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Multiple-Choice Answer Key

The following contains the answers to
the multiple-choice questions in this exam.

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Answer Key for AP Physics 2 Exam, Section I

Question 1: C
Question 2: D
Question 3: A
Question 4: A
Question 5: C
Question 6: C
Question 7: B
Question 8: B
Question 9: B
Question 10: C
Question 11: A
Question 12: C
Question 13: D
Question 14: A
Question 15: A
Question 16: A
Question 17: B
Question 18: B
Question 19: D
Question 20: B
Question 21: B
Question 22: C
Question 23: B
Question 24: B
Question 25: C
Question 26: B
Question 27: C
Question 28: D
Question 29: C
Question 30: A
Question 31: A
Question 32: C
Question 33: A
Question 34: C
Question 35: D
Question 36: A
Question 131: B, D
Question 132: C, D
Question 133: B, D
Question 134: B, C

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Free-Response Scoring Guidelines

The following contains the scoring guidelines for the free-response questions in this exam.

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AP® PHYSICS
2015 SCORING GUIDELINES

GENERAL NOTES ABOUT 2015 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 an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the 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; Physics C: Mechanics, Physics C: Electricity and Magnetism Course Description* or "Terms Defined" in the *AP Physics 1: Algebra-Based and AP Physics 2: Algebra-Based Course and Exam 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 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.

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AP® PHYSICS 2
2015 SCORING GUIDELINES

Question 1

10 points total | **Distribution of points**

(a) 5 points

For explaining that the light that results in spot X reflects at the glass-liquid interface — 1 point

For explaining that the light that results in spot Y is refracted both as it leaves the glass and reenters the glass (direction of refraction need not be correct) — 1 point

For explaining that the light that results in spot Y is reflected at the liquid-air interface — 1 point

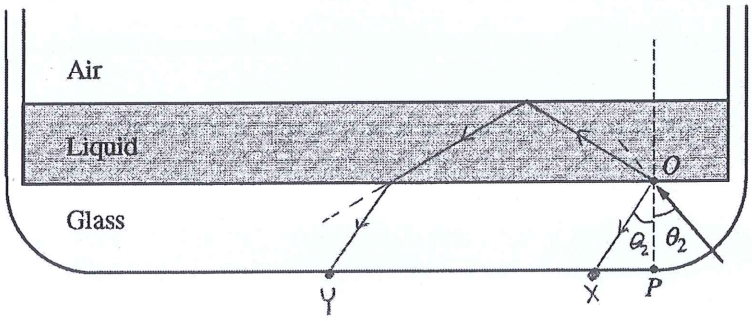
For explaining that Y is farther from P than X in terms of the geometry of the path — 1 point

For explaining that at each interface the brightness is affected by reflection, and by transmission and/or refraction as appropriate — 1 point

Students may reference a diagram to support the reasoning, but it cannot supplant the written reasoning.

(b)

i) 2 points



For drawing a reasonably accurate path for the rays that form spot X — 1 point

For drawing a reasonably accurate path for the rays that form spot Y, including correct directions of refraction, with no rays in the air — 1 point

ii) 1 point

For indicating that Y becomes brighter in terms of the distribution of energy with and without total internal reflection — 1 point

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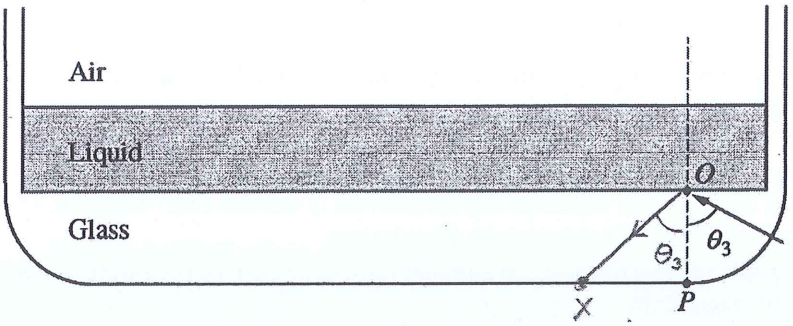
Question 1 (continued)

Distribution of points

(c)

i) 1 point



For drawing rays to show reflection at the glass-liquid interface — 1 point
One point will be deducted for drawing any rays above the glass-liquid interface.

ii) 1 point

For indicating that Y disappears and indicating that total internal reflection takes place at the glass-liquid interface — 1 point

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AP® PHYSICS 2
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Question 2

12 points total | **Distribution of points**

(a)

i) 3 points

For indicating that R_{eq} of the entire circuit or the combination of bulbs 2 and 3 decreases — 1 point

For indicating a change in I_{tot} or the potential difference across bulb 1 consistent with Ohm's law and the change in R_{eq} stated in the response — 1 point

For indicating a change in brightness consistent with the current or potential difference change stated in the response — 1 point

ii) 3 points

For indicating that $P_1 = \frac{1}{4}\left(\mathcal{E}^2/R\right)$ — 1 point

For indicating that the new equivalent resistance of the circuit is $R_{eq,new} = (3/2)R$ — 1 point

Note: Credit is earned if calculation is done in part (i) and used here.

For manipulating equations to show that the power expended by bulb 1 is $P_{new} = \frac{16}{9}P_1$ — 1 point

iii) 1 point

For using or referring to the expression from part (a)(ii) to support the claim made in (a)(i) regarding the brightness of bulb 1: e.g., $16/9 > 1$, and indicating an understanding that brightness is related to power consumption — 1 point

(b)

i) 1 point

For explaining that the brightness of bulb 2 decreases after the switch is closed because it expends less power (or the current through bulb 2 decreases, or the potential difference across bulb 2 decreases) — 1 point

ii) 1 point

For a calculation that supports the reasoning in part i — 1 point

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Question 2 (continued)

		Distribution of points
(c)	3 points	
	For indicating in either part (c)i or part (c)ii that brightness is dependent on potential difference across the bulb OR on current through the bulb	1 point
i)		
	For a reasonable explanation for why bulb 1 is brighter than bulb 2 Example: Immediately after the switch is closed, the potential difference across the capacitor will be zero (like a short in the circuit), so the current through bulb 2 would be zero, which is less than the current through bulb 1. Note: No points will be awarded for indicating that bulb1 is brighter than bulb 2 with no justification.	1 point
ii)		
	For a reasonable explanation for why bulb 1 is the same brightness as bulb 2 Example: The current through bulb 2 increases as the potential difference across the capacitor increases (becomes like an open circuit), so a long time after the switch is closed, the current through bulb 2 will be equal to the full current through bulb 1. Note: No points will be awarded for indicating that bulb 1 is the same brightness as bulb 2 without a justification.	1 point

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AP® PHYSICS 2
2015 SCORING GUIDELINES

Question 3

12 points total

Distribution of points

(a) 2 points

For indicating that the ideal gas law ($PV = nRT$ or $PV = NkT$) gives the relevant relationship between pressure and temperature of a gas and attempting to use it to support some reasoning — 1 point

For indicating that the volume and number of moles (or particles) of gas are held constant — 1 point

Note: The student will not be penalized for not specifying that pressure and temperature are only directly proportional when the temperature is measured in Kelvin.

Alternate Solution — *Alternate Points*

For indicating that the density of a sample of gas increases as its temperature decreases (if the pressure and number of moles or molecules of gas are held constant), and a sample of denser gas will sink below samples of gas that are less dense — *1 point*

For indicating that the gas near the North Pole is not a closed system and its pressure will increase as additional sinking gas molecules are added to it — *1 point*

(b) 4 points

For selecting one of the cylinders and indicating or implying that volume is held constant — 1 point

For selecting all the equipment described in the procedure and no extraneous equipment — 1 point

For describing a method of measuring the temperature of the enclosed gas — 1 point

For describing a method for measuring the pressure at more than just two temperatures — 1 point

Example: Insert the thermometer and pressure sensor in the gasket to measure the gas temperature and pressure. Place the cylinder in the bath with hot (cold) water. Take measurements periodically as the bath water cools (heats) over time.

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Question 3 (continued)

Distribution of points

(c) 2 points

For selecting a set of trials in which volume is held constant and explaining that the volume must be held constant to test the relationship between pressure and temperature — 1 point

For selecting trials in which volume is $5.0\ \text{cm}^3$, and explaining that there are the most trials for this volume, and the most trials will result in the most reliable test — 1 point

Alternate Solution — *Alternate points*

For selecting the full set of trials and explaining that the effect of changing volume on the relationship between pressure and temperature can be taken into account by multiplying pressure by volume (or plotting P/T as a function of $1/V$, etc.) — *1 point*

For explaining that selecting the most trials will result in the most reliable test OR that selecting the widest range of pressure values will result in the most precise determination of the proportionality constant relating pressure and temperature — *1 point*

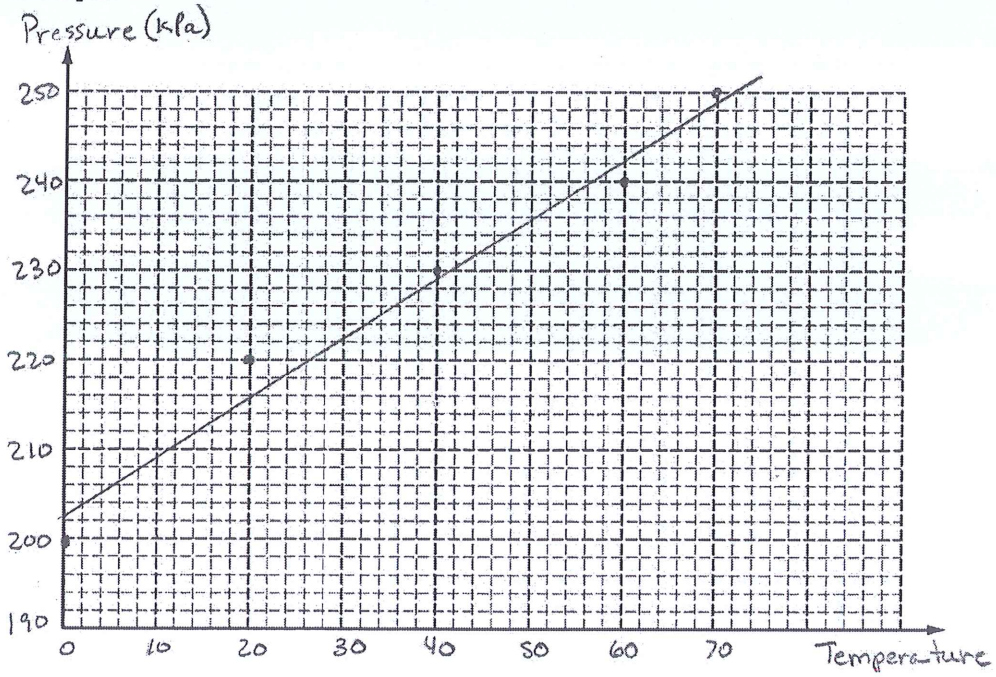
(d) 3 points

For plotting P as a function of T (or T as a function of $1/P$, etc.) OR plotting PV as a function of T (or P as a function of V/T, etc.) for each trial selected in part (c) — 1 point

For appropriate axis labels with units and appropriate scales — 1 point

For drawing an appropriate best-fit line or curve — 1 point

Example:



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Question 3 (continued)

		Distribution of points
(e)	1 point	
	For correctly describing the relationship depicted in part (d) Examples: The relationship between P and T is linear. The relationship between P and V/T is hyperbolic.	1 point

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Question 4

10 points total | **Distribution of points**

(a) 2 points

The top plate is negative.
For relating the direction of force or acceleration to the direction of the field — 1 point
For relating the direction of the electric field to the sign of the charge on the top plate — 1 point
No points are awarded for identifying that the top plate is negative with no attempt to explain why.

(b) 4 points

For using an appropriate kinematic relation to determine the acceleration of the electron while it is between the plates — 1 point

$a = (v_f - v_i)/t$

For using Newton's second law to determine an expression for the magnitude of the force needed to give the electron the calculated acceleration — 1 point

$F = ma = m(v_f - v_i)/t$

For setting eE equal to the force calculated from Newton's second law — 1 point
For correctly manipulating equations to solve for the magnitude of the electric field and arriving at a correct numerical answer with units — 1 point

$E = m(v_f - v_i)/et$

$$E = \frac{(9.11 \times 10^{-31}\ \text{kg})(8.02 \times 10^{6}\ \text{m/s} - 5.40 \times 10^{6}\ \text{m/s})}{(1.6 \times 10^{-19}\ \text{C})(1.49 \times 10^{-9}\ \text{s})} = 10{,}000\ \text{N/C}$$

Alternate Solution | *Alternate Points*

For applying conservation of energy for the time the electron is between the plates — *1 point*

$\Delta K = \Delta U$

For using the correct relationship between potential energy and potential difference — *1 point*

$\Delta U = e\,\Delta V$

$$\frac{1}{2}m_e(v_f^2 - v_i^2) = e\,\Delta V$$

For using the relation between potential difference, electric field, and plate separation — *1 point*

$\Delta V = Ed$

$$\frac{1}{2}m_e(v_f^2 - v_i^2) = e\,Ed$$

For correctly manipulating equations to solve for the magnitude of the electric field and arriving at a correct numerical answer with units — *1 point*

$E = m_e(v_f^2 - v_i^2)/2ed$

$$E = \frac{(9.11 \times 10^{-31})\left((8.02 \times 10^{6}\ \text{m/s})^2 - (5.40 \times 10^{6}\ \text{m/s})^2\right)}{2(1.6 \times 10^{-19}\ \text{C})(0.010\ \text{m})} = 10{,}000\ \text{N/C}$$

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Question 4 (continued)

Distribution of points

(c) 1 point

$E = Q/\varepsilon_0 A$

$Q = \varepsilon_0 AE$

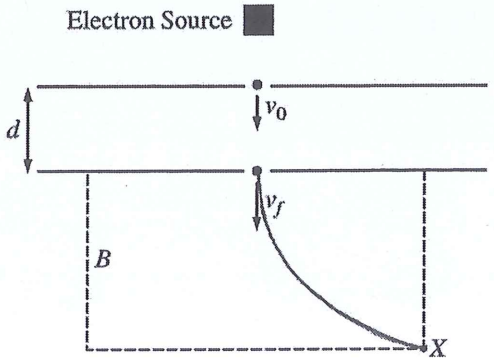
For correct substitution of values into the equation to calculate the magnitude of charge on each parallel plate — 1 point

$Q = \left(8.85 \times 10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2\right)\left(0.25\ \text{m}^2\right)(10{,}000\ \text{N/C})$

$Q = 2.2 \times 10^{-8}\ \text{C}$

(d)

i. 2 points



Note: Figure not drawn to scale.

For drawing a reasonably circular path from the point where the electrons leave the bottom plate to point X — 1 point

Note: There is no penalty for starting the path at the tip of the arrow.

For explaining that the field is always perpendicular to the velocity, so the force is also always perpendicular to the velocity which creates a curved (circular) path — 1 point

ii. 1 point

In order for the electron to reach point X, the magnetic field must exert a centripetal force on the electron toward the top right corner of the dashed box.

For using the right hand rule and reasoning that the force on a negatively charged object is in the opposite direction from the force exerted on a positively charged object (or using the "left hand rule") to conclude that the direction of the magnetic field is directed out of the page — 1 point

Notes:

No points are awarded for identifying that the direction of the magnetic field is out of the page without explaining why.

Credit can be earned for a correct analysis at any individual point on the path.

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Scoring Worksheet

The following provides a scoring worksheet and conversion table used for calculating a composite score of the exam.

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2015 AP Physics 2 Scoring Worksheet

Section I: Multiple Choice

_____ × 1.0000 = _____

Number Correct (out of 40) — Weighted Section I Score (Do not round)

Section II: Free Response

Question 1 _____ (out of 10) × 0.9090 = _____ (Do not round)

Question 2 _____ (out of 12) × 0.9090 = _____ (Do not round)

Question 3 _____ (out of 12) × 0.9090 = _____ (Do not round)

Question 4 _____ (out of 10) × 0.9090 = _____ (Do not round)

Sum = _____

Weighted Section II Score (Do not round)

Composite Score

_____ + _____ = _____

Weighted Section I Score — Weighted Section II Score — Composite Score (Round to nearest whole number)

AP Score Conversion Chart
Physics 2

Composite Score Range	AP Score
59-80	5
49-58	4
34-48	3
19-33	2
0-18	1

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AP Physics 2: Algebra-Based

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