AP® Physics B
2009 Scoring Guidelines

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AP® PHYSICS
2009 SCORING GUIDELINES

General Notes About 2009 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point and a student's solution contains the application of that equation to the problem, but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics 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 Course Description*.

4. The scoring guidelines typically show numerical results using the value $g = 9.8\ \text{m/s}^2$, but use of $10\ \text{m/s}^2$ is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

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Question 1

15 points total **Distribution of points**

(a) 3 points

For a correct statement of conservation of mechanical energy (which might be implied in the next statement) 1 point

For correct energy expressions set equal 1 point

$$mgh = \frac{1}{2}kx^2$$

For solving for h, consistent with the energy equation 1 point

$$h = \frac{kx^2}{2mg}$$

(b)

(i) 2 points

For a correct combination of ($1/m$ and h) or ($1/h$ and m), with or without constants 2 points

Notes:

- If both $1/m$ and $1/h$ were chosen, only 1 point was earned.
- If part (b)(i) contained quantities that would not yield a correct graph for part (c), no credit was given for parts (b)(ii) through (d). But if part (b)(i) was left blank, parts (b)(ii) through (d) were examined for correct results.

The example of h versus $1/m$ is used in the remainder of the scoring guideline.

(ii) 2 points

$1/m$ $\left(\text{kg}^{-1}\right)$	m (kg)	h (m)	
50	0.020	0.49	
33	0.030	0.34	
25	0.040	0.28	
20	0.050	0.19	
17	0.060	0.18	

For correctly filling in the table with the appropriate data 1 point

For including the correct units in the table 1 point

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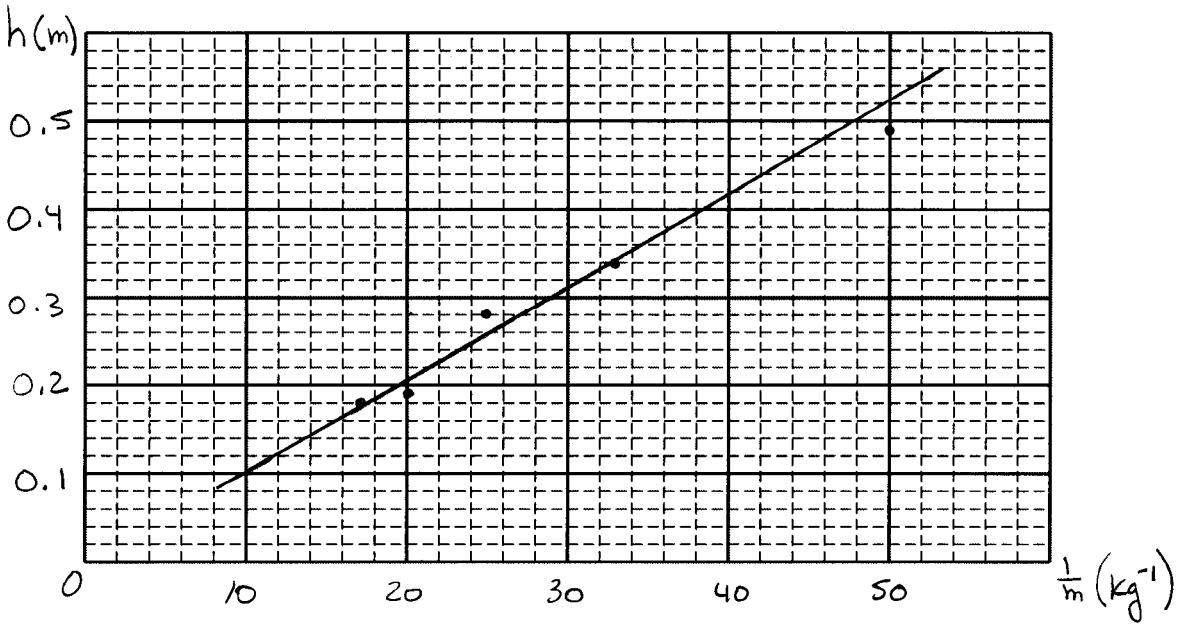
Question 1 (continued)

Distribution of points

(c) 4 points



For correctly plotting appropriate data (all five data points plotted correctly, assuming the data represented an inverse relationship between m and h) 1 point

For correctly drawing a best-fit straight line (a single straight line with data points reasonably scattered above and below the line) 1 point

For correctly labeling both axes 1 point

For correctly indicating the scale on both axes 1 point

(d) 2 points

For correctly calculating the slope from points on the line 1 point

For example: $\text{slope} = \dfrac{(0.42 - 0.10)\ \text{m}}{(40 - 10)\ \text{kg}^{-1}} = \dfrac{0.32\ \text{m}}{30\ \text{kg}^{-1}} = 1.07 \times 10^{-2}\ \text{m•kg}$

For a correct numerical value of the spring constant 1 point

From (a), $h = \dfrac{kx^2}{2mg}$, so the slope of the line = $\dfrac{kx^2}{2g}$

$$k = \frac{2g(\text{slope})}{x^2}$$

$$k = \frac{2\left(9.8\ \text{m/s}^2\right)\left(1.07 \times 10^{-2}\ \text{m•kg}\right)}{(0.02\ \text{m})^2}$$

$k = 524\ \text{N/m}$ $(535\ \text{N/m}$ using $g = 10\ \text{m/s}^2)$

Note: Values between $450\ \text{N/m}$ and $550\ \text{N/m}$ were accepted.

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Question 1 (continued)

Distribution of points

(e) 2 points

For a correct, complete procedure 2 points

Examples: Use a meter stick and a visual recorder, such as the eye, a video camera, or a camera.
Use a sonic range finder and appropriate computer software.
Measure the time (either to rise or for a round trip) and give the correct appropriate kinematics equations (the equations must be included in the answer).

One point was awarded for a partially correct or incomplete procedure.

Examples: Use a meter stick.
Use a photogate.

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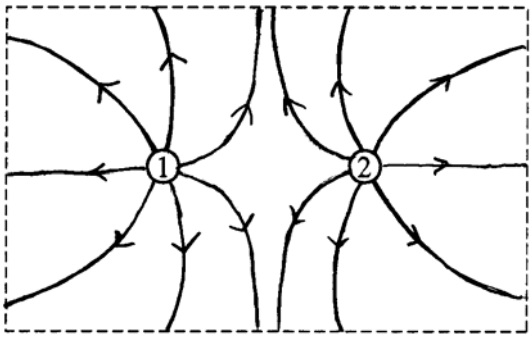
Question 2

10 points total **Distribution of points**

(a) 3 points



For the direction of all field lines away from the source charges 1 point
For the correct shape, symmetry, and curvature of the field lines 1 point
For a clear indication that the net field about point *A*, the point midway between the two charges, is zero; example: an absence of field lines in the area around point *A* 1 point

(b) 2 points

For clearly showing the addition of both contributions to the potential at point *A* 1 point

$V = \frac{kq_1}{r_1} + \frac{kq_2}{r_2}$ OR $V = \frac{1}{4\pi\epsilon_0}\left(\frac{Q}{d} + \frac{Q}{d}\right)$ OR equivalent

For a correct expression in terms of the given quantities 1 point

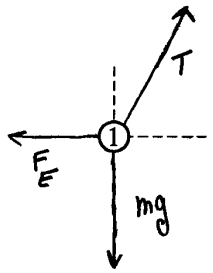
$V = \frac{2kQ}{L\sin\theta}$ OR $\frac{2Q}{4\pi\epsilon_0 L\sin\theta}$ OR $\frac{Q}{2\pi\epsilon_0 L\sin\theta}$ OR equivalent

Notes:

- The answer with no work shown earned 1 point.
- The following expression or its equivalents, with no other work shown, earned both points:

$$V = \frac{kQ}{L\sin\theta} + \frac{kQ}{L\sin\theta}$$

(c) 2 points



For all three vectors correctly drawn, with arrowheads, and no extraneous vectors 1 point
For appropriate labeling of vectors (only if first point was awarded) 1 point

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Question 2 (continued)

Distribution of points

(d) 3 points

For an expression indicating that the *x*-component of tension is equal to F_E 1 point

$T_x - F_E = 0$ OR $T\sin\theta = F_E$ OR equivalent

For an expression indicating that the *y*-component of tension is equal to *mg* 1 point

$T_y - mg = 0$ OR $T\cos\theta = mg$ OR equivalent

For stating the two equations in terms of the given quantities 1 point

$T\sin\theta = \dfrac{kQ^2}{4L^2\sin^2\theta}$ OR $\dfrac{Q^2}{16\pi\epsilon_0 L^2\sin^2\theta}$ OR $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q^2}{4L^2\sin^2\theta}$ OR equivalent

$T\cos\theta = mg$

Notes:

- Correct statement of both of the final two equations, in the absence of any other expressions, earned full credit.
- One point was deducted if sine and cosine were interchanged at any point.

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Question 3

15 points total **Distribution of points**

(a) 3 points

For a correct statement of Ohm's law (symbolic or numeric) 1 point
For a correct statement of Faraday's law (symbolic or numeric) 1 point

$I = \dfrac{\mathcal{E}}{R} = \dfrac{B\ell v}{R}$

$I = \dfrac{(0.80\ \text{T})(0.52\ \text{m})(1.8\ \text{m/s})}{3.0\ \Omega}$

For the correct answer 1 point

$I = 0.25\ \text{A}$

(b) 4 points

For a correct expression for the friction force (symbolic or numeric) 1 point

$F_f = \mu_k mg$

$F_f = (0.20)(0.22\ \text{kg})\left(9.8\ \text{m/s}^2\right)$

$F_f = 0.43\text{N}\ \ (0.44\ \text{N using}\ g = 10\ \text{m/s}^2)$

For a correct expression for the magnetic force (symbolic or numeric) 1 point

$F_B = BI\ell$

$F_B = (0.80\ \text{T})(0.25\ \text{A})(0.52\ \text{m})$

$F_B = 0.10\text{N}$

For any indication of multiple forces (explicit, implied, free-body diagram, etc.) 1 point

$F = F_f + F_B$

For a correct answer consistent with the current from part (a) 1 point

$F = 0.43\ \text{N} + 0.10\ \text{N} = 0.53\ \text{N}\quad (0.54\ \text{N using}\ g = 10\ \text{m/s}^2)$

(c) 3 points

For a correct expression for energy (including time) 1 point

$E_{diss} = Pt$

For a correct expression for power (individually or in another expression) 1 point

$P = I^2R\ \text{ OR }\ P = IV\ \text{ OR }\ P = V^2/R$

For consistent substitution of current or voltage from part (a) into a correct equation 1 point

$E_{diss} = I^2Rt\ \text{ OR }\ E_{diss} = IVt\ \text{ OR }\ E_{diss} = V^2t/R$

For example:

$E_{diss} = (0.25\ \text{A})^2(3.0\ \Omega)(2.0\ \text{s})$

$E_{diss} = 0.38\ \text{J}$

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Question 3 (continued)

Distribution of points

(d) 2 points

For a correct expression for distance 1 point
$d = vt$
$d = (1.8\ \text{m/s})(2.0\ \text{s})$
$d = 3.6\ \text{m}$
For a consistent substitution of force from part (b) 1 point
$W = Fd$
$W = (0.54\ \text{N})(3.6\ \text{m})$
$W = 1.9\ \text{J}$
Full credit could also be given for equivalent solutions (e.g., combining the expression $P = Fv$ for power with the expression $W = Pt$ for work to get $W = Fvt$, followed by consistent substitutions).

(e) 2 points

For mentioning the force of friction but not including the concept of work 1 point
For including a statement that friction does work or dissipates energy 1 point
Note: If the answer for part (d) is less than or equal to the answer for part (c), no credit was given.

Units point

For correct units on <u>all</u> numerical answers 1 point

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Question 4

10 points total **Distribution of points**

(a) 3 points

For any attempt to use the ideal gas equation of state, i.e., by attempting to substitute values into the equation (simply writing the equation did not earn this point) 1 point

$PV = nRT$

$T = PV/nR$

For correctly calculating the number of moles 1 point

$n = 2.2 \text{ kg}/18 \times 10^{-3} \text{ kg/mol} = 122 \text{ mol}$

For substituting the correct values for pressure, volume, and the universal gas constant into the ideal gas equation 1 point

$T_A = \left(3.0 \times 10^5 \text{ Pa}\right)\left(2.0 \text{ m}^3\right)/(122 \text{ mol})(8.31 \text{ J/mol•K})$

$T_A = 590 \text{ K}$

(b) 1 point

$T = PV/nR$

$T_C = \left(4.0 \times 10^5 \text{ Pa}\right)\left(2.5 \text{ m}^3\right)/(122 \text{ mol})(8.31 \text{ J/mol•K})$

For the correct answer, with the correct unit 1 point

$T_C = 980 \text{ K}$

Note: An alternate solution uses the ratios $P_A V_A/T_A = P_C V_C/T_C$ to obtain $T_C = 5T_A/3$. The point could be earned if the answers in parts (b) and (a) were in the ratio $5/3$ and the temperatures were in Kelvin.

(c) 3 points

For indicating that the internal energy increases 1 point

For a correct justification, with no incorrect statements 2 points

For example: internal energy is proportional to the temperature, which increases as the gas is taken from *A* to *C*.

One point could be earned for an incomplete justification or one that would be complete and correct but for an incorrect physical statement.

(d) 3 points

W = area under the curve = $-P\Delta V$ (the minus sign is not needed for this point) 1 point

$W = -\left(4.0 \times 10^5 \text{ Pa}\right)\left(0.5 \text{ m}^3\right)$

For an answer having the correct magnitude, including the correct unit 1 point

For the negative sign on the answer 1 point

$W = -2.0 \times 10^5 \text{ J}$

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Question 5

10 points total **Distribution of points**

(a) 3 points

For checking "No" 1 point
For a complete and correct justification, with no incorrect statements 2 points
For example: the tension in each string depends on the weight and the buoyant force. The buoyant force depends on the volume of the object. Objects of identical mass have the same weight but need not have identical volumes.
One point could be earned for a partial justification, or one that contained an incorrect statement.

(b) 3 points

For any correct expression of the equilibrium of the three forces on object A 1 point
$T = mg - B$, where B is the buoyant force
For correctly using the density and volume of object A to calculate its weight and labeling as such 1 point

$$mg = \rho Vg = \left(1300\ \text{kg/m}^3\right)\left(1.0 \times 10^{-5}\ \text{m}^3\right)\left(9.8\ \text{m/s}^2\right) = 0.13\ \text{N}$$

$$B = mg - T = 0.13\ \text{N} - 0.0098\ \text{N}$$

For an answer consistent with preceding work 1 point
$B = 0.12$ N

(c) 2 points

The buoyant force equals the weight of the displaced liquid, which depends on its density.

$$B = \rho_\ell Vg$$

$$\rho_\ell = B/Vg$$

For substituting the buoyant force from part (b) and the correct values for volume and g into a correct expression 1 point

$$\rho_\ell = (0.12\ \text{N})/\left(1.0 \times 10^{-5}\ \text{m}^3\right)\left(9.8\ \text{m/s}^2\right)$$

For an answer consistent with the above substitutions, including correct units 1 point

$$\rho_\ell = 1200\ \text{kg/m}^3$$

An alternate solution using the ratio of forces $F_B/F_g = \rho_\ell Vg/\rho_A Vg = \rho_\ell/\rho_A$ earned similar substitution and answer points.

(d) 2 points

For indicating that the tension increases 1 point
For a correct justification 1 point
For example: less of the object submerged means less liquid displaced, which means less buoyant force. By the equation in part (b), the tension is greater.

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Question 6

10 points total **Distribution of points**

(a) 2 points

For a meaningful attempt to use the equation $f = c/\lambda$ 1 point

$f = \left(3.00 \times 10^{8} \text{ m/s}\right)/\left(550 \times 10^{-9} \text{ m}\right)$

For the correct answer, with correct units 1 point

$f = 5.5 \times 10^{14} \text{ Hz}$

(b) 3 points

For writing one or more equations that can be used to solve the problem 1 point

$x \approx m\lambda L/d$ OR $d\sin\theta = m\lambda$ and $\sin\theta \approx x/L$ (or $\tan\theta \approx x/L$)

For indicating that the calculation is for the spacing between fringes, rather than the position of a single fringe 1 point

$\Delta x = \Delta m\lambda L/d$

Adjacent fringes means $\Delta m = 1$

$\Delta x = \lambda L/d$

For correct substitutions into the correct expression 1 point

$\Delta x = \left(550 \times 10^{-9} \text{ m}\right)(2.2 \text{ m})/\left(1.8 \times 10^{-5} \text{ m}\right)$

$\Delta x = 0.067 \text{ m}$

(c) 2 points

For indicating that the frequency is the same as in part (a) 2 points

$f = 5.5 \times 10^{14} \text{ Hz}$

Note: If there was no answer in part (a) and a calculation was done in this part, the scoring guideline for part (a) was applied.

(d) 3 points

For correctly indicating that the fringe spacing decreases 1 point

For indicating in the explanation that the wavelength decreases 1 point

For indicating in the explanation that Δx is proportional to the wavelength 1 point

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Question 7

10 points total **Distribution of points**

(a) 3 points

$\lambda = h/p = h/m\upsilon$

$\upsilon = h/m\lambda$

For substituting the correct value of the electron wavelength into a correct expression 1 point

For substituting a correct value of Planck's constant into a correct expression 1 point

$\upsilon = \left(6.63 \times 10^{-34}\ \text{J•s}\right)/\left(9.11 \times 10^{-31}\ \text{kg}\right)\left(0.85 \times 10^{-9}\ \text{m}\right)$

$\upsilon = 8.56 \times 10^{5}\ \text{m/s}$

For substituting the correct value of the electron mass into a correct expression for the kinetic energy 1 point

$K = m\upsilon^2/2$

$K = \left(9.11 \times 10^{-31}\ \text{kg}\right)\left(8.56 \times 10^{5}\ \text{m/s}\right)^2/2$

$K = 3.3 \times 10^{-19}\ \text{J}$ (or 2.1 eV)

(b) 3 points

For any indication that the student used the equation for the photoelectric effect 1 point

$K_{\max} = hf - \phi$

$\phi = hf - K_{\max} = (hc/\lambda) - K_{\max}$

For substituting the correct value of the photon wavelength into the correct expression 1 point

For substituting for hc in appropriate energy units into the correct expression 1 point

$\phi = \left[\left(6.63 \times 10^{-34}\ \text{J•s}\right)\left(3.00 \times 10^{8}\ \text{m/s}\right)/\left(250 \times 10^{-9}\ \text{m}\right)\right] - 3.3 \times 10^{-19}\ \text{J}$

$\phi = 4.7 \times 10^{-19}\ \text{J}$ (or 2.9 eV)

Units point

For correct units in both parts (a) and (b) 1 point

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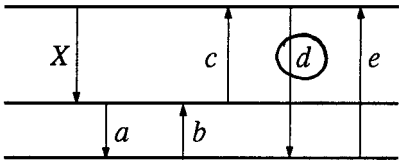
Question 7 (continued)

Distribution of points

(c) 3 points



For choosing the correct transition 1 point

For indicating that the emission of a photon requires the atom to go to a lower energy level 1 point

For indicating that $E = hc/\lambda$ for a photon, so a smaller wavelength means a larger energy difference 1 point

Notes:

- Two points could be earned by choosing transition *a* and stating that the emission of a photon requires a drop to a lower energy level.
- Two points could be earned by choosing transition *e* and stating that the shorter photon wavelength implies a larger difference between energy levels.

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