Multiple-Choice Answer Key

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

Answer Key for AP Physics 2
Practice Exam, Section I

Question 1: D
Question 2: B
Question 3: C
Question 4: B
Question 5: B
Question 6: C
Question 7: C
Question 8: A
Question 9: D
Question 10: B
Question 11: C
Question 12: C
Question 13: C
Question 14: D
Question 15: A
Question 16: D
Question 17: A
Question 18: B
Question 19: D
Question 20: B
Question 21: C
Question 22: A
Question 23: D
Question 24: A
Question 25: C
Question 26: D
Question 27: C
Question 28: D
Question 29: A
Question 30: D
Question 31: A
Question 32: D
Question 33: B
Question 34: A
Question 35: B
Question 36: C
Question 132: A, C
Question 133: B, C
Question 134: B, D
Question 135: A, C

Free-Response Scoring Guidelines

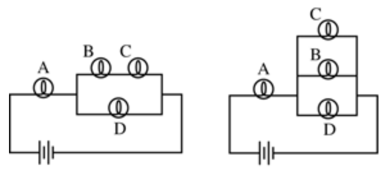
The following contains the scoring guidelines
for the free-response questions in this exam.

Question 1

10 points total **Distribution of points**

A student is performing some lab experiments with batteries, ohmic resistors, capacitors, and some identical ohmic lightbulbs.

(a) LO 4.E.5.2, SP 6.1, 6.4; LO 5.C.3.4, SP 7.2
5 points



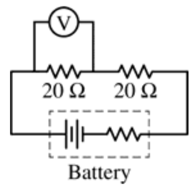
The student first connects four lightbulbs and an ideal battery as shown above in circuit 1 and observes the brightness of each lightbulb. The student then moves lightbulb C to obtain circuit 2. In a coherent, paragraph-length response, describe how the brightnesses of lightbulbs A and D in circuit 2 compare to their brightnesses in circuit 1. Support your claims with appropriate physics principles.

For indicating that moving C decreases the equivalent resistance of the circuit or increases the current through the battery		1 point
For indicating the link between brightness and current, potential difference, or power		1 point
For indicating that the brightness of A is greater, with correct reasoning		1 point
For indicating that the brightness of D is lower, with correct reasoning		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
Example: With C in the new position, the equivalent resistance of the three parallel branches is less than the two branches in circuit 1. That is added to only one bulb, so the total resistance of circuit 2 is less than circuit 1. That means the total current in circuit 2 is greater. The total current goes through A, so it’s brighter in 2. Since the parallel branches have less resistance, they have a smaller potential difference in circuit 2. That means D is dimmer.		

Question 1 (continued)

Distribution of points

(b) LO 4.E.5.2, SP 6.1, 6.4; LO 5.B.9.6, SP 2.2; LO 5.B.9.7, SP 5.3
3 points

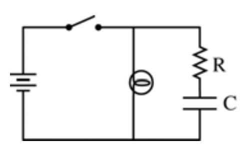


The student thinks that one of the available batteries has a nonnegligible internal resistance. The student measures the potential difference across the battery as 9 V when it is not connected to any other circuit elements. The student then connects the circuit shown above, where the battery is represented by the circuit elements in the dashed box. The voltmeter indicates that the potential difference across one resistor is 4 V. Calculate the internal resistance of the battery.

For correctly using Ohm's law to find the current in the circuit (either the numerical value or an equivalent expression embedded in another equation)		1 point
$4\text{ V} = I(20\ \Omega)$		
$I = 0.2\text{ A}$		
For a correct expression for the terminal voltage or use of the loop rule		1 point
$(9 - 4 - 4)\text{ V} = 1\text{ V}$ across the battery's internal resistance, and $R = 1\text{ V}/0.2\text{ A}$ OR $9\text{ V} = (40\ \Omega + R)(0.2\text{ A})$, $(9\text{ V})/(0.2\text{ A}) = 45\ \Omega = 40\ \Omega + R$		
For the correct answer with units		1 point
$R = 5\ \Omega$		

(c) LO 4.E.5.2, SP 6.1, 6.4; LO 5.B.9.5, SP 6.4
2 points

One of the lightbulbs is now connected with an ideal battery, an open switch, a resistor R and an initially uncharged capacitor C, as shown below. The resistance of the lightbulb and the resistor are about the same. The switch is then closed and left closed for a long time. Describe how, if at all, the brightness of the lightbulb changes during the time the switch remains closed, and explain why.



For indicating that the brightness of the bulb stays the same with an attempt at a justification		1 point
For a correct justification		1 point
Example: The potential difference across the bulb is constant since it is in parallel with the battery		

Question 1 (continued)

Learning Objectives (LO)

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. **[SP 6.1, 6.4]**

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. **[SP 6.4]**

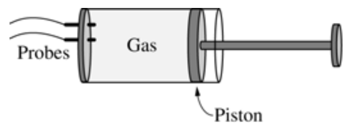
LO 5.B.9.6: The student is able to mathematically express the changes in electric potential energy of a loop in a multiloop electrical circuit and justify this expression using the principle of the conservation of energy. **[SP 2.1, 2.2]**

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. **[SP 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. **[SP 6.4, 7.2]**

Question 2

12 points total **Distribution of points**



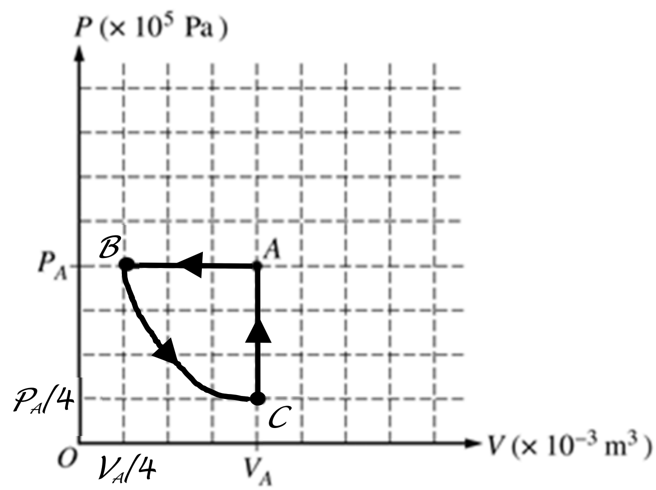
A cylinder with a movable piston contains a sample of ideal gas. A temperature probe and a pressure probe are inserted into the cylinder, as shown above. The sample of gas is taken through a three-step cycle, *ABCA*.

- In process *AB*, the volume is decreased to $1/4$ its original value while constant pressure is maintained.
- In process *BC*, the gas expands back to its original volume isothermally.
- In process *CA*, the gas returns to its original state without any work being done on or by the gas.

a)

i) LO 5.B.7.2, SP 1.1; LO 5.B.7.3, SP 2.2
5 points

On the axes below, draw a graph of pressure *P* as a function of volume *V* for the three-step process *ABCA*, labeling states *B* and *C*. The pressure and volume of state *A* are P_A and V_A, respectively. Label the axes with the values of pressure and volume for states *B* and *C* in terms of P_A and V_A.



For a horizontal line to the left of *A*, that stops at $V_A/4$		1 point
For a concave up curve representing an isotherm for process *BC* (does not have to go through all the right points between *B* and *C*)		1 point
For a vertical line for *CA*		1 point
For locating *C* such that $P_C = P_A/4$		1 point
For labeling axes and points (scaling of grid doesn't matter here, as long as labels are logical with respect to *A*)		1 point
Applying this scheme, if *B* is to the right of *A* you cannot earn the point for isotherm but can still get the point for the vertical line.		

Question 2 (continued)

Distribution of points

a) (continued)

ii) LO 5.B.7.1, SP 6.4; LO 5.B.7.3, SP 1.4, 2.2
3 points

For process *BC*, is energy added to the gas by heating or removed from the gas by cooling? Support your claim using physics principles.

For recognizing that $\Delta U = 0$ because the process is isothermal		1 point
For recognizing that the gas loses energy via work		1 point
For using the first law of thermodynamics or conservation of energy with above two ideas to get a consistent answer for the energy transfer		1 point
Any appropriate sign convention can be used when applying the first law.		

(b) LO 4.C.3.1, SP 6.4
2 points

For process *CA*, is the net flow of energy into the gas or out of the gas? Explain your reasoning using physics principles. Describe one method by which this flow of energy could be accomplished in the laboratory.

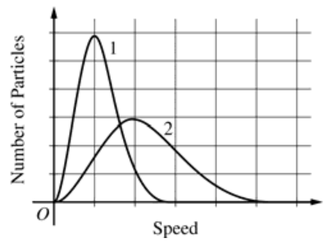
For correctly justifying that the net flow of energy is into the gas		1 point
For a correct procedure to accomplish process *CA* experimentally that is consistent with the heat flow direction stated		1 point
Example: By the ideal gas law the temperature increases and thus the internal energy, so energy must be added. This can be accomplished by fixing the piston and placing the cylinder in a warm bath.		

Question 2 (continued)

Distribution of points

(c) LO 7.A.2.2, SP 7.1; LO 7.A.3.3, SP 5.1
2 points

Curves 1 and 2 below show the distributions of particle speeds when the sample of gas is in two of the states, with curve 1 a state that occurs before curve 2 as the gas goes through the cycle. Which states correspond to curve 1 and 2? Support your claim using physics principles.



For identifying the curves with the states consistent with previous responses		1 point
Given correct previous responses, curve 1 is state *C* and/or *B* and curve 2 is state *A*.		
For a correct justification		1 point
Example: Curve 1 represents a lower temperature since the distribution has a lower average speed. Since *B* and *C* are on the same isotherm they have the same temperature so it cannot be these two states. Using $PV = nRT$, state *A* has a higher temperature than *B* and *C*. Since the lower temperature occurs first, curve 1 is state *C* and curve 2 is state *A*.		
Note: Students can be awarded the second point for clearly indicating an understanding that the speed distribution shown in Curve 2 relates to a greater temperature or internal energy than Curve 1.		

Learning Objectives (LO)

LO 4.C.3.1: The student is able to make predictions about the direction of energy transfer due to temperature differences based on interactions at the microscopic level. **[SP 6.4]**

LO 5.B.7.1: The student is able to predict qualitative changes in the internal energy of a thermodynamic system involving transfer of energy due to heat or work done and justify those predictions in terms of conservation of energy principles. **[SP 6.4, 7.2]**

LO 5.B.7.2: The student is able to create a plot of pressure versus volume for a thermodynamic process from given data. **[SP 1.1]**

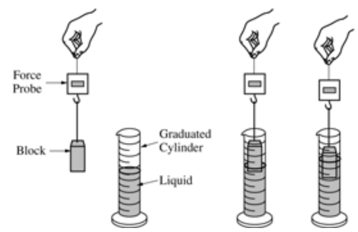
LO 5.B.7.3: The student is able to use a plot of pressure versus volume for a thermodynamic process to make calculations of internal energy changes, heat, or work, based upon conservation of energy principles (i.e., the first law of thermodynamics). **[SP 1.1, 1.4, 2.2]**

LO 7.A.2.2: The student is able to connect the statistical distribution of microscopic kinetic energies of molecules to the macroscopic temperature of the system and to relate this to thermodynamic processes. **[SP 7.1]**

LO 7.A.3.3: The student is able to analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law $PV = nRT$. **[SP 5.1]**

Question 3

12 points total **Distribution of points**

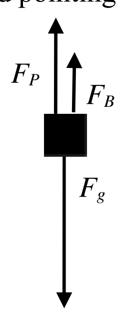


Two groups of students are given samples of the same unknown liquid and are asked to identify the liquid. The first group decides to do this by determining its density ρ_L . The students pour a volume V_i of the liquid into a graduated cylinder. They then hang a long solid block of mass m_b from a force probe and lower the block partially into the liquid, as shown above. The students record the reading on the force probe and the volume reading V_f on the graduated cylinder for various amounts of the block lowered into the liquid.

(a)

i) LO 3.A.2.1, SP 1.1
2 points

On the square below, which represents the block, draw and label the forces (not components) that are exerted on the block when it is stationary and partially submerged in the liquid. Each force must be represented by a distinct arrow starting on, and pointing away from, the square.



For one correct force pointing toward the top of the page with a reasonable label		1 point
For a second correct force toward the top of the page and the weight toward the bottom of the page, with reasonable labels, and no extraneous forces		1 point

ii) LO 1.E.1.2, SP 4.1; LO 3.A.2.1, SP 1.1; LO 5.B.10.1, SP 2.2
2 points

Derive an equation for the force probe reading F_p in terms of ρ_L , m_b , V_i , V_f , and physical constants, as appropriate.

For applying Newton's second law in a manner consistent with the forces drawn in a(i)		1 point
$F_P + F_B = F_g$ and $F_g = m_b g$, therefore $F_P = m_b g - F_B$		
For a correct equation for F_p using the expression for buoyant force		1 point
$F_P = m_b g - \rho_L g\left(V_f - V_i\right)$, where V_i is the initial volume of water		

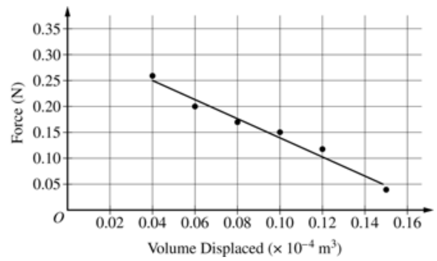
Question 3 (continued)

Distribution of points

(b)

The data the students collected and the graph they plotted are shown below. The initial volume V_i of liquid in the cylinder is $1.00 \times 10^{-4}\ \text{m}^3$.

Volume Reading $V_f\ \left(\times 10^{-4}\ \text{m}^3\right)$	1.04	1.06	1.08	1.1	1.12	1.15
Volume Displaced $\Delta V\ \left(\times 10^{-4}\ \text{m}^3\right)$	0.04	0.06	0.08	0.10	0.12	0.15
Force Probe Reading (N)	0.26	0.20	0.17	0.15	0.12	0.04



i) LO 1.E.1.2, SP 4.1; LO 3.A.2.1, SP 1.1; LO 5.B.10.1, SP 2.2
2 points

State the physical meaning of the slope of the line and its intercept with the vertical axis.

For correctly identifying the slope of the best fit line as the density of the liquid times g, with or without reference to the negative sign		1 point
For correctly identifying the vertical intercept as the weight of the object		1 point

ii) LO 1.E.1.2, SP 4.1; LO 5.B.10.1, SP 2.2
2 points

Use the graph to calculate the density of the liquid.

For correct calculation of the slope value using two points from the best fit line (not data points since none are on the best-fit line)		1 point
For correctly using the slope to determine the density of the object (no units needed)		1 point
$\text{slope} = \dfrac{(0.25 - 0.05)\ \text{N}}{(0.04 - 0.15)\left(\times 10^{-4}\ \text{m}^3\right)} = -1.8 \times 10^4\ \text{N/m}^3$		
$\rho_L = \left\|\text{slope}/\left(9.8\ \text{m/s}^2\right)\right\| = 1.9 \times 10^3\ \text{kg/m}^3$ (or $1.8 \times 10^3\ \text{kg/m}^3$ using $g = 10\ \text{m/s}^2$)		

Distribution of points

(b) (ii) (continued)

Alternate Solution	*Alternate Points*
For using the intercept with the vertical axis to determine $m_b g$ *, then using any other point on the line with the equation from part (a)(ii)*	*1 point*
When $\Delta V = 0$, $F_p = 0.325\text{ N} = m_b g$	
From part (a)(ii): $F_P = m_b g - \rho_L g\left(V_f - V_i\right)$	
$\rho_L = \left(m_b g - F_P\right)/g\left(V_f - V_i\right)$	
For correctly substituting values for one point on the line to determine the density of the object (no units needed)	*1 point*
Example:	
$\rho_L = \left(0.325\text{ N} - 0.10\text{ N}\right)/\left(9.8\text{ m/s}^2\right)\left(0.12\times10^{-4}\text{ m}^3\right) = 1.9\times10^3\text{ kg/m}^3$	

The students in the second group decide to determine the index of refraction of the liquid. They have a laser pointer and a transparent, thin-walled rectangular container to hold the liquid. They also have access to common laboratory equipment.

(c) LO 6.E.3.1, SP 4.1, 5.1, 5.2, 5.3
4 points

Describe an experimental procedure this group could use to determine the index of refraction of the unknown liquid. In your description include the measurements to be taken. Also include the corresponding equipment needed. Sketch a diagram showing the experimental setup with labels corresponding to the measurements you indicated. Describe how the measurements will be used to calculate the index of refraction of the liquid.

For a diagram with a non-normal incident ray, and the angle of incidence and angle of refraction labeled in relationship to the normal line (or other angles or measurements that allow calculations equivalent to using these angles)		1 point
For a reasonable method to determine the angles based on measurements and explanation of what equipment is needed to make the measurements		1 point
Examples: use a protractor and measure the angles of incidence and refraction (from incident laser ray to normal); create a right angle triangle and determine the value of the angles of incidence and refraction using appropriate trigonometry		
For a reasonable explanation of how the index of refraction can be determined from the experimental data using Snell's law		1 point
For reasonable evidence of multiple trials, either more than two measurements at the same angle or measurements at more than two angles		1 point

Question 3 (continued)

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. **[SP 4.1, 6.4**]

LO 3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. **[SP 1.1**]

LO 5.B.10.1: The student is able to use Bernoulli's equation to make calculations related to a moving fluid. **[SP 2.2**]

LO 6.E.3.1: The student is able to describe models of light traveling across a boundary from one transparent material to another when the speed of propagation changes, causing a change in the path of the light ray at the boundary of the two media. **[SP 1.1, 1.4]**

Question 4

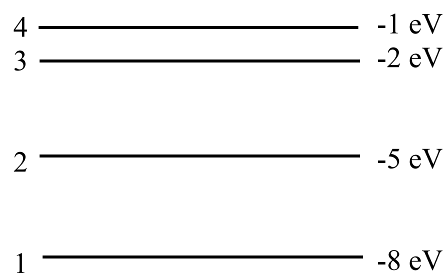
10 points total **Distribution of points**

The allowed energy levels of a hypothetical atom have principal quantum numbers $n = 1, 2, 3$, and 4 and energies of -8 eV, -5 eV, -2 eV, and -1 eV.

(a)

i) LO 1.A.4.1, SP 1.1
1 point

Draw the energy-level diagram for the atom. Label each level with the appropriate energy and principal quantum number.



For a correct energy level diagram that includes the four given states, with -8 eV at one end of the scale and -1 eV at other, and correctly labeled with quantum numbers ($n = 1$ is -8 eV etc.) ($n = \infty$ can also be included.)		1 point

ii) LO 6.F.3.1, SP 6.4
2 points

Calculate the frequency of a photon that will excite the atom from its ground state to the $n = 3$ state.

For correctly calculating the energy difference between the ground state and the $n = 3$ state		1 point
$\Delta E = \left[-2\text{ eV} - \left(-8\text{ eV}\right)\right] = 6\text{ eV}$		
For correctly calculating the frequency of the incoming photon, using consistent units for Planck's constant		1 point
$\Delta E = hf$		
$f = \Delta E/h = \left(8\text{ eV} - 2\text{eV}\right)\Big/\left(4.14 \times 10^{-15}\text{ eV}\bullet\text{s}\right)$		
$f = 1.45 \times 10^{15}$ Hz		

Question 4 (continued)

Distribution of points

(a) (continued)

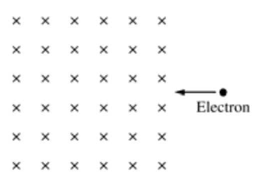
iii) LO 5.B.4.2, SP 2.2; LO 6.F.3.1, SP 6.4
3 points

A photon of wavelength 124 nm is incident on the atom and causes an electron in the ground state to be ejected from the atom. Neglecting relativistic effects, calculate the speed of the electron.

For correctly calculating the energy of the incoming photon		1 point
$E = hc/\lambda = \left(1.24 \times 10^3 \text{ eV}\bullet\text{nm}\right)/\left(124 \text{ nm}\right) = 10 \text{ eV}$		
For determining the energy available as kinetic energy, consistent with photon energy		1 point
$K = 10 \text{ eV} - 8 \text{ eV} = 2 \text{ eV}$		
For calculating the speed of the ejected electron, with units, consistent with previous work		1 point
$K = (1/2)mv^2$		
$v = \sqrt{2K/m} = \sqrt{2(2\text{eV})\left(1.6 \times 10^{-19} \text{ J/eV}\right)/\left(9.11 \times 10^{-31} \text{ kg}\right)}$		
$v = 8.4 \times 10^5 \text{ m/s}$		

(b)

The ejected electron then enters a region of space that contains a constant, uniform magnetic field directed into the plane of the page. The electron is moving to the left in the plane of the page when it enters the field.



i) LO 2.D.1.1, SP 2.2; LO 3.C.3.1, SP 1.4
2 points

On the figure above, draw a possible path for the electron as it travels through the region of the magnetic field. Describe what happens to the speed of the electron as it passes through the field, and explain why this happens.

For drawing a curved arc through the field, curved upward where the electron enters		1 point
Anything greater than a semi-circle or a path that does not reach the edge of the field does <u>not</u> earn credit. Any path after exiting the field is ignored.		
For indicating that the speed does not change with a correct reason		1 point
Examples: the force is always perpendicular to the velocity; the force acts as a centripetal force; no work is done		

Question 4 (continued)

Distribution of points

(b) (continued)

ii) LO 2.C.1.1, SP 6.4; LO 3.B.1.4, SP 6.4, 7.2; LO 3.B.2.1, SP 1.1, 1.4
2 points

To make the electron travel in a straight line to the left through the magnetic field, an electric field can be applied in the region. What is the direction of the required electric field? Justify your choice based on physics principles.

For indicating that the electric force on the electron must be opposite the direction of the force of the magnetic field (credit awarded for specific direction consistent with path drawn)		1 point
For indicating that the electric field should be in the opposite direction to the electric force on the electron (credit awarded for specific direction consistent with path drawn)		1 point

Learning Objectives (LO)

LO 1.A.4.1: The student is able to construct representations of the energy-level structure of an electron in an atom and to relate this to the properties and scales of the systems being investigated. **[SP 1.1, 7.1**]

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.**[SP 6.4, 7.2**]

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. **[SP 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. **[SP 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. **[SP 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. **[SP 1.4]**

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. **[SP 1.4, 2.1, 2.2]**

LO 6.F.3.1: The student is able to support the photon model of radiant energy with evidence provided by the photoelectric effect. **[SP 6.4**]

Scoring Worksheet

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

2018 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
63-80	5
54-62	4
38-53	3
19-37	2
0-18	1

Question Descriptors and Performance Data

The following contains tables showing the content assessed, the correct answer, and how AP students performed on each question.

Multiple-Choice Questions

Question	Learning Objectives	Essential Knowledge	Science Practice	Key	% Correct
1	2-6.A.2.2	6.A.2	6.4|7.2	D	90
2	2-2.C.4.1	2.C.4	6.4|7.2	B	81
3	2-5.C.2.3	5.C.2	4.1	C	78
4	2-5.C.3.4|2-5.C.3.5	5.C.3|5.C.3	6.4|1.4|2.2	B	77
5	2-5.B.7.3	5.B.7	1.1|2.2	B	80
6	2-7.A.1.2	7.A.1	1.4|2.2	C	51
7	2-5.B.7.1	5.B.7	6.4	C	63
8	2-6.B.3.1	6.B.3	1.5	A	84
9	2-3.B.1.4|2-3.C.4.1	3.B.1|3.C.4	6.4|7.2|6.1	D	67
10	2-4.E.4.3	4.E.4	5.1	B	74
11	2-3.B.1.4|2-3.C.3.1	3.B.1|3.C.3	6.4|7.2|1.4	C	65
12	2-6.E.5.1|2-6.E.5.2	6.E.5|6.E.5	1.4|5.1|5.3	C	71
13	2-2.C.5.1	2.C.5	1.1	C	82
14	2-2.C.1.1	2.C.1	6.4	D	64
15	2-2.C.5.2	2.C.5	2.2	A	70
16	2-5.G.1.1	5.G.1	6.4	D	80
17	2-6.E.4.1|2-6.E.4.2	6.E.4|6.E.4	5.1|5.3|1.4|2.2	A	70
18	2-6.E.3.3|2-6.E.5.1	6.E.3|6.E.5	6.4|7.2|1.4	B	67
19	2-1.E.1.1|2-3.B.1.4|2-3.B.2.1	1.E.1|3.B.1|3.B.2	6.4|6.4|7.2|1.1|1.4	D	88
20	2-3.B.2.1	3.B.2	1.1|1.4|2.2	B	41
21	2-4.C.4.1	4.C.4	2.2|2.3|7.2	C	58
22	2-5.B.9.5|2-5.B.9.6	5.B.9|5.B.9	6.4|2.2	A	60
23	2-5.B.4.1|2-7.A.2.1	5.B.4|7.A.2	6.4|7.1	D	62
24	2-4.C.4.1|2-5.B.11.1|2-6.F.3.1	4.C.4|5.B.11|6.F.3	2.2|7.2|2.2|7.2|6.4	A	29
25	2-5.B.5.4	5.B.5	6.4|7.2	C	61
26	2-4.E.5.2|2-5.C.3.5	4.E.5|5.C.3	6.4|1.4|2.2	D	45
27	2-4.E.3.1|2-4.E.3.3	4.E.3|4.E.3	6.4|1.1|1.4|6.4	C	53
28	2-5.B.9.7|2-5.B.9.8	5.B.9|5.B.9	5.1|1.5	D	37
29	2-5.B.10.3	5.B.10	2.2	A	41
30	2-4.E.3.1|2-4.E.3.5	4.E.3|4.E.3	6.4|3.2|5.3	D	52
31	2-6.F.3.1	6.F.3	6.4	A	47
32	2-6.C.3.1	6.C.3	1.4|6.4	D	43
33	2-4.E.2.1	4.E.2	6.4	B	51
34	2-5.B.8.1	5.B.8	1.2	A	55
35	2-4.E.4.1	4.E.4	6.4	B	47
36	2-1.B.1.1|2-5.B.9.5|2-5.B.9.6	1.B.1|5.B.9|5.B.9	6.4|6.4|2.2	C	38

Question	Learning Objectives	Essential Knowledge	Science Practice	Key	% Correct
131	2-4.E.3.4	4.E.3	1.1|1.4|6.4	A,C	61
132	2-7.A.2.1	7.A.2	7.1	B,C	44
133	2-2.D.1.1|2-2.E.3.1|2-3.C.3.2	2.D.1|2.E.3|3.C.3	2.2|2.2|5.1	B,D	26
134	2-7.C.2.1	7.C.2	1.4	A,C	26

Free-Response Questions

Question	Learning Objectives	Essential Knowledge	Science Practices	Mean Score
1	2-4.E.5.2|2-5.B.9.5|2-5.B.9.6|2-5.B.9.7|2-5.C.3.4	4.E.5|5.B.9|5.B.9|5.B.9|5.C.3	6.1|6.4|6.4|2.2|5.3|6.4|7.2	4.55
2	2-4.C.3.1|2-5.B.7.1|2-5.B.7.2|2-5.B.7.3|2-7.A.2.1|2-7.A.2.2	4.C.3|5.B.7|5.B.7|25.B.7|7.A.2|7.A.2	6.4|6.4|1.1|1.4|2.2|7.1|7.1	6.17
3	2-1.E.1.2|2-3.A.2.1|2-5.B.10.1|2-6.E.3.2	1.E.1|3.A.2|5.B.10|6.E.3	4.1|1.1|2.2|4.1|5.1|5.2|5.3	6.23
4	2-1.A.4.1|2-2.C.1.1|2-2.D.1.1|2-5.B.4.2|2-6.F.3.1	1.A.4|2.C.1|2.D.1|5.B.4|6.F.3	1.1|7.1|6.4|7.2|2.2|2.2|6.4	4.70

AP Physics 2: Algebra-Based

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