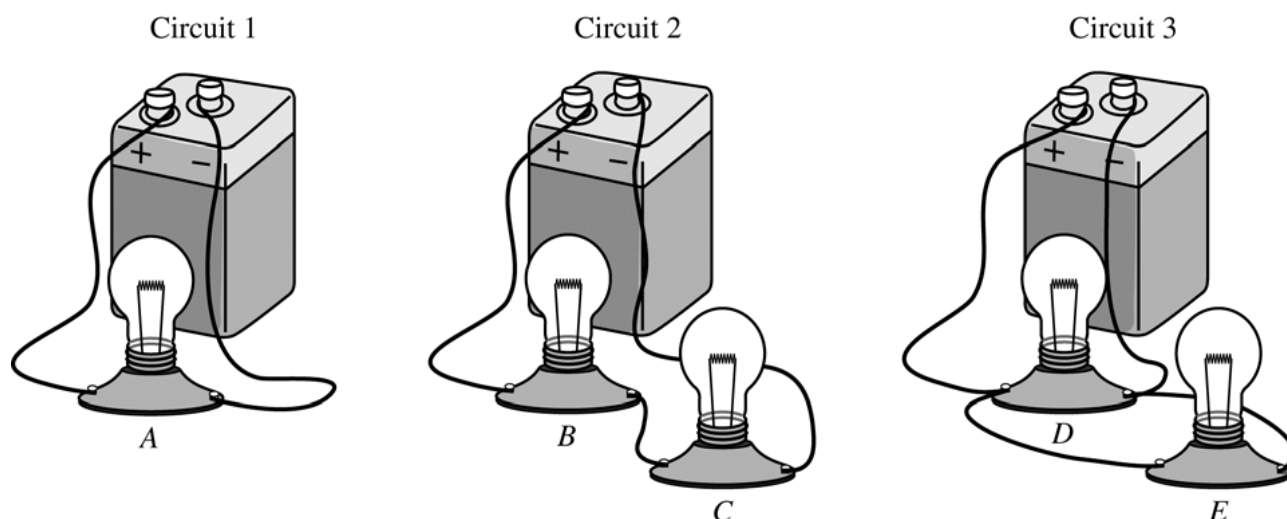
- (b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



- i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.
 - ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.
- (c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

PHYSICS 1**Section II****5 Questions****Time—90 minutes**

Directions: Questions 1, 4, and 5 are short free-response questions that require about 13 minutes each to answer and are worth 7 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



1. (7 points, suggested time 13 minutes)

In the three circuits shown above, the batteries are all identical, and the lightbulbs are all identical. In circuit 1 a single lightbulb is connected to the battery. In circuits 2 and 3, two lightbulbs are connected to the battery in different ways, as shown. The lightbulbs are labeled *A*–*E*.

- (a) Rank the magnitudes of the potential differences across lightbulbs *A*, *B*, *C*, *D*, and *E* from largest to smallest. If any lightbulbs have the same potential difference across them, state that explicitly.

Ranking:

Briefly explain how you determined your ranking.

- (b) The batteries all start with an identical amount of usable energy and are all connected to the lightbulbs in the circuits at the same time.

In which circuit will the battery run out of usable energy first?

___ Circuit 1 ___ Circuit 2 ___ Circuit 3

In which circuit will the battery run out of usable energy last?

___ Circuit 1 ___ Circuit 2 ___ Circuit 3

In a clear, coherent paragraph-length response that may also contain equations and drawings, explain your reasoning.