AP® PHYSICS B
2007 SCORING GUIDELINES

General Notes About 2007 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point, and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive and expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics Course Description* .

4. The scoring guidelines typically show numerical results using the value $g = 9.8\ \mathrm{m/s^2}$, but use of $10\ \mathrm{m/s^2}$ is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 3

15 points total | **Distribution of points**

(a)

(i) 2 points

For ranking I_A as the greatest — 1 point

For ranking I_C as the second greatest and I_B as the third greatest — 1 point

(ii) 2 points

For a correct statement justifying that I_A is greatest. (For example: The total current flows through R_A and gets divided between the other two resistors.) — 1 point

For a correct statement justifying that I_C is second and I_B is third. (For example: R_B and R_C share the current in the parallel segment, and that current divides between R_B and R_C so that the smaller resistor R_C carries the most current.) — 1 point

(b)

(i) 1 point

For the correct ranking $V_A,\ V_B,\ V_C = 1,\ 2,\ 2$ — 1 point

(ii) 2 points

For a correct justification that V_A is the greatest. (For example, because no resistor is greater than R_A, and R_A has the full current through it. Or, because R_A is greater than the equivalent parallel resistance of R_B and R_C.) — 1 point

For a correct justification that $V_B = V_C$. (For example, since the voltage across the parallel resistors R_B and R_C is the same.) — 1 point

(c) 3 points

Let R_{BC} be the resistance of the parallel combination of R_B and R_C.

For one correct form for determining R_{BC} — 1 point

$$\frac{1}{R_{BC}} = \frac{1}{R_B} + \frac{1}{R_C} = \frac{1}{2R} + \frac{1}{R} = \frac{1}{400\ \Omega} + \frac{1}{200\ \Omega} = \frac{3}{400\ \Omega}$$

$$R_{BC} = \frac{2R}{3} = \frac{400\ \Omega}{3} = 133\ \Omega$$

For one correct form for determining the total resistance — 1 point

$$R_{tot} = R_A + R_{BC} = 2R + \frac{2R}{3} = 400\ \Omega + 133\ \Omega$$

For the correct numerical value — 1 point

$$R_{tot} = 533\ \Omega$$

Question 3 (continued)

Distribution of points

(d) 3 points

For one correct form for the current I_A, using R_{tot} from part (c) — 1 point

$$I_A = \frac{\mathcal{E}}{R_{tot}} = \frac{12\text{ V}}{533\ \Omega} = 0.0225\text{ A}$$

For the correct value of V_C — 1 point

$$V_C = \mathcal{E} - V_A = \mathcal{E} - I_A R_A = 12\text{ V} - (0.0225\text{ A})(400\ \Omega) = 3.0\text{ V}$$

$$I_C = \frac{V_C}{R_C} = \frac{3\text{ V}}{200\ \Omega}$$

For the correct numerical value of I_C — 1 point

$$I_C = 0.015\text{ A}$$

Alternate solution — *Alternate points*

Using $R_B = 2R_C$ and $V_B = V_C$ so that $I_B R_B = I_C R_C$

$$I_C = \frac{R_B}{R_C} I_B = \frac{2R_C}{R_C} I_B = 2I_B$$

For the correct numerical value for I_{tot} — *1 point*

$$I_{tot} = \mathcal{E}/R_{tot} = 0.0225\text{ A}$$

For correctly relating I_{tot} to I_C — *1 point*

$$I_{tot} = I_B + I_C = \frac{I_C}{2} + I_C = \frac{3I_C}{2}$$

For the correct numerical value of I_C — *1 point*

$$I_C = \frac{2I_{tot}}{3} = \frac{2}{3}(0.0225\text{ A}) = 0.015\text{ A}$$

(e) 2 points

In the new circuit, $I_B = 0$ at equilibrium, so the total current goes through each of the two resistors

$$I_{tot} = \frac{\mathcal{E}}{R_A + R_C} = \frac{\mathcal{E}}{2R + R} = \frac{\mathcal{E}}{3R} = \frac{12\text{ V}}{600\ \Omega} = 0.02\text{ A}$$

For the correct value of the voltage across the capacitor — 1 point

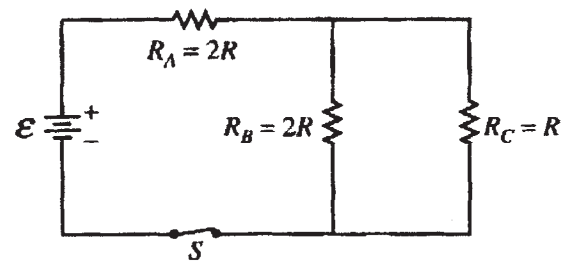
$$V_C = I_{tot} R_C = (0.02\text{ A})(200\ \Omega) = 4.0\text{ V}$$

$$Q = CV_C$$

$$Q = (2.0 \times 10^{-6}\text{ F})(4.0\text{ V})$$

For the correct numerical value of Q — 1 point

$$Q = 8.0 \times 10^{-6}\text{ C}$$



3. (15 points)

The circuit above contains a battery with negligible internal resistance, a closed switch S, and three resistors, each with a resistance of R or $2R$.

(a)

i. Rank the currents in the three resistors from greatest to least, with number 1 being greatest. If two resistors have the same current, give them the same ranking.

$I = \frac{V}{R}$ 1 I_A 3 I_B 2 I_C

ii. Justify your answers.

As the total current through the parallel paths of R_B and R_C must add to the current passing through R_A, I_A is the largest by definition.

More current will run through R_C compared to R_B as R_C provides the path of least resistance. The voltage drop over R_B and R_C is the same, and as $I = \frac{V}{R}$, the smaller resistor (R_C) has more current.

(b)

i. Rank the voltages across the three resistors from greatest to least, with number 1 being greatest. If two resistors have the same voltage across them, give them the same ranking.

$V = IR$ $R_{eq} = \frac{2R}{3}$ $I_T = \frac{\mathcal{E}}{2R}$

1 V_A 2 V_B 2 V_C

ii. Justify your answers.

~~The fir~~ As R_A has the most current running through it, it has the largest voltage drop, as no other resistor is larger than R_A.

As R_B and R_C are on parallel paths, the voltage drop across each of them must be identical.

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For parts (c) through (e), use $\mathcal{E} = 12$ V and $R = 200\ \Omega$.

(c) Calculate the equivalent resistance of the circuit.

$2R + \frac{1}{\left(\frac{1}{2R}+\frac{1}{R}\right)} = 2R + \frac{2R}{3} = \frac{8R}{3} = \frac{8(200\Omega)}{3} = 533\ \Omega$

$\uparrow$

$\frac{1}{\left(\frac{1}{2R}+\frac{2}{2R}\right)} = \frac{1}{\left(\frac{3}{2R}\right)} = \frac{2R}{3}$

The equivalent resistance of the circuit is 533 Ω.

(d) Calculate the current in resistor R_C.

$I = \frac{V}{R_T} = \frac{12\text{ V}}{533\Omega} = 0.0225\text{ A}$

$V_A = I_A R_A = (0.0225\text{A})(400\Omega) = 9\text{ V}$ ∴ 3 V drop over R_B & R_C

$I = \frac{V}{R} = \frac{3\text{ V}}{200\Omega} = 0.015\text{ A}$

There is a current of 0.015 A across R_C.

(e) The switch S is opened, resistor R_B is removed and replaced by a capacitor of capacitance 2.0×10^{-6} F, and the switch S is again closed. Calculate the charge on the capacitor after all the currents have reached their final steady-state values.

$V = IR \quad R_T = 2R + \frac{1}{\left(\frac{1}{R}\right)} = 3R = 600\Omega$

$I = \frac{V}{R_T} = \frac{12\text{ V}}{600\Omega} = 0.02\text{ A}$

$V_A = I_A R_A = (0.02\text{A})(400\Omega) = 8\text{ V}$ ∴ 4 V across R_C & C_1

$Q = CV = (2\times10^{-6}\text{ F})(4\text{ V}) = 8\times10^{-6}\text{ C}$

Final charge on the capacitor is 8.0×10^{-6} C.

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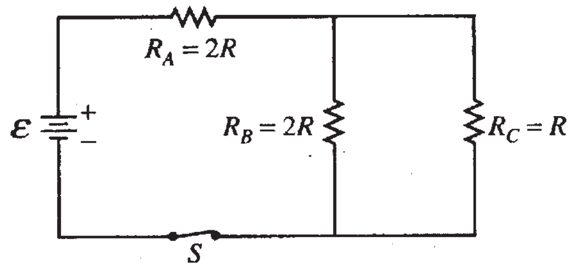

3. (15 points)

The circuit above contains a battery with negligible internal resistance, a closed switch S, and three resistors, each with a resistance of R or $2R$.

(a)

i. Rank the currents in the three resistors from greatest to least, with number 1 being greatest. If two resistors have the same current, give them the same ranking.

1 I_A 3 I_B 2 I_C

ii. Justify your answers.

R_A gets all of the current through it

R_B and R_c split the current, but ~~more~~ R_c gets more because it has less resistance than R_B

(b)

i. Rank the voltages across the three resistors from greatest to least, with number 1 being greatest. If two resistors have the same voltage across them, give them the same ranking.

1 V_A 1 V_B 1 V_C

ii. Justify your answers.

The voltage supplied to the resistors is the same throughout the entire circuit

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For parts (c) through (e), use $\mathcal{E} = 12$ V and $R = 200\ \Omega$.

(c) Calculate the equivalent resistance of the circuit.

$\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_T}$ $\left(\frac{1}{200\,\Omega}\right) + \left(\frac{1}{400\,\Omega}\right) = \frac{1}{R_T}$

$R_T = \frac{400}{3}\,\Omega$ $R_T = 133.33\,\Omega$

$R_1 + R_2 + \ldots = R_T$

$R_T = 133.33\,\Omega + 400\,\Omega = 533.33\,\Omega$

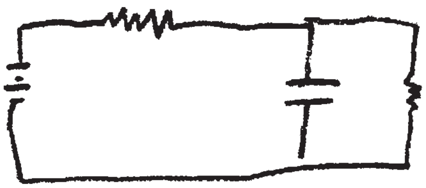
(d) Calculate the current in resistor R_C.

$I = \frac{V}{R}$

$I = \frac{8V}{200\,\Omega}$

$I = .04$ A

(e) The switch S is opened, resistor R_B is removed and replaced by a capacitor of capacitance 2.0×10^{-6} F, and the switch S is again closed. Calculate the charge on the capacitor after all the currents have reached their final steady-state values.



$C = \frac{Q}{V}$

$(4V)\ 2.0 \times 10^{-6}\,F = \frac{Q}{4V} \cdot (4V)$

$Q = (4V)(2.0 \times 10^{-6}\,F)$

$Q = 8 \times 10^{-6}$ C

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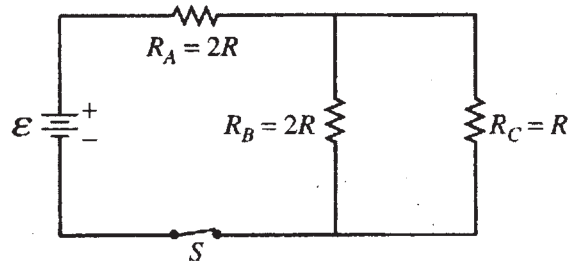

3. (15 points)

The circuit above contains a battery with negligible internal resistance, a closed switch S, and three resistors, each with a resistance of R or $2R$.

(a)

i. Rank the currents in the three resistors from greatest to least, with number 1 being greatest. If two resistors have the same current, give them the same ranking.

2 I_A 2 I_B 1 I_C

ii. Justify your answers.

V= IR

Because the greater the resistance, the lower the currents. C has th lowest ~~capacitor~~ resistance, so it will have the higher currents, and A and B were ranked the same because they will offer the same resistance.

(b)

i. Rank the voltages across the three resistors from greatest to least, with number 1 being greatest. If two resistors have the same voltage across them, give them the same ranking.

1 V_A 2 V_B 3 V_C

ii. Justify your answers.

V = IR

A will have the most voltage because it had not gone through any resistors yet, so the voltage is the highest. Since current is the same going through the parallel wires, B will have the greatest ~~resistance~~ voltage since it has the higher resistance.

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For parts (c) through (e), use $\mathcal{E} = 12$ V and $R = 200\ \Omega$.

(c) Calculate the equivalent resistance of the circuit.

$$\frac{1}{400} + \frac{1}{200} = \frac{1}{400} + \frac{2}{400} = \frac{3}{400} = 133.33V + 400V = 533.33V$$

(d) Calculate the current in resistor R_C.

$12V = I\,(400\,\Omega)$ V↓,

$I = .03$ A

(e) The switch S is opened, resistor R_B is removed and replaced by a capacitor of capacitance 2.0×10^{-6} F, and the switch S is again closed. Calculate the charge on the capacitor after all the currents have reached their final steady-state values.

$C = \frac{Q}{V}$

$2.0 \times 10^{-6} F = \frac{Q}{12V}$

$Q = 2.4 \times 10^{-5}$

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Question 3

Overview

This question's purpose was to investigate student knowledge of an electrical circuit containing a set of two parallel resistors in series with another resistor and a battery. The subquestions required both conceptual and computational responses: parts (a) and (b), which assessed students' conceptual understanding of the circuit by asking for rankings of currents through, and voltages across, the resistors, along with justifications for those rankings; parts (c) and (d), which asked for calculations of the equivalent resistance for the whole circuit and of the current through a particular resistor; and part (e), which required a calculation of steady-state capacitor charge when one of the parallel resistors is replaced by a capacitor.

Sample: 3A
Score: 15

Parts (a) and (b) contain justifications showing good conceptual understanding.

Sample: 3B
Score: 9

Part (a) received full credit, but part (b) is incorrect and received nothing. Part (c) received full credit. Part (d) has no correct work and earned nothing. Part (e) received full credit even though it does not show an explicit calculation for V_C, since that can be easily determined mentally using ratios.

Sample: 3C
Score: 3

Parts (a) and (b) received no credit. Part (c) is correct, but parts (d) and (e) are not and received nothing.