

# AP<sup>®</sup> PHYSICS

## 2012 SCORING GUIDELINES

### General Notes About 2012 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 in part (b). One exception to this practice may occur in cases where the numerical answer to a later part should easily be recognized as wrong, for example, a speed faster than the speed of light in vacuum.
3. Implicit statements of concepts normally receive credit. For example, if the use of an equation expressing a particular concept is worth 1 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 an 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 sheets. 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  $g = 9.8 \text{ m/s}^2$ , but use of  $10 \text{ m/s}^2$  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 owing 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 eliminate the level of accuracy required to determine the difference in the numbers, and some credit may be lost.

**AP<sup>®</sup> PHYSICS B**  
**2012 SCORING GUIDELINES**

**Question 5**

**15 points total**

**Distribution  
of points**

(a)

(i) 2 points

For substituting the electron charge into the equation for potential energy

1 point

$$\Delta U = -W = -q\Delta V = -(-1.6 \times 10^{-19} \text{ C})(0 - 24 \text{ V})$$

For the correct answer, with units

1 point

$$\Delta U = -3.8 \times 10^{-18} \text{ J} = -24 \text{ eV}$$

Note: Full credit is given for the correct answer, with units, with no supporting calculations.

(ii) 1 point

For selecting “Loses energy”

1 point

(b) 4 points

For recognizing that the equivalent resistance is a series sum of two parallel combinations

1 point

For the correct calculation of  $R_{AB}$

1 point

$$\frac{1}{R_{AB}} = \frac{1}{R_A} + \frac{1}{R_B} = \frac{1}{6 \Omega} + \frac{1}{3 \Omega}$$

$$R_{AB} = 2 \Omega$$

For the correct calculation of  $R_{CD}$

1 point

$$\frac{1}{R_{CD}} = \frac{1}{R_C} + \frac{1}{R_D} = \frac{1}{12 \Omega} + \frac{1}{24 \Omega}$$

$$R_{CD} = 8 \Omega$$

For the correct calculation of  $R_T$

1 point

$$R_T = R_{AB} + R_{CD} = 2 \Omega + 8 \Omega$$

$$R_T = 10 \Omega$$

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**2012 SCORING GUIDELINES**

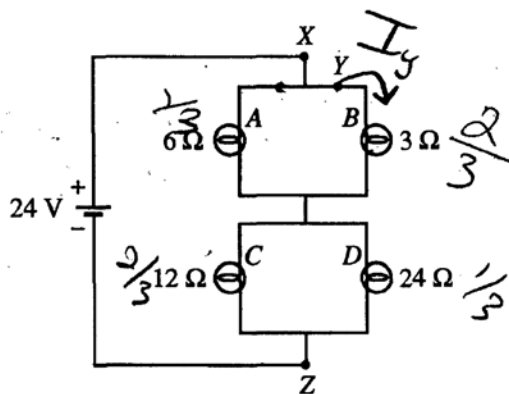
**Question 5 (continued)**

	<b>Distribution of points</b>
(c)	
(i) 3 points	
For calculation of the total current, with calculations consistent with the value of $R_T$ found in part (b)	1 point
$I_T = \frac{V_T}{R_T} = \frac{(24 \text{ V})}{(10 \ \Omega)}$	
$I_T = 2.4 \text{ A}$	
For the use of $V_{AB} = I_T R_{AB}$ to find $V_{AB}$	1 point
$V_{AB} = I_T R_{AB} = (2.4 \text{ A})(2 \ \Omega)$	
$V_{AB} = 4.8 \text{ V}$	
For the use of $I_Y = V_{AB}/R_B$ to find $I_Y$	1 point
$I_Y = \frac{V_{AB}}{R_B} = \frac{(4.8 \text{ V})}{(3 \ \Omega)}$	
$I_Y = 1.6 \text{ A}$	
<i>Alternate solution</i>	<i>Alternate points</i>
For calculation of total current with calculations consistent with calculation of $R_T$ found in part (b)	1 point
$I_T = \frac{V_T}{R_T} = \frac{(24 \text{ V})}{(10 \ \Omega)}$	
$I_T = 2.4 \text{ A}$	
For indicating that the current splits at the juncture	1 point
For correct calculations of the current at Y using the correct ratio	1 point
$V_B = V_{AB}$	
$I_Y R_B = I_{AB} R_{AB}$	
$I_Y = \frac{R_{AB}}{R_B} I_T = \frac{2}{3}(2.4 \text{ A})$	
$I_Y = 1.6 \text{ A}$	
(ii) 1 point	
For an arrow drawn at point Y pointing to the right	1 point

**AP<sup>®</sup> PHYSICS B**  
**2012 SCORING GUIDELINES**

**Question 5 (continued)**

	<b>Distribution of points</b>
(d) 3 points	
For a correct calculation of $P_C$	1 point
$P_C = \frac{V_C^2}{R_C} = I_C^2 R_C$	
<u>Note:</u> Because the ratios of resistances in the two parallel segments are the same, the current in bulb $C$ is the same as at point $Y$ .	
$P_C = (1.6 \text{ A})^2 (12 \ \Omega)$	
$P_C = 30.7 \text{ W}$	
For using $U_C = P_C t$ or an equivalent statement with consistent values	1 point
$U_C = P_C t = (30.7 \text{ W})(5 \text{ s})$	
For a consistent answer, with units	1 point
$U_C = 154 \text{ J}$	
(e) 1 point	
For a correct ranking of the bulbs in order of brightness, with 1 being the brightest	1 point
Bulb $A = 4$ Bulb $B = 3$ Bulb $C = 1$ Bulb $D = 2$	



5. (15 points)

Four lightbulbs are connected in a circuit with a 24 V battery as shown above.

(a)

i. Determine the average potential energy change of an electron as it moves from point Z to point X.

$$\Delta V = \frac{V}{q} \quad 24 = \frac{PE}{1.6 \times 10^{-19}} \quad \boxed{PE = 3.84 \times 10^{-18} \text{ J}}$$

ii. Indicate whether the electron gains or loses potential energy as it moves from point Z to point X.

Gains energy     Loses energy

(b) Calculate the equivalent resistance of the circuit.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} \dots$$

$$\frac{2}{6} + \frac{1}{6} = \frac{3}{6} \quad \frac{1}{24} + \frac{1}{24} = \frac{2}{24}$$

$$2\Omega \quad + \quad 8\Omega \quad R_T = \boxed{10\Omega}$$

(c)

i. Calculate the magnitude of the current through point Y.

$$R = \frac{V}{I} \quad I_T = 2.4 \quad \frac{2}{3}(2.4) \quad \boxed{I_Y = 1.6 \text{ A}}$$

$$10 = \frac{24}{I_T}$$

ii. Indicate on the diagram the direction of the current through point Y.

(d) Calculate the energy dissipated in the  $12\ \Omega$  bulb in 5 s.

B5-A

2 of 2

$$P = VI$$
$$W = VIt$$

$$R = \frac{V}{I}$$
$$8 = \frac{V}{2.4}$$
$$V = 19.2$$

$$\frac{2}{3}(2.4) = 1.6\text{A}$$
$$12\ \Omega$$
$$19.2\text{V}$$

$$W = 19.2(1.6)(5)$$
$$W = 153.6\text{ J}$$

(e) Rank the bulbs in order of brightness, with 1 being the brightest. If any bulbs have the same brightness, give them the same ranking.

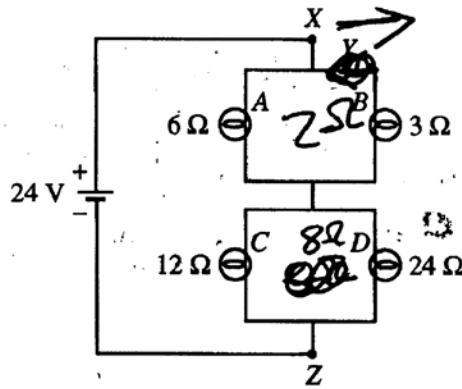
4 Bulb A    3 Bulb B    1 Bulb C    2 Bulb D

A	B	C	D
6 $\Omega$	8	12	24

.8	1.6	1.6	.8	<u>I</u>
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4.8	4.8	19.2	19.2	<u>V</u>
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384	7.68	28.8	15.36
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5. (15 points)

Four lightbulbs are connected in a circuit with a 24 V battery as shown above.

(a)

i. Determine the average potential energy change of an electron as it moves from point Z to point X.

~~24V~~ ~~1.6e-19 C~~

$$V_e = qV = (1.60 \times 10^{-19} \text{ C})(24 \text{ V}) = \boxed{3.84 \times 10^{-18} \text{ J}}$$

ii. Indicate whether the electron gains or loses potential energy as it moves from point Z to point X.

Gains energy     Loses energy

(b) Calculate the equivalent resistance of the circuit.

$$\frac{1}{R_T} = \frac{1}{R_C} + \frac{1}{R_D}$$

$$\frac{1}{R_T} = \frac{1}{12\Omega} + \frac{1}{24\Omega}$$

$$\frac{1}{R_T} = \frac{2}{24\Omega} + \frac{1}{24\Omega}$$

$$\frac{1}{R_T} = \frac{3}{24\Omega} \quad 8\Omega = R_T \quad (C \& D)$$

$$\frac{1}{R_T} = \frac{1}{R_A} + \frac{1}{R_B}$$

$$\frac{1}{R_T} = \frac{1}{6\Omega} + \frac{1}{3\Omega}$$

$$\frac{1}{R_T} = \frac{1}{6\Omega} + \frac{2}{6\Omega}$$

$$\frac{1}{R_T} = \frac{3}{6\Omega} \quad R_T = 2\Omega \quad (A \& B)$$

$$R_T = R_{T(C\&D)} + R_{T(A\&B)}$$

$$R_T = 8\Omega + 2\Omega$$

$$\boxed{R_T = 10\Omega}$$

(c)

i. Calculate the magnitude of the current through point Y.

~~24V = I \cdot 10\Omega~~  
~~24V = I \cdot 11\Omega~~  
~~12A = I~~  
~~12A = I~~

$$V = IR \quad R = R_{T(C\&D)} + R_B$$

$$R = 8\Omega + 3\Omega = 11\Omega$$

$$\frac{24V}{11\Omega} = \frac{24V}{11\Omega}$$

$$\boxed{\frac{24}{11} \text{ A} = I}$$

ii. Indicate on the diagram the direction of the current through point Y.

(d) Calculate the energy dissipated in the  $12\ \Omega$  bulb in 5 s.  $V=IR$

$$E = P \cdot T$$

$$E = IV \cdot T$$

$$E = 2A \cdot 24V \cdot 5s$$

$$E = 540J \quad \bullet W$$

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

$$I = \frac{24V}{12\ \Omega}$$

$$I = 2A$$

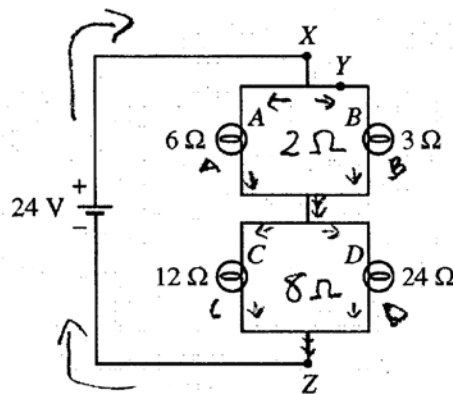
B5-B

2 of 2

(e) Rank the bulbs in order of brightness, with 1 being the brightest. If any bulbs have the same brightness, give them the same ranking.

4 Bulb A    3 Bulb B    1 Bulb C    2 Bulb D





$\frac{1}{6} + \frac{2}{6} = \frac{3}{6}$   
 $\Rightarrow \frac{1}{12} + \frac{1}{24}$   
 $\frac{2}{24} + \frac{1}{24} = \frac{3}{24}$

5. (15 points)

Four lightbulbs are connected in a circuit with a 24 V battery as shown above.

(a)

i. Determine the average potential energy change of an electron as it moves from point Z to point X.

~~$V = k \left( \frac{q_1}{r_1} + \frac{q_2}{r_2} \right)$~~   
 $U_E = qV = \frac{kq_1q_2}{r}$

ii. Indicate whether the electron gains or loses potential energy as it moves from point Z to point X.

Gains energy     Loses energy

(b) Calculate the equivalent resistance of the circuit.

Parallel  $\rightarrow \frac{1}{6} + \frac{1}{3} = \frac{1}{2} \Rightarrow R_p = 2\Omega$   
 $\frac{1}{6} + \frac{2}{6} = \frac{3}{6} = \frac{1}{2} \Rightarrow R_p = 2\Omega$     series  $2\Omega + 8\Omega = 10\Omega$

Parallel  $\frac{1}{12} + \frac{1}{24} = \frac{2}{24} + \frac{1}{24} = \frac{3}{24} \Rightarrow R_p = 8\Omega$

(c)

i. Calculate the magnitude of the current through point Y.

$V = IR$   
 $I = \frac{V}{R}$   
 $I = \frac{(24)}{10}$   
 $I = 2.4A$

ii. Indicate on the diagram the direction of the current through point Y.

(d) Calculate the energy dissipated in the  $12\ \Omega$  bulb in 5 s.

B5-C

$$P = IV \quad \text{or} \quad P = \frac{W}{\Delta t}$$

~~$Q = I$~~   
 $I =$

2 of 2

$$P = (24)(24)$$

$$P = 57.6\ \text{J}$$

(e) Rank the bulbs in order of brightness, with 1 being the brightest. If any bulbs have the same brightness, give them the same ranking.

1 Bulb A    1 Bulb B    2 Bulb C    2 Bulb D

**AP<sup>®</sup> PHYSICS B**  
**2012 SCORING COMMENTARY**

**Question 5**

**Overview**

This question assessed students' understanding of energy and electric current in a circuit containing four resistors/lightbulbs, arranged with two pairs of parallel resistors in a series configuration.

**Sample: B5-A**

**Score: 15**

This excellent, well-organized response earned full credit. All parts are done well. Work is shown in an orderly fashion and is easy to follow.

**Sample: B5-B**

**Score: 10**

Full credit was earned in parts (a) and (b). In part (c)-i no points were awarded because of the incorrect calculation of the total current. Also, there is no attempt to then calculate the current through point Y. The direction point was earned in part (c)-ii. Only 1 point was earned in part (d) for using the correct equation to find the energy dissipated. In part (e) 1 point was earned for correctly identifying the order of brightness of the bulbs.

**Sample: B5-C**

**Score: 6**

No credit was earned in part (a) because the potential energy change of an electron is not found and the incorrect answer is chosen. Full credit was awarded in part (b). One point was earned in part (c)-i for the correct calculation of the total current, but the student does not attempt to then calculate the current through point Y. In part (c)-ii the direction point was earned. No points were awarded in parts (d) and (e) because power is incorrectly calculated, there is no attempt to then calculate the energy dissipated, and the order of brightness of the bulbs is not correctly identified.