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Multiple-Choice Answer Key

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

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Answer Key for AP Physics 2 Practice Exam, Section I

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

*Item 3 was not used in scoring.

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Free-Response Scoring Guidelines

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

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Question 1

10 points total **Distribution of points**

(a)

i) 1 point

For indicating that $V_1 = V_2$ and giving a correct explanation — 1 point

Examples:

- When the switch is closed, charge flows to eliminate the initial potential difference between the spheres.
- There is no source of potential besides the spheres, and they are now effectively one conductor.

ii) 2 points

For using the fact that $V_1 = V_2$ (or whatever relationship was indicated in part i) — 1 point

For equating the expressions for potential, $kQ_1/r_1 = kQ_2/r_2$, and indicating that since $r_1 > r_2$, $Q_1 > Q_2$ (or logic consistent with answer to part i) — 1 point

Alternate Solution — *Alternate points*

For indicating that the larger sphere has more surface area — *1 point*

For indicating that a greater surface area will hold more charge — *1 point*

iii) 1 point

For combining $E = kQ/r^2$ and $V = kQ/r$ and using $V_1 = V_2$ and $r_1 > r_2$ to show that $E_1 < E_2$ (or logic consistent with answer to part i) — 1 point

Alternate solution — *Alternate points*

Since the fields are just outside the spheres, $E \approx \sigma/\varepsilon_0$ *. Letting* $r_1 = cr_2$*, we have* — *1 point*

$Q_1 = cQ_2$ *. Then* $\sigma_1 = Q_1/4\pi r_1^2 = cQ_2/4\pi(cr_2)^2 = \sigma_2/c$ *. So* $\sigma_1 < \sigma_2$ *and* $E_1 < E_2$ *.*

(b) 3 points

For any indication that when the spheres are released, the electric potential energy is converted into kinetic energy of the spheres — 1 point

For any indication that momentum of the spheres must be conserved — 1 point

For both correct equations — 1 point

$kQ_1Q_2/D = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

$0 = m_1\vec{v}_1 + m_2\vec{v}_2$ or $m_1v_1 = m_2v_2$

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Question 1 (continued)

Distribution of points

(c)

i) 1 point

For indicating that spheres 1 and 3 have a positive charge, which is always true — 1 point
If spheres 1 and 2 are well separated, all three spheres will ultimately have a positive charge. If the student assumes spheres 1 and 2 are close enough that charging by induction can occur, sphere 2 might end up with positive, zero, or negative charge depending on the size and placement of sphere 3 relative to sphere 2.

ii) 2 points

For indicating that charge on sphere 2 is split between spheres 2 and 3 when they come into contact, which implies that $Q_1 > Q_3$ since it was shown that $Q_1 > Q_2$ — 1 point

For indicating that sphere 3 has more charge than sphere 2 because it is larger, which justifies the ranking of $Q_1 > Q_3 > Q_2$ (or some correct reasoning relating the charges on spheres 1 and 3 based on the answer to part (a) and part (c)i — 1 point

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Question 2

12 points total | **Distribution of points**

(a) 3 points

For indicating that the volume of water in the pool is given by $V = A_{\text{hose}}vt$ — 1 point

For combining the volume expression with the appropriate expression for total pressure — 1 point

$P_{tot} = P_{\text{atm}} + \rho gh$

$P_{tot} = P_{\text{atm}} + \rho g A_{\text{hose}} vt / A_{\text{pool}}$

$\rho g A_{\text{hose}} vt = \left(1 \times 10^{3}\ \text{kg/m}^3\right)\left(10\ \text{m/s}^2\right)\pi\left(3 \times 10^{-2}\ \text{m}\right)^2 (2.00\ \text{m/s})(3\ \text{hr})(3600\ \text{s/hr})$

$= 6.1 \times 10^{13}\ \text{Pa}\cdot\text{m}^2$

$A_{\text{pool}} = (10.0\ \text{m})(8.00\ \text{m}) = 80.0\ \text{m}^2$

$P_{tot} = 1.01 \times 10^{5}\ \text{Pa} + \left(6.1 \times 10^{13}\ \text{Pa}\cdot\text{m}^2\right)/80.0\ \text{m}^2$

For the correct numerical answer with units — 1 point

$P_{tot} = 1.09 \times 10^{5}$ Pa (or 1.08×10^{5} Pa using atmospheric pressure from the table of information)

(b) 1 point

For indicating that the buoyant force stays the same with a correct justification — 1 point

Examples:

The buoyant force on the ball depends only on the amount of water displaced by the ball which does not change as long as the ball is floating.

Since the ball is moving up at constant speed as the pool fills, the net force on it is zero. Gravity and the buoyant force are the vertical forces, gravity is constant, and so the buoyant force must also be constant.

(c)

i) 1 point

For indicating that the pool fills at the same rate because mass is conserved or the volume flow rate stays the same $(A_1 v_1 = A_2 v_2)$ — 1 point

Example: Mass is conserved, and since the water is a non-compressible fluid, the volume flow rate of the water leaving the nozzle is the same as the rate at which it left the bare hose. So the pool will not fill faster.

ii) 2 points

For using the continuity equation $A_{\text{hose}} v_{\text{hose}} = A_{\text{nozzle}} v_{\text{nozzle}}$ to calculate that water leaves the nozzle at 8 m/s — 1 point

For explaining the fill time remains constant despite the faster speed by referring to the conservation principle used in part (c)(i) — 1 point

Example: Although the water speed through the nozzle is greater, the area is smaller so that the volume of water that flows per time remains constant.

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Question 2 (continued)

Distribution of points

(d)

i) 2 points

For indicating that the water exerts a buoyant force on the person that is equal and opposite to the force exerted by gravity (Newton's 2nd Law) — 1 point

For using Newton's second and third laws to explain how the weight of the person causes an additional force on the bottom of the pool — 1 point

Example: The person exerts a force on the water that is equal and opposite to the buoyant force exerted by the water on the person (Newton's 3rd Law). This means that the bottom of the pool must exert an additional force on the water to maintain it at rest, and by Newton's third law the water is thus exerting a greater force on the bottom of the pool.

ii) 1 point

For indicating that the force would not be different, with an explanation that in both cases the total mass is being supported by the bottom of the pool — 1 point

(e) 2 points

For indicating that pressure of a fluid is exerted in all directions — 1 point

For indicating that since the force is greater (as argued in (d)(i)) then the pressure is greater. — 1 point

Alternate solution — *Alternate points*

For indicating the depth of the water increases due to the displacement by the floating person — *1 point*

For indicating the pressure on the sides is greater due to the increased water depth — *1 point*

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Question 3

12 points total | **Distribution of points**

(a) 2 points

For electrical energy input ΔE correctly expressed in terms of a combination of ΔV, I, and t — 1 point

$\Delta E = I\Delta Vt$

For equating the electrical energy input to the energy of the gas expressed in terms of temperature, and an attempt to solve for ΔT — 1 point

$I\Delta Vt = 5/2\, Nk_B\Delta T$

$\Delta T = 2\Delta VIt/5Nk_B$

(b) 4 points

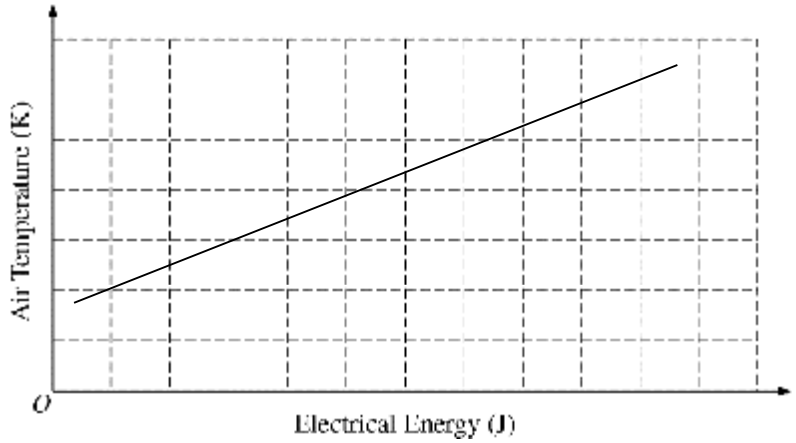
For a valid description of the setup and procedure, including a diagram — 1 point

For measuring current and potential difference, with symbols defined as needed — 1 point

For measuring the temperature change of the air, with a symbol defined as needed — 1 point

For a description of how the measurements will be used to calculate the energy — 1 point

(c) 1 point



For a line with a positive slope and a positive temperature intercept (the line would not extend to the origin, because the air would initially be at ambient temperature) — 1 point

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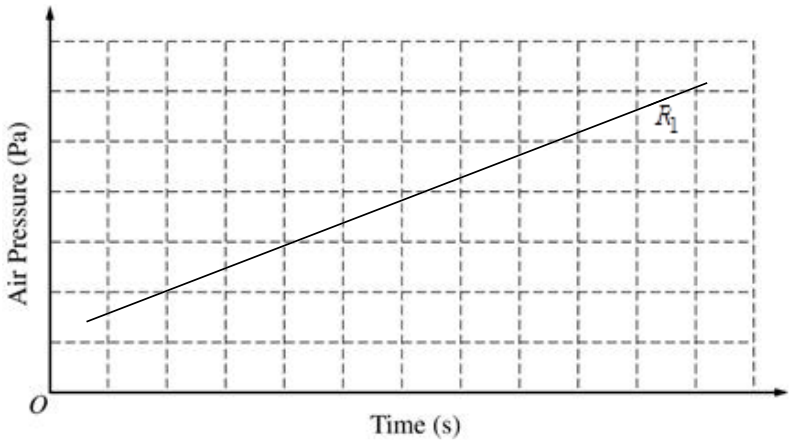
Question 3 (continued)

Distribution of points

(d)

i) 2 points

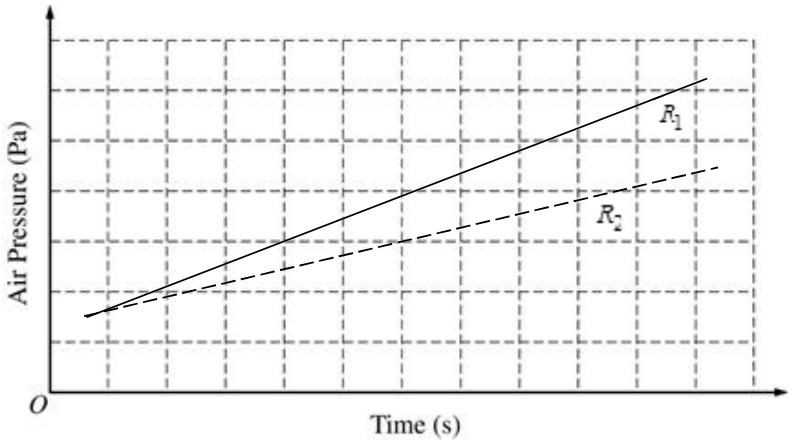


For a correct graph with positive slope and positive pressure intercept, or a graph consistent with the graph in part (c) — 1 point

For a correct explanation — 1 point

Example: Since the gas is ideal, $PV = nRT$ applies. Volume is constant, so pressure will rise in direct proportion to temperature. The power dissipated by the resistor is constant, so the temperature rises at a steady rate. The line does not go through zero because the lowest temperature is the nonzero temperature of the surrounding air.

ii) 2 points



For a second graph with a clear indication that R_2 has the smaller slope, or for a graph consistent with the graph in part (d)i that begins with a smaller slope — 1 point

For a correct explanation — 1 point

Example: A longer resistor means greater resistance. Since power is V^2/R and the potential difference is the same, the temperature and thus the pressure rise more slowly with time.

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Question 3 (continued)

		Distribution of points
(e)	1 point	
	For an indication that the new graph will have a different slope, and with no indication that the shape of the new graph would be different	1 point

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Question 4

10 points total | **Distribution of points**

(a) 5 points

For indicating that electrons can have wave properties — 1 point
For indicating that the wavelength of the electron can be about the same size as the spacing in the crystal — 1 point
For indicating that the evenly spaced pattern of atoms in the crystal acts like slits — 1 point
For indicating that the difference in path lengths that produce the constructive and destructive interference pattern can be used to determine the crystal spacing of the atoms in the crystal — 1 point
For a response that has sufficient paragraph structure, as described in the published requirements for the paragraph length response — 1 point

(b)

i) 1 point

For using appropriate expression(s) with correct substitutions to calculate the energy of the x-rays — 1 point

$E = hf$ and $\lambda = c/f$, so $E = hc/\lambda$

$E = 1.24 \times 10^{3}$ eV•nm/8.30 nm or 1.99×10^{-25} J•m/8.30×10^{-9} m

$E = 149$ eV or 2.40×10^{-17} J

ii) 2 points

For converting the electron energy to joules and using the expression for kinetic energy to calculate the speed or momentum of the electrons (Point is earned for correct setup; numerical answer need not be correct) — 1 point

$K = 1/2\, mv^2$ or $K = p^2/2m$

$v = \sqrt{2K/m}$ or $p = \sqrt{2mK}$

$v = \sqrt{2(100 \text{ eV})\left(1.6 \times 10^{-19} \text{ J/eV}\right)/\left(9.11 \times 10^{-31} \text{ kg}\right)} = 5.9 \times 10^{6}$ m/s or

$p = \sqrt{2\left(9.11 \times 10^{-31} \text{ kg}\right)(100 \text{ eV})\left(1.6 \times 10^{-19} \text{ J/eV}\right)} = 5.40 \times 10^{-24}$ kg•m/s

For using the speed or momentum to calculate the de Broglie wavelength of the electrons (Point is earned for correct setup; numerical answer need not be correct) — 1 point

$\lambda = h/(mv)$ or h/p

$\lambda = 6.63 \times 10^{-34}$ J•s/$\left(9.11 \times 10^{-31} \text{ kg}\right)\left(5.9 \times 10^{6} \text{ m/s}\right)$ or

6.63×10^{-34} J•s/5.40×10^{-24} kg•m/s

$\lambda = 0.12$ nm

Both points are earned if the equations are combined algebraically and then a single numerical calculation is performed.

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Question 4 (continued)

	Distribution of points
iii) 2 points	
For indicating that the x-ray wavelength is much larger than the crystal spacing and will not be diffracted by the crystal	1 point
For indicating that the electron beam wavelength is on the order of the size of the crystal spacing, so a diffraction pattern will appear, or an answer consistent with part (b)i	1 point

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Scoring Worksheet

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

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2016 AP Physics 2 Scoring Worksheet

Section I: Multiple Choice

_____	× 1.0256 =	_____
Number Correct (out of 39*)		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
54-80	5
44-53	4
30-43	3
18-29	2
0-17	1

*Although 40 multiple-choice items were administered in Section I, item 3 was not used in scoring.

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Question Descriptors and Performance Data

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

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2016 AP Physics 2: Algebra-Based
Question Descriptors and Performance Data

Multiple-Choice Questions

Question	Learning Objectives	Essential Knowledge	Science Practice	Key	% Correct
1	2-4.C.3.1	4.C.3	6.4	D	98
2	2-4.E.3.3	4.E.3	1.1|1.4|6.4	C	82
3	2-5.F.1.1	5.F.1	2.1|2.2|7.2	*	*
4	2-3.C.2.3	3.C.2	2.2	C	71
5	2-5.B.9.7	5.B.9	5.1	D	82
6	2-7.A.3.3	7.A.3	5.1	B	78
7	2-5.B.6.1	5.B.6	1.2	B	80
8	2-6.E.3.3	6.E.3	6.4|7.2	A	65
9	2-5.C.3.5	5.C.3	1.4|2.2	C	78
10	2-5.B.9.8	5.B.9	1.5	C	91
11	2-5.B.7.3	5.B.7	1.4|2.2	B	40
12	2-6.A.2.2	6.A.2	6.4	D	65
13	2-6.B.3.1	6.B.3	1.5	D	51
14	2-5.B.9.5|2-5.B.9.6	5.B.9	6.4|2.2	D	69
15	2-2.C.5.3	2.C.5	1.1|7.1	C	51
16	2-3.G.3.1	3.G.3	7.2	D	58
17	2-3.A.2.1|2-3.A.3.4|2-3.B.1.4|2-3.C.2.3|2-4.E.3.5	3.A.2|3.A.3|3.B.1|3.C.2|4.E.3	1.1|6.4|6.4|2.2|5.1	A	46
18	2-5.B.10.1	5.B.10	2.2	D	82
19	2-5.B.8.1|2-7.C.4.1	5.B.8|7.C.4	1.2|7.2|1.2	C	63
20	2-5.C.1.1|2-5.G.1.1	5.C.1|5.G.1	6.4|6.4	B	63
21	2-6.A.1.2	6.A.1	1.2	B	53
22	2-6.C.2.1	6.C.2	6.4	C	31
23	2-6.E.5.2	6.E.5	5.1	C	52
24	2-4.E.4.1	4.E.4	2.2|6.4	B	48
25	2-3.A.4.2|2-3.C.2.1	3.A.4|3.C.2	6.4|6.4	A	60
26	2-2.C.2.1	2.C.2	6.4	A	63
27	2-5.B.4.1	5.B.4	6.4|7.2	B	38
28	2-1.A.5.2|2-5.B.4.1	1.A.5|5.B.4	1.4|6.4	D	51
29	2-4.E.3.2|2-4.E.3.3	4.E.3	6.4|1.4|6.4	A	63
30	2-4.C.4.1|2-5.B.11.1	4.C.4|5.B.11	7.2|7.2	C	48
31	2-7.A.2.2	7.A.2	7.1	B	48
32	2-3.C.3.1	3.C.3	1.4	A	66
33	2-5.B.10.4	5.B.10	6.2	C	37
34	2-7.A.1.2	7.A.1	1.4|2.2	D	27
35	2-2.D.1.1	2.D.1	2.2	D	45
36	2-6.E.5.1	6.E.5	1.4|2.2	B	37

* Item not included in scoring

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2016 AP Physics 2: Algebra-Based
Question Descriptors and Performance Data

Question	Learning Objectives	Essential Knowledge	Science Practice	Key	% Correct
131	2-1.D.1.1|2-5.B.8.1|2-6.C.1.1|2-6.C.3.1|2-6.F.3.1	1.D.1|5.B.8|6.C.1|6.C.3|6.F.3	6.3|1.2|6.4|6.4|6.4	A, C	53
132	2-5.B.9.7	5.B.9	4.1|4.2	A, B	33
133	2-2.D.1.1|2-2.D.2.1|2-3.C.3.1	2.D.1|2.D.2|3.C.3	2.2|1.1|1.4	B, D	70
134	2-4.E.2.1	4.E.2	6.4	B, D	46

Free-Response Questions

Question	Learning Objectives	Essential Knowledge	Science Practices	Mean Score
1	2-1.B.1.2|2-2.C.3.1|2-2.E.3.1|2-2.E.3.2|2-4.E.3.2|2-4.E.3.3|2-5.B.4.2|2-5.C.2.1|2-5.D.3.2	1.B.1|2.C.3|2.E.3|4.E.3|5.B.4|5.C.2|5.D.3	6.4|6.2|2.2|1.4|6.4|6.4|6.4|1.4|2.1|2.2|6.4|6.4	2.01
2	2-3.A.2.1|2-3.A.4.1|2-3.A.4.2|2-3.B.1.4|2-5.B.10.2|2-5.B.10.3|2-5.F.1.1	3.A.2|3.A.4|3.B.1|5.B.10|5.F.1	1.1|1.4|6.2|6.4|7.2|6.4|2.2|2.2|2.1|7.2	4.51
3	2-4.E.4.2|2-4.E.5.3|2-5.B.7.1|2-5.B.9.8|2-7.A.2.1|2-7.A.3.2|2-7.A.3.3	4.E.4|4.E.5|5.B.7|5.B.9|7.A.2|7.A.3	4.1|4.2|4.2|6.4|7.2|1.5|7.1|4.2|5.1	4.23
4	2-6.C.2.1|2-6.C.3.1|2-6.F.3.1|2-6.F.4.1|2-6.G.1.1|2-6.G.2.1|2-6.G.2.2	6.C.2|6.C.3|6.F.3|6.F.4|6.G.1|6.G.2	1.4|6.4|7.2|1.4|6.4|6.4|6.4|7.1|6.4|7.1|6.1|6.4	2.79

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AP Physics 2: Algebra-Based

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