张老师答疑微信：15940415847

AP® Physics 2
2015 Scoring Guidelines

© 2015 The College Board. College Board, Advanced Placement Program, AP, AP Central, and the acorn logo are registered trademarks of the College Board.
Visit the College Board on the Web: www.collegeboard.org.
AP Central is the official online home for the AP Program: apcentral.collegeboard.org.

张老师答疑微信：15940415847

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

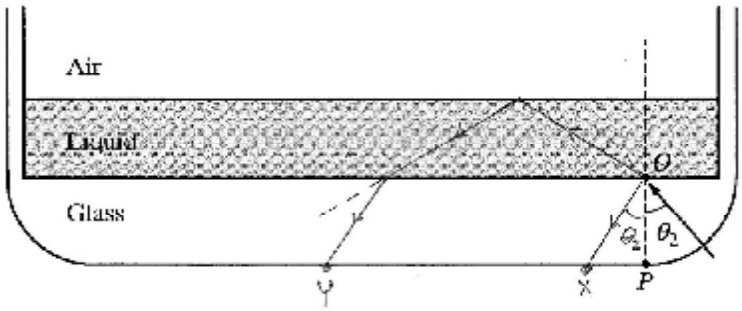
For explaining that Y is farther from P than X in terms of the geometry of the path — 1 point

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

© 2015 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

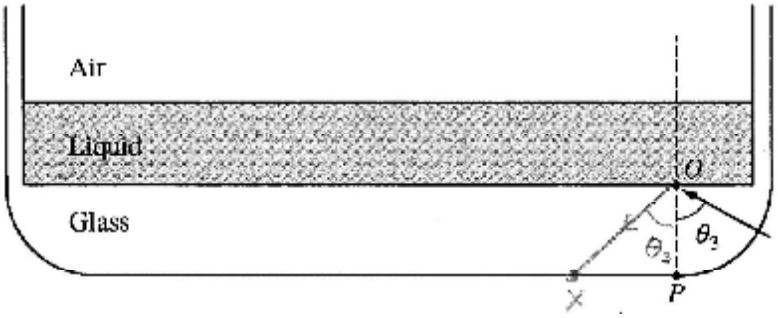
张老师答疑微信：15940415847

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

© 2015 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

AP® PHYSICS 2
2015 SCORING GUIDELINES

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

© 2015 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

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

© 2015 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

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.

© 2015 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

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*

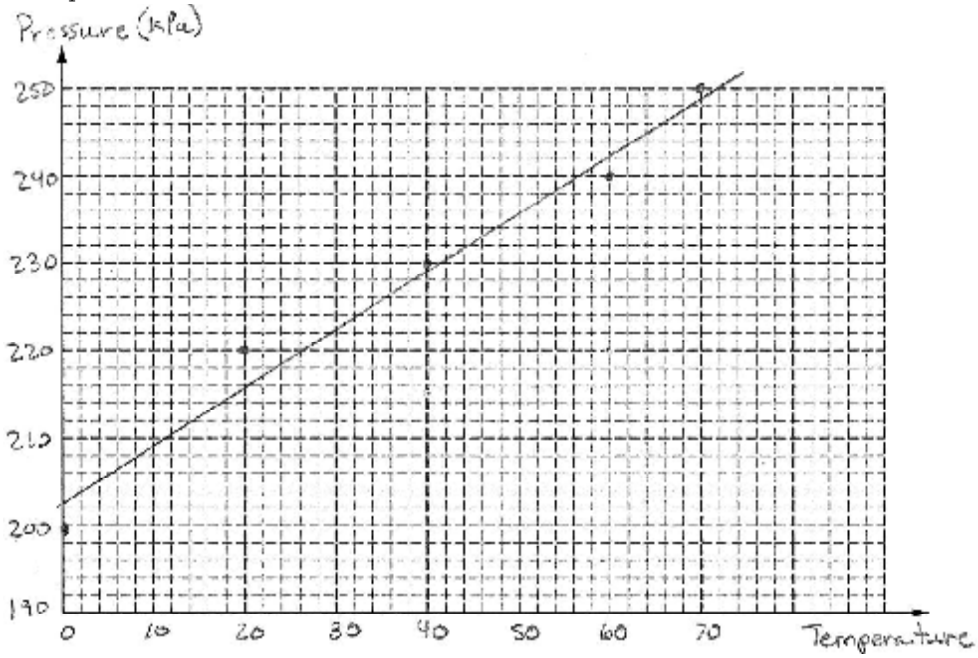
(d) 3 points

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:



© 2015 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 3 (continued)

Distribution of points

(e) 1 point

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

© 2015 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

AP® PHYSICS 2
2015 SCORING GUIDELINES

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*

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

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

© 2015 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 4 (continued)

Distribution of points

(c) 1 point

$E = Q/\varepsilon_0 A$

$Q = \varepsilon_0 AE$

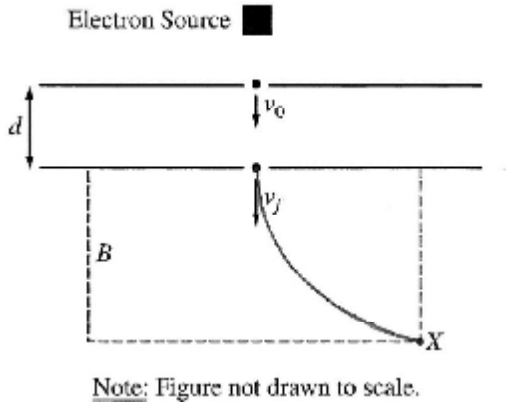
For correct substitution of values into the equation to calculate the magnitude of charge on each parallel plate — 1 point

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

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

(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.

© 2015 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847



AP® Physics 2
2016 Scoring Guidelines

© 2016 The College Board. College Board, Advanced Placement Program, AP, AP Central, and the acorn logo are registered trademarks of the College Board.
Visit the College Board on the Web: www.collegeboard.org.
AP Central is the official online home for the AP Program: apcentral.collegeboard.org.



张老师答疑微信：15940415847

AP® PHYSICS 2
2016 SCORING GUIDELINES

Question 1

10 points total | **Distribution of points**

(a)

i. 2 points

For showing the calculation of the force on the piston and a correct answer with units — 1 point

$F = PA = \left(1.0 \times 10^5 \text{ Pa}\right)\left(5 \times 10^{-3} \text{ m}^2\right) = 500 \text{ N}$

For explaining the force in terms of gas atom collisions — some change in the atoms' momentum or velocity must be identified to justify a force between atoms and piston — 1 point

Example: The collisions of the gas atoms with the container walls cause a change in the momentum of the gas atoms, which means forces are exerted between the atoms and the piston. Each gas molecule colliding with a wall experiences a force from the wall that changes the molecule's velocity or momentum.

ii. 2 points

For showing the calculation of the temperature and a correct answer with units — 1 point

$PV = nRT$

$T = PV/nR = \left(1.0 \times 10^5 \text{ Pa}\right)\left(0.10 \text{ m}^3\right)/(2)(8.31 \text{ J/mol•K}) = 602 \text{ K}$

For indicating that temperature characterizes the average speed or average kinetic energy or RMS velocity of the molecules — 1 point

(b)

i. 2 points

For identifying that the temperature increases due to increasing volume and constant pressure — 1 point

For relating temperature change with internal energy change — 1 point

Example: Because the volume increases at a constant pressure, the temperature goes up because $PV = nRT$. Increasing temperature means increasing average kinetic energy or total internal energy.

ii. 3 points

For calculating the work done in process *ABC* (i.e., the area under the line) — 1 point

$W_{AB} = -\left(1.0 \times 10^5 \text{ Pa}\right)\left(0.10 \text{ m}^3 - 0.04 \text{ m}^3\right) = -6000 \text{ J}$ and $W_{BC} = 0$

For calculating T_A and T_C (or ΔT between the states) and using them to determine internal energy change — 1 point

$T_A = P_A V_A / nR = \left(1.0 \times 10^5 \text{ Pa}\right)\left(0.04 \text{ m}^3\right)/(2 \text{ mol})(8.31 \text{ J/mol•K}) = 241 \text{ K}$

$T_C = P_C V_C / nR = \left(0.5 \times 10^5 \text{ Pa}\right)\left(0.10 \text{ m}^3\right)/(2 \text{ mol})(8.31 \text{ J/mol•K}) = 301 \text{ K}$

$\Delta U = \Delta K_{\text{per molecule}}\, nN_0 = (3/2) k_B \Delta T n N_0$

$\Delta U = (3/2)\left(1.38 \times 10^{-23} \text{ J/K}\right)(301 \text{ K} - 241 \text{ K})(2 \text{ mol})\left(6.02 \times 10^{23}\right) = 1500 \text{ J}$

© 2016 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 1 (continued)

Distribution of points

(b)

ii. (continued)

Alternately, ΔU can be calculated directly from the given data

$\Delta U = (3/2)nR\Delta T = (3/2)(P_C V_C - P_A V_A)$

$= (3/2)\left(\left(0.5 \times 10^5 \text{ Pa}\right)\left(0.10 \text{ m}^3\right) - \left(1.0 \times 10^5 \text{ Pa}\right)\left(0.04 \text{ m}^3\right)\right) = 1500 \text{ J}$

For substituting ΔU and W (whether correct or incorrect) into some form of the first law of thermodynamics to find Q and for including units in a numerical answer — 1 point

$Q = \Delta U - W = 1500 \text{ J} - (-6000 \text{ J})$

$Q = 7500 \text{ J}$

(c) 1 point

For recognizing that the change in kinetic energy for process CA has the same numerical value as ΔU from (b)ii but with the opposite sign OR for calculating ΔK using the correct temperature change or $\Delta K_{\text{total}} = (3/2)nR\,\Delta T$ as shown below — 1 point

$\Delta K_{\text{total}} = (3/2)k_B \Delta T\, nN_0$ or $\Delta K_{\text{total}} = (3/2)nR\,\Delta T$

$\Delta K_{\text{total}} = (3/2)\left(1.38 \times 10^{-23} \text{ J/K}\right)(241 \text{ K} - 301 \text{ K})(2 \text{ mol})\left(6.02 \times 10^{23} \text{ mol}^{-1}\right)$

$\Delta K_{\text{total}} = -1500 \text{ J}$

© 2016 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

AP® PHYSICS 2
2016 SCORING GUIDELINES

Question 2

12 points total | **Distribution of points**

(a) 3 points

For graphing angles or functions of angles on the axes	1 point
For plotting sines of angles on the axes and indicating or implying that the index of refraction of air is 1	1 point
For indicating a method to determine the index of refraction of the glass that is consistent with the graph described	1 point

Example: If 1 refers to air and 2 to the glass, use $n_1 \sin\theta_1 = n_2 \sin\theta_2$ and graph $\sin\theta_1$ as a function of $\sin\theta_2$. Because $n_1 = 1$, the slope of the line is n_2.

(b) 4 points

For indicating that the light from the lamp needs to be a beam when it enters the glass (either referring to a beam, explicitly describing how to create a beam, or showing a beam in a diagram)	1 point
For describing some method of determining angles with a protractor (or equivalent tool) in both media at an appropriate boundary	1 point
For using angles with respect to the normal (can measure any angles as long as reference is made to converting them to the correct ones)	1 point
For repeating the measurement at three or more different incidence angles to obtain sufficient data	1 point

(c) 2 points

For indicating that when light travels across the boundary from air to glass, the ray bends toward the normal	1 point
For indicating that the speed of light is slower in glass than in air (or an answer consistent with response for bending of the ray)	1 point

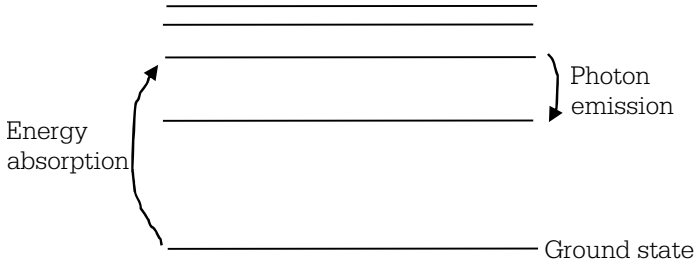
© 2016 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 2 (continued)

		Distribution of points
(d)	3 points	
	For an appropriate energy-level diagram showing absorption from the lowest level and emission	1 point
	For indicating that a hydrogen atom can be excited from the ground state to a higher energy state by absorbing energy	1 point
	For indicating that transitions to lower energy levels cause emission of photons	1 point

Example:



Atoms in the ground state absorb energy from the electricity delivered to the lamp. The atoms enter an excited state. Then the atoms emit photons as they drop to a lower energy state.

© 2016 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

AP® PHYSICS 2
2016 SCORING GUIDELINES

Question 3

12 points total **Distribution of points**

(a) 1 point

For correctly labeling the magnitude of lines ($A = 60$ V and $B = 80$ V, units not required) and for having the correct signs on each line (either explicit positive signs or no negative signs) 1 point

(b)

i. 2 points

For indicating that Y has more charge than X with a correct explanation, such as the nearest potential of the same value is farther from Y 1 point

For indicating X and Y must be the same sign with a correct explanation 1 point

Examples:

- Field vectors are perpendicular to equipotentials, and the pattern of field vectors indicates that both must have the same sign.
- There is no zero potential line between the spheres, so the potentials from the two charges do not cancel anywhere.

ii. 1 point

For a correct explanation that addresses the charge to mass ratio and distance relationship 1 point

Example: Both spheres would gravitationally attract a third sphere just like two charges of the same sign would attract a third charge of the opposite sign because both forces are dependent on the distance and also dependent on the product of the charges or masses.

(c) 2 points

For a similarity that does not generally apply to all forces 1 point

Example: The forces have the same dependence on the distance and are both functions of $1/r^2$.

For a difference that does not generally apply to all forces 1 point

Examples:

The proton is the same sign as the spheres, so it is electrostatically repelled, but gravity is always attractive. Therefore, the directions of the forces are different.

The forces are different in magnitude.

© 2016 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 3 (continued)

Distribution of points

(d)

i. 2 points

The proton is repelled by both spheres, so it will move toward point A.
For some attempt to apply $\Delta U_E = q\Delta V$ using the given variables — 1 point
For using the correct variables and getting $\Delta U = q(V_A - V_B)$ (no credit for using numeric values of electric potential) — 1 point

ii. 2 points

For using a correct expression for work — 1 point
$W = Fd$ or $-\Delta U_E = q\Delta V$
For a correct expression for F or ΔV in terms of E_{avg} — 1 point
$F_{avg} = qE_{avg}$ or $\Delta V = E_{avg}d$
$W = qE_{avg}d$ (full credit is awarded for just writing the correct expression)

iii. 2 points

For indicating that student 1 is correct and a correct discussion of why — 1 point
Example: Student 1 is correct. Because the system contains all the objects, the energy is transferred from one form to another within the system due to the law of conservation of energy.
For indicating that student 2 is correct and a correct discussion of why — 1 point
Example: Student 2 is correct. Because the system is just the proton, there must be a force external to the system due to the electric field of the two spheres. That force does work on the proton which changes the kinetic energy of the proton.

© 2016 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

AP® PHYSICS 2
2016 SCORING GUIDELINES

Question 4

10 points total **Distribution of points**

(a)

i. 1 point

For indicating that $I = \mathcal{E}/R$ and $V_C = 0$ 1 point

Because there is no charge on the capacitor, there is no potential difference across it. Therefore, entire battery potential is across the resistor, so the current is that potential divided by the resistance.

ii. 1 point

For indicating that $I = 0$ and $V_C = \mathcal{E}$ 1 point

Once the capacitor is fully charged, it allows no current to pass. Because all the components are in series, there is no current at all in the circuit. With no current, there is no potential difference across the resistor, so the entire battery potential is across the capacitor.

(b)

i. 2 points

For a calculation that indicates one of the following: 1 point

- The potential difference across each capacitor in the new circuit is half that across the single capacitor in the original circuit
- The equivalent capacitance of the new circuit is one-half the capacitance of the original circuit

$U_1 = (1/2)C\mathcal{E}^2$

$U_2 = 2\left[(1/2)C(\mathcal{E}/2)^2\right]$ or $(1/2)(C/2)\mathcal{E}^2$, which both equal $C\mathcal{E}^2/4$

For correctly calculating the ratio 1 point

$U_1/U_2 = \left(C\mathcal{E}^2/2\right)/\left(C\mathcal{E}^2/4\right) = 2$

ii. 1 point

For any combination of area and spacing that is consistent with the student's answer for the ratio in part (b)(i), with a proper principle or model as support 1 point

Example: $U = (1/2)CV^2$. The potential difference across each of the single capacitors is the same. For the energy stored in the single new capacitor to be half that of the original single capacitor, the new capacitor must have half the capacitance. $C = \varepsilon_0 A/d$, so half the plate area with the same distance between the plates will accomplish this.

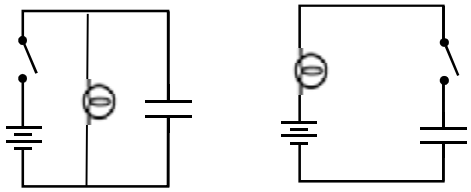
© 2016 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 4 (continued)

Distribution of points

(c) 5 points



Arrangement 1 Arrangement 2

For two correct circuit diagrams, each matched with the correct situation — arrangement 1 has lightbulb and capacitor in parallel, and arrangement 2 has them in series — 1 point

For indicating that the lightbulb is brightest when the current through it is maximum and that the capacitor eventually stops current from flowing in its branch when the potential difference across its plates is equal in magnitude to the emf of the battery (or something similar) — 1 point

Response using current

For indicating that in the series circuit (where the same current flows through both components) the most current flows right after the switch is closed and decreases as the capacitor charges

Response using potential difference

For indicating that in the series circuit (where the potential is shared) the resistor has its maximum potential difference right after the switch is closed, because the capacitor starts out uncharged (no potential difference) and then charges until it has the same potential as the battery — 1 point

For indicating that in the parallel circuit (where the current is shared between the components) the most current flows through the lightbulb a long time after the switch is closed, because the full current initially goes through the capacitor branch because it acts like a wire (very low potential difference), then ends up all through the lightbulb once the fully charged capacitor acts like an open circuit (same potential difference as battery)

For indicating that in a parallel circuit (where both components have the same potential difference) the bulb starts out with the same zero potential difference as the capacitor and ends up with the total battery potential — 1 point

For a response that has sufficient paragraph structure, as described in the published requirements for the paragraph-length response — 1 point

© 2016 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

2017

AP Physics 2: Algebra-Based

Scoring Guidelines

© 2017 The College Board. College Board, Advanced Placement Program, AP, AP Central, and the acorn logo are registered trademarks of the College Board. Visit the College Board on the Web: www.collegeboard.org.
AP Central is the official online home for the AP Program: apcentral.collegeboard.org

张老师答疑微信：15940415847

AP® PHYSICS
2017 SCORING GUIDELINES

General Notes About 2017 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. The requirements that have been established for the paragraph length response in Physics 1 and Physics 2 can be found on AP Central at https://secure-media.collegeboard.org/digitalServices/pdf/ap/paragraph-length-response.pdf.

3. 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.

4. 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 embeds the application of that equation to the problem in other work, 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*.

5. 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.

6. 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.

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

AP® PHYSICS 2
2017 SCORING GUIDELINES

Question 1

10 points total | **Distribution of points**

(a)

i. 1 point

For indicating that student Y is correct in stating that the water moves faster at point *B*, and not indicating any other aspect — 1 point

ii. 2 points

Student Y's statement that P_B is greater than P_A is not correct.

For a correct indication of how height affects pressure using the Bernoulli equation (i.e., conservation of energy principles) — 1 point

For correct indication of how the speed affects pressure using the Bernoulli equation (i.e., conservation of energy principles) — 1 point

Example: The pressure at point *B* is not greater. Because the water at *B* is moving faster and is higher than at point *A*, the kinetic energy and the gravitational potential energy terms in Bernoulli's equation are both greater. Because the sum of pressure and these energy terms is a constant, the pressure must be less.

iii. 1 point

For indicating one of the following: — 1 point

- Student Z is correct in stating that the potential energy of the water-Earth system has increased.
- Student Z is correct in stating that conservation of energy applies.
- Stating that nothing is correct or giving no response, with a justification in (iv).

iv. 1 point

For indicating that student Z is incorrect in stating that the speed is less at point *B*, not indicating any other aspect, and using continuity or the Bernoulli equation (i.e., conservation of energy principles) to show that it is greater — 1 point

OR

if third bullet for (iii) applies, indicating that work is done on the water due to the pressure difference, so the energy is not constant

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 1 (continued)

Distribution of points

(b)

i. 2 points

For a correct application of the continuity equation including substitutions — 1 point

$A_A v_A = A_B v_B$

$v_B = A_A v_A / A_B = r_A^2 v_A / r_B^2 = (2.5 \text{ cm})^2 (0.5 \text{ m/s}) / (1.5 \text{ cm})^2$

For a correct answer with units — 1 point

$v_B = 1.4 \text{ m/s}$

ii. 1 point

For an application of Bernoulli's equation to this situation and substitutions consistent with (b)(i) — 1 point

$P_A + \rho g y_A + \frac{1}{2}\rho v_A^2 = P_B + \rho g y_B + \frac{1}{2}\rho v_B^2$

$P_B = P_A + \rho g (y_A - y_B) + \frac{1}{2}\rho \left(v_A^2 - v_B^2\right)$

$P_B = 2 \times 10^5 + (1000)(10)(-5) + \frac{1}{2}(1000)\left(0.5^2 - 1.4^2\right) = 2 \times 10^5 - 50000 - 855$

$P_B = 1.5 \times 10^5 \text{ Pa}$

(c)

i. 1 point

For substituting correctly in an appropriate equation for determining the pressure — 1 point

$P = P_0 + \rho g h_A = 1 \times 10^5 \text{ Pa} + \left(1000 \text{ kg/m}^3\right)\left(10 \text{ m/s}^2\right)(6 \text{ m})$

$P = 1.6 \times 10^5 \text{ Pa}$

ii. 1 point

For indicating that the buoyant force is toward the top of the page and gravity is toward the bottom of the page, with the buoyant force longer — 1 point

Student can draw lots of pressure forces around the dot instead of one buoyant force, as long as there is no buoyant force labeled and they add up to a net buoyant force that is longer than the gravitational force.

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

AP® PHYSICS 2
2017 SCORING GUIDELINES

Question 2

12 points total | **Distribution of points**

(a)

i. 5 points

For drawing a circuit with the battery, rod, and ammeter in series (rods can be drawn to look like rods, or schematically as resistors)	1 point
For drawing the voltmeter parallel to the rod, or indicating that the setting on the power supply will be used	1 point
For measuring potential difference and current for a rod	1 point
For measuring the length and diameter of a rod	1 point
For including multiple trials with appropriate controls Examples: 1) Use one rod and apply different potential differences 2) Use different rods	1 point

ii. 2 points

For graphing appropriate quantities whose slope can be used to calculate resistance directly or indirectly	1 point
For correctly stating how the slope relates to the resistivity	1 point

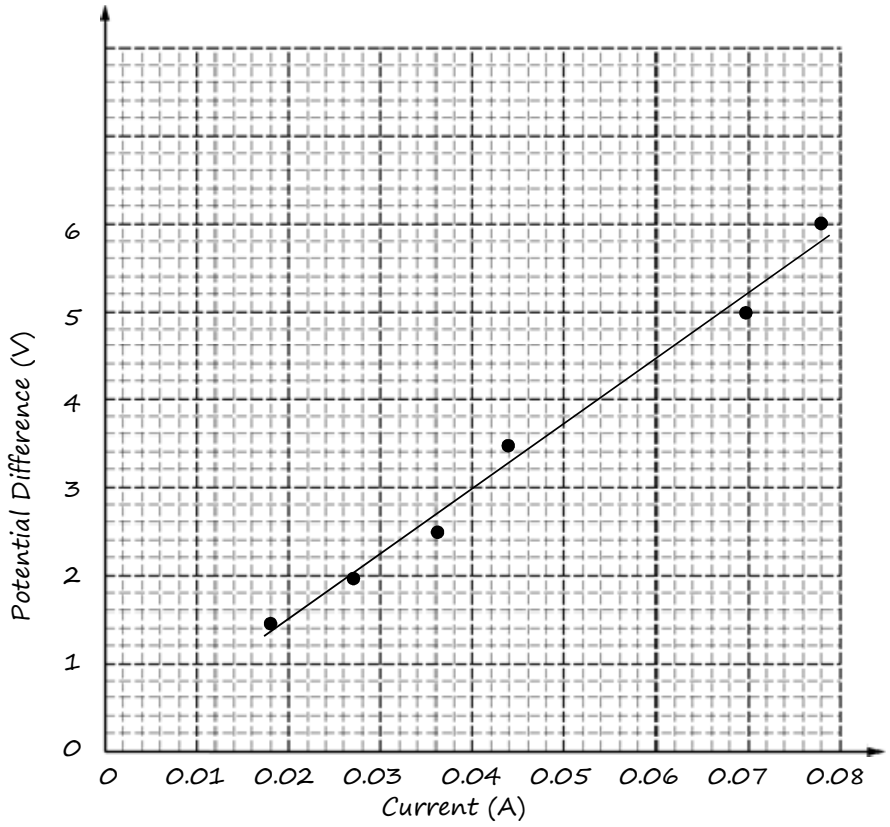
© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 2 (continued)

Distribution of points

(b) 3 points



For plotting the data on the graph with potential difference on one axis and current on the other, labeled with units, using a reasonable scale — 1 point

For a clearly shown calculation of slope from a reasonable best-fit line — 1 point

For a correct answer with units — 1 point

Acceptable range is $70 - 79\ \Omega$.

For a graph of I as a function of V, the slope should end up near $0.013\ \Omega^{-1}$ and the resistance is the inverse

For a graph of V as a function of I, the slope should end up near $74\ \Omega$ and equals the resistance

For the example shown above

$$\text{slope} = \frac{(5.8 - 2.4)\ \text{V}}{(0.078 - 0.032)\ \text{A}} = 73.9\ \Omega$$

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 2 (continued)

Distribution of points

(c)

i. 1 point

For indicating that the internal resistance of the power supply will not affect the data acquired, with correct reasoning — 1 point

Example: Because potential difference is measured across each rod, $\Delta V/I$ is not affected by the internal resistance of the battery.

ii. 1 point

For indicating either: — 1 point

The students should be concerned because a change in temperature causes a change in the resistance or resistivity.

OR

The students should not be concerned because any change in resistivity as the temperature increases is small compared to measurement error.

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

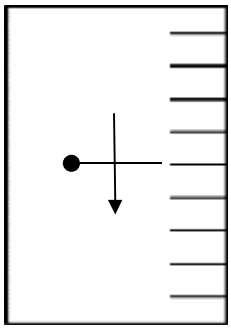
张老师答疑微信：15940415847

AP® PHYSICS 2
2017 SCORING GUIDELINES

Question 3

12 points total **Distribution of points**

(a) 2 points



For the arrow drawn upside down relative to the object 1 point
For bar/circle drawn left-to-right reversed relative to the object or consistent with an (incorrect) upright arrow 1 point

(b)

i. 1 point

For correctly showing a calculation of the focal length and a correct answer with units 1 point

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{20\text{ cm}} + \frac{1}{30\text{ cm}}$$

$$f = 12\text{ cm}$$

ii. 1 point

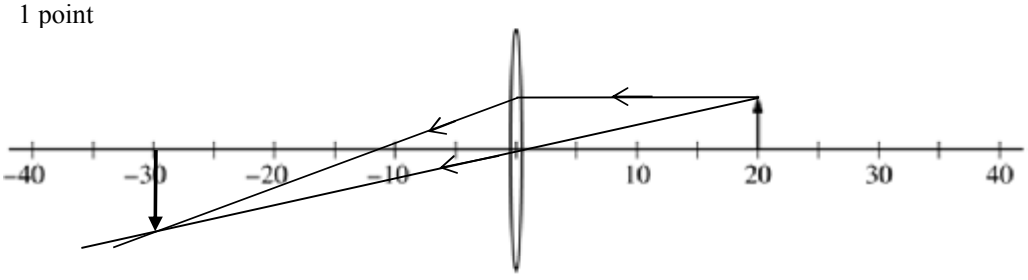
For correctly showing a calculation of the magnitude of the magnification (with or without sign) and a correct answer 1 point

$$M = d_i/d_o = 30\text{ cm}/20\text{ cm}$$

$$M = 1.5$$

(c)

i. 1 point



For two reasonably correctly drawn rays consistent with the calculated focal length, and inclusion of an inverted image 1 point

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 3 (continued)

Distribution of points

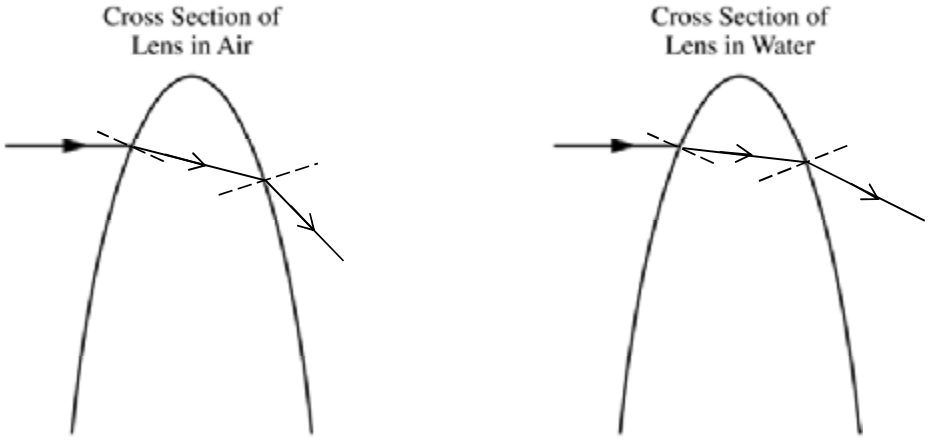
(c) (continued)

ii. 2 points

For a correct explanation of how the rays drawn relate to the focal length — 1 point
For a correct explanation of how the image relates to the magnification — 1 point
Example: The horizontal ray from the object bends to cross the axis at 12 cm from the middle of the lens, which is the focal length. The image arrow is about 1.5 times the height of the object, which is the magnification.

(d)

i. 2 points



For showing the downward refraction of the rays at each surface of the lens in air (i.e., toward the normal entering the lens and away from the normal leaving the lens) — 1 point
For the rays refracted by the lens in water at greater angles to the normal than the corresponding angles for the lens in air — i.e., less bending (can be earned even if first point was not, scoring is relative to whatever is drawn for the lens in air) — 1 point

ii. 3 points

For describing a greater focal length when the lens is in water or a comparison consistent with part (d)(i) — 1 point
For describing a larger image distance and image size or a comparison consistent with part (d)(i) — 1 point
For describing how the rays drawn in (d)(i) support the descriptions — 1 point
Example: The rays do not bend as much as they pass from water to glass as when they pass from air to glass (and vice versa). This means parallel rays coming into the lens will converge at a farther distance, so the focal length is longer. Rays from an object also will converge farther from the lens, so the new image is farther and larger.

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

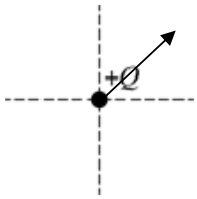
张老师答疑微信：15940415847

AP® PHYSICS 2
2017 SCORING GUIDELINES

Question 4

10 points total **Distribution of points**

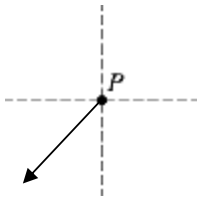
(a) 1 point



For an arrow pointing outward from the object, along a diagonal of the square and away from the object with charge $-2Q$, with no other arrows — 1 point

(b)

i. 3 points



For correctly determining magnitudes of the field from individual objects — 1 point
The fields from the $+2Q$ objects cancel. This can be implicit or explicit in the calculations.

For the $-2Q$ object, $E = 2kQ/d^2$

For the $+Q$ object, $E = kQ/d^2$

For correctly adding the individual fields — 1 point
$E = 3kQ/d^2$

For showing the correct direction on the diagram, along a diagonal of the square and toward the object with charge $-2Q$ — 1 point

ii. 1 point

For showing a correct scalar potential summation — 1 point
A final answer is not required; however, no credit is given if an incorrect final answer is included.

$V = (k/d)(+2Q + Q + 2Q - 2Q) = 3kQ/d$

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 4 (continued)

Distribution of points

(c) 5 points

For indicating that electric potential energy is the energy stored in a configuration of charged objects — 1 point

For indicating that the change in potential energy is equal to the work done by an external force to create a particular configuration — 1 point

For indicating that moving the object with $+2Q$ charge results in an increase in energy and indicating that moving the object with $+Q$ charge results in a decrease in energy (i.e., for showing understanding that moving charges of the same sign closer together increases the energy and/or moving charges of opposite sign closer together decreases the energy, with some support such as $U = kqQ/r$ or a description of doing work against forces) — 1 point

For indicating that the net result is an increase in the energy with some explanation — 1 point

For a logical, relevant, and internally consistent response that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response — 1 point

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

2018

AP Physics 2: Algebra-Based

Scoring Guidelines

© 2018 The College Board. College Board, Advanced Placement Program, AP, AP Central, and the acorn logo are registered trademarks of the College Board. Visit the College Board on the Web: www.collegeboard.org.
AP Central is the official online home for the AP Program: apcentral.collegeboard.org

张老师答疑微信：15940415847

AP® PHYSICS
2018 SCORING GUIDELINES

General Notes About 2018 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. The requirements that have been established for the paragraph-length response in Physics 1 and Physics 2 can be found on AP Central at https://secure-media.collegeboard.org/digitalServices/pdf/ap/paragraph-length-response.pdf.

3. 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.

4. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth 1 point, and a student's solution embeds the application of that equation to the problem in other work, 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 Course and Exam Description* and the *AP Physics 2: Algebra-Based Course and Exam Description*.

5. The scoring guidelines typically show numerical results using the value $g = 9.8\ \text{m/s}^2$, but the 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.

6. 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.

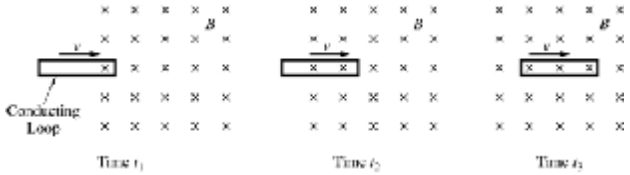
© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

AP® PHYSICS 2
2018 SCORING GUIDELINES

Question 1

10 points total **Distribution of points**



The figures above show a rectangular conducting loop at three instants in time. The loop moves at a constant speed *v* into and through a region of constant, uniform magnetic field *B* directed into the page. The magnetic field is zero outside the region.

(a) LO 2.D.1.1, SP 2.2; LO 4.E.2.1, SP 6.4
5 points

In a coherent paragraph-length response, compare the magnitude and direction of the current at times t_1, t_2, and t_3. Include an explanation of why there is or is not a current and the direction of the current if one is present. Use fundamental physics concepts and principles in your explanation.

For indicating that the currents at t_1 and t_2 have equal nonzero magnitudes and are in the same direction		1 point
For indicating that there is no current at t_3		1 point
For correctly indicating that the currents depend on the change in flux through the loop or the forces on the charges moving in the field		1 point
For correctly identifying the direction of the current as counter-clockwise and either explaining that the direction of the current generates a magnetic field that opposes the change in flux or analyzing the force on the charge carriers in each segment of the loop		1 point
For an on-topic response that has sufficient paragraph structure, as described in the published requirements for the paragraph length response		1 point

(b)

The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.



© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 1 (continued)

Distribution of points

(b) (continued)

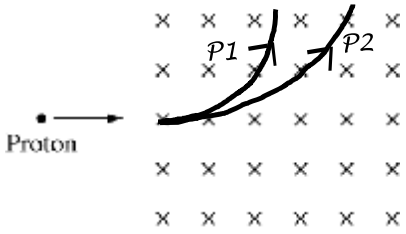
i. LO 2.D.1.1, SP 2.2
1 point

Calculate the magnitude of the force on the proton as it enters the field.

For correct substitutions into a correct expression and correct units on the final answer		1 point
$F = qvB$		
$F = \left(1.6 \times 10^{-19}\ \text{C}\right)\left(3.0 \times 10^{5}\ \text{m/s}\right)(0.03\ \text{T})$		
$F = 1.4 \times 10^{-15}\ \text{N}$		

ii. LO 2.D.1.1, SP 2.2; LO 3.B.1.4, SP 6.4; LO 3.C.3.1, SP 1.4
1 point

On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.



For drawing a curved arc through the field, curved upward where the proton enters		1 point
Anything greater than a semi-circle or a path that does not reach the edge of the field does not earn credit. Any path after exiting the field is ignored.		

iii. LO 2.D.1.1, SP 2.2; LO 3.B.1.4, SP 6.4
1 point

A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

For drawing a path with a larger radius that is consistent with answer to (b)(ii)		1 point

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 1 (continued)

Distribution of points

(b) (continued)

iv. LO 2.C.1.1, SP 6.4; LO 2.C.1.2, SP 2.2; LO 3.B.2.1, SP 1.4, 2.2
2 points

Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

For indicating a direction of the electric field that is consistent with the response to (b)(ii)		1 point
Given the correct response to (b)(ii) illustrated above, the electric field must be directed in the *-y* direction (or toward the bottom of the page)		
For equating the electric and magnetic forces and substituting into the correct expression using values consistent with the response to (b)(i)		1 point
$qE = qvB$ (Implicitly equating the calculated magnetic force to the electric force is acceptable.)		
$E = vB$		
$E = \left(3.0 \times 10^5 \text{ m/s}\right)(0.03 \text{ T})$		
$E = 9000 \text{ N/C}$		

Learning Objectives (LO)

LO 2.C.1.1: The student is able to predict the direction and the magnitude of the force exerted on an object with an electric charge q placed in an electric field E using the mathematical model of the relation between an electric force and an electric field: $\vec{F} = q\vec{E}$; a vector relation. [See Science Practices 6.4, 7.2]

LO 2.C.1.2: The student is able to calculate any one of the variables — electric force, electric charge, and electric field — at a point given the values and sign or direction of the other two quantities. [See Science Practice 2.2]

LO 2.D.1.1: The student is able to apply mathematical routines to express the force exerted on a moving charged object by a magnetic field. [See Science Practice 2.2]

LO 3.B.1.4: The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations. [See Science Practices 6.4, 7.2]

LO 3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See Science Practices 1.1, 1.4, 2.2]

LO 3.C.3.1: The student is able to use right-hand rules to analyze a situation involving a current-carrying conductor and a moving electrically charged object to determine the direction of the magnetic force exerted on the charged object due to the magnetic field created by the current-carrying conductor. [See Science Practice 1.4]

LO 4.E.2.1: The student is able to construct an explanation of the function of a simple electromagnetic device in which an induced emf is produced by a changing magnetic flux through an area defined by a current loop (i.e., a simple microphone or generator) or of the effect on behavior of a device in which an induced emf is produced by a constant magnetic field through a changing area. [See Science Practice 6.4]

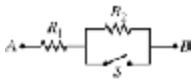
© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

AP® PHYSICS 2
2018 SCORING GUIDELINES

Question 2

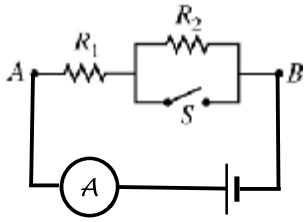
12 points total **Distribution of points**



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) LO 4.E.5.3, SP 2.2, 4.2, 5.1; LO 5.B.9.5, SP 6.4; LO 5.C.3.4, SP 6.4
4 points

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.



For a diagram with an ammeter and battery in series with the resistor combination		1 point
For indicating that the current should be measured with the switch closed and open		1 point
For correctly indicating that with the switch closed $R_1 = V/I_1$		1 point
For correctly indicating that with the switch open $R_2 = (V/I_2) - R_1$		1 point



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.

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 2 (continued)

Distribution of points

(b)

i. LO 4.E.5.2, SP 6.1, 6.4; LO 5.B.9.5, SP 6.4; LO 5.C.3.7, SP 1.4
3 points

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.

For indicating that the current through resistor 1 immediately after the switch is closed is greater than the current a long time after the switch is closed		1 point
For indicating that the current through resistor 2 is zero immediately after the switch is closed and nonzero a long time after the switch is closed		1 point
For indicating that the current through the switch is nonzero immediately after the switch is closed and zero a long time after the switch is closed		1 point

ii. LO 4.E.5.1, SP 2.2, 6.4
2 points

Calculate the values of R_1 and R_2.

For using the correct value of current and correctly calculating R_1		1 point
$9\ \text{V} = (0.9\ \text{A})R_1$		
$R_1 = 10\ \Omega$		
For using the correct value of current and correctly calculating R_2, consistent with the calculated value of R_1		1 point
$9\ \text{V} = (0.3\ \text{A})(R_1 + R_2) = (0.3\ \text{A})(10\ \Omega + R_2)$		
$R_2 = 20\ \Omega$		

iii. LO 4.E.5.1, SP 2.2; LO 5.B.9.6, SP 2.2, LO 5.C.3.7, SP 1.4, 2.2
1 point

Determine the potential difference across the capacitor a long time after the switch is closed.

For correctly calculating the potential difference across the capacitor, including correct units, consistent with part (b)(ii)		1 point
$V_C = V_{\text{battery}} - V_{\text{resistor 1}} = 9\ \text{V} - (0.3\ \text{A})(10\ \Omega)$		
$V_C = 6\ \text{V}$		

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 2 (continued)

Distribution of points

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) LO 5.B.9.7, SP 5.3
2 points

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.

For correctly explaining that the third group's measured current is smaller		1 point
For correctly indicating that the third group's value of R_1 is higher than the second group's or the resistance they will determine is actually $R_1 + r$		1 point

Learning Objectives (LO)

LO 4.E.5.1: The student is able to make and justify a quantitative prediction of the effect of a change in values or arrangements of one or two circuit elements on the currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel. [See Science Practices 2.2, 6.4]
LO 4.E.5.2: The student is able to make and justify a qualitative prediction of the effect of a change in values or arrangements of one or two circuit elements on currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel. [See Science Practices 6.1, 6.4]
LO 4.E.5.3: The student is able to plan data collection strategies and perform data analysis to examine the values of currents and potential differences in an electric circuit that is modified by changing or rearranging circuit elements, including sources of emf, resistors, and capacitors. [See Science Practices 2.2, 4.2, 5.1]
LO 5.B.9.5: The student is able to use conservation of energy principles (Kirchhoff's loop rule) to describe and make predictions regarding electrical potential difference, charge, and current in steady-state circuits composed of various combinations of resistors and capacitors. [See Science Practice 6.4]
LO 5.B.9.6: The student is able to mathematically express the changes in electric potential energy of a loop in a multiloop electrical circuit and justify this expression using the principle of the conservation of energy. [See Science Practices 2.1, 2.2]
LO 5.B.9.7: The student is able to refine and analyze a scientific question for an experiment using Kirchhoff's loop rule for circuits that includes determination of internal resistance of the battery and analysis of a non-ohmic resistor. [See Science Practices 4.1, 4.2, 5.1, 5.3]
LO 5.C.3.4: The student is able to predict or explain current values in series and parallel arrangements of resistors and other branching circuits using Kirchhoff's junction rule and relate the rule to the law of charge conservation. [See Science Practices 6.4, 7.2]
LO 5.C.3.7: The student is able to determine missing values, direction of electric current, charge of capacitors at steady state, and potential differences within a circuit with resistors and capacitors from values and directions of current in other branches of the circuit. [See Science Practice 1.4, 2.2]

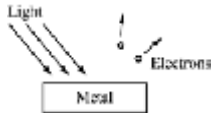
© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

AP® PHYSICS 2
2018 SCORING GUIDELINES

Question 3

12 points total **Distribution of points**

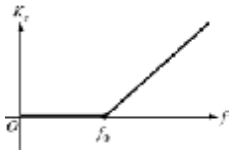


Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

i. LO 5.B.4.2, SP 1.4, 2.1, 2.2; LO 6.F.3.1, SP 6.4
3 points

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.



For indicating that A represents the slope or the rate of change of K_e as a function of f and equals Planck's constant		1 point
For indicating that $-B$ is the intercept with the K_e axis and equals the minimum energy needed to release an electron from the metal (the work function)		1 point
For indicating that f_0 is the minimum frequency that will release an electron from the metal (the cutoff or threshold frequency)		1 point

ii. LO 6.F.3.1, SP 6.4
1 point

Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

For indicating that the horizontal portion of the graph represents frequencies of light whose energy is insufficient to eject an electron		1 point

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

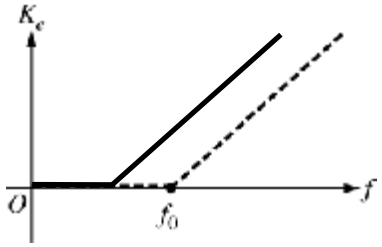
Question 3 (continued)

Distribution of points

(a) (continued)

iii. LO 6.F.3.1, SP 6.4
3 points

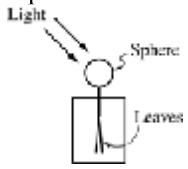
A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



For drawing a line that is parallel to the given line		1 point
For drawing the horizontal intercept on either side of f_0 with the line ending at the horizontal axis (The horizontal segment does not have to be drawn.)		1 point
For indicating that the K_e or f intercept changes because the work function or the frequency at which electrons can be emitted is different		1 point

(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. LO 1.B.1.2, SP 6.4, 7.2, LO 4.E.3.3, SP 6.4; LO 6.F.3.1, SP 6.4
2 points

Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

For indicating that the UV light causes electrons to be ejected from the electroscope		1 point
For indicating that the electroscope becomes less negatively charged, causing the leaves to move closer together		1 point

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

AP® PHYSICS 2
2018 SCORING GUIDELINES

Question 3 (continued)

Distribution of points

(b) (continued)

ii. LO 6.F.1.1, SP 6.4, 7.2, LO 6.F.3.1, SP 6.4
1 point

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.

For indicating that the green light frequency or energy per photon is too low to eject electrons		1 point

(c) LO 6.F.3.1, SP 6.4
2 points

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.

For indicating that the increase in brightness causes an increase in the number of photons in the beam or increases the amplitude of the wave		1 point
For indicating that the leaves would not separate because the energy per photon or frequency of the light remains the same		1 point
The particle nature of light (photons) must be discussed to receive full credit.		

Learning Objectives (LO)

LO 1.B.1.2: The student is able to make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits. [See Science Practices 6.4, 7.2]
LO 4.E.3.3: The student is able to construct a representation of the distribution of fixed and mobile charge in insulators and conductors. [See Science Practices 1.1, 1.4, 6.4]
LO 5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. [See Science Practices 1.4, 2.1, 2.2]
LO 6.F.1.1: The student is able to make qualitative comparisons of the wavelengths of types of electromagnetic radiation. [See Science Practices 6.4, 7.2]
LO 6.F.3.1: The student is able to support the photon model of radiant energy with evidence provided by the photoelectric effect. [See Science Practice 6.4]

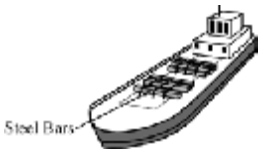
© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

AP® PHYSICS 2
2018 SCORING GUIDELINES

Question 4

10 points total **Distribution of points**



A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) LO 1.E.1.2, SP 6.4; LO 3.B.2.1, SP 1.1, 1.4, 2.2; LO 5.B.10.1, SP 2.2
4 points

Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

For equating the correct forces acting on the boat-steel system: gravity (weight) and the buoyant force		1 point
For correctly calculating the weight of the boat-steel system		1 point
$W_{system} = (M_b + N_{steel}\rho_{steel}V_{steel})g$, where N is the number of steel beams (must clearly use mass of boat)		
For correctly calculating the buoyant force		1 point
$F_b = \rho_{water}gV_b$		
For algebraic manipulation of the equations to get an expression for the number of beams consistent with the equations for weight and buoyant force		1 point
$(M_b + N\rho_{steel}V_{steel})g = \rho_{water}gV_b$		
$N = (\rho_{water}V_b - M_b)/\rho_{steel}V_{steel}$		

(b) LO 6.C.1.1, SP 6.4, 7.2; LO 6.E.1.1, SP 6.4, 7.2; LO 6.E.3.3, SP 6.4, 7.2
4 points

The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

The constructive interference is between light reflected from the air-oil interface and light reflected from the oil-water interface.		
For indicating that the green appearance is the result of interference of light from two waves		1 point
For indicating that there is a phase shift due to one of the reflections		1 point
For indicating that the wavelength of the light is different in air and oil		1 point
For indicating that there is a path-length difference of the light reflected from the two surfaces		1 point

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

张老师答疑微信：15940415847

Question 4 (continued)

Distribution of points

(c) LO 5.F.1.1, SP 2.2, 7.2
2 points

Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of $5\ \text{km/hr}$. Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

For an attempting to apply the principle of continuity		1 point
$A_{wide}v_{wide} = A_{narrow}v_{narrow}$		
$(60\ \text{m})(\text{depth})(5\ \text{km/hr}) = (30\ \text{m})(\text{depth})(v_{narrow})$		
For correctly calculating the speed		1 point
$v_{narrow} = 10\ \text{km/hr}$		

Learning Objectives (LO)

LO 1.E.1.2: The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects. [See Science Practices 4.1, 6.4]
LO 3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See Science Practices 1.1, 1.4, 2.2]
LO 5.B.10.1: The student is able to use Bernoulli's equation to make calculations related to a moving fluid. [See Science Practice 2.2]
LO 5.F.1.1: The student is able to make calculations of quantities related to flow of a fluid, using mass conservation principles (the continuity equation). [See Science Practices 2.1, 2.2, 7.2]
LO 6.C.1.1: The student is able to make claims and predictions about the net disturbance that occurs when two waves overlap. Examples should include standing waves. [See Science Practices 6.4, 7.2]
LO 6.E.1.1: The student is able to make claims using connections across concepts about the behavior of light as the wave travels from one medium into another, as some is transmitted, some is reflected, and some is absorbed. [See Science Practices 6.4, 7.2]
LO 6.E.3.3: The student is able to make claims and predictions about path changes for light traveling across a boundary from one transparent material to another at non-normal angles resulting from changes in the speed of propagation. [See Science Practices 6.4, 7.2]

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.