AP® Physics B
2005 Scoring Guidelines
Form B

General Notes About 2005 AP Physics Scoring Guidelines

1. The solutions contain the most common method(s) of solving the free-response questions and the allocation of points for these solutions. 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.

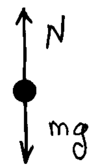
4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable.

5. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. The exception is usually 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.

Question 1

10 points total — **Distribution of points**

(a) 2 points



For an upward force with a label indicating a normal force or a force from the scale — 1 point
For a downward force with a label appropriate for a weight — 1 point
One point was deducted for each extraneous force until the net score was zero.

(b) 3 points

The scale reading is the magnitude of the normal force on the student.
For starting with Newton's second law — 1 point
$F_{net} = ma$
For correctly expressing the net force — 1 point
$N - mg = ma$
For correctly solving for the normal force — 1 point
$N = m(g + a)$

(c)
(i) 2 points

The normal force exerted by the scale is maximum when the acceleration has its maximum positive value.
The force is maximum from 12 to 16 seconds.
For an interval beginning at 12 seconds — 1 point
For an interval ending at 16 seconds — 1 point
One point was deducted for each interval with no correct endpoints until the net score was zero.

(ii) 1 point

Using the expression for the normal force from part (b)
$N = m(g + a)$
$N = (45\ \text{kg})\left(9.8\ \text{m/s}^2 + 1.2\ \text{m/s}^2\right)$
$N = (45\ \text{kg})\left(11.0\ \text{m/s}^2\right)$
For the correct answer with units — 1 point
$N = 500\ \text{N}$

Question 1 (continued)

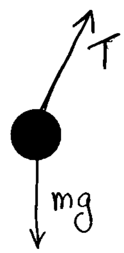
	Distribution of points
(d) 2 points	
The speed of the elevator is constant when the acceleration is zero.	
This occurs from 7 to 10 seconds and from 17 to 20 seconds.	
For each correct interval	1 point each
One point was deducted for each extraneous interval until the net score was zero.	
One point was awarded if the scale was misread for both intervals and the response was given as both 6.5 to 10 and 16.5 to 20.	

Question 2

10 points total | **Distribution of points**

(a)

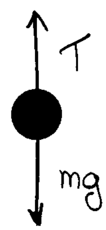
(i) 2 points



For each correctly drawn and labeled force — 1 point each

One point was deducted if any extraneous forces were shown.

(ii) 2 points



For each correctly drawn and labeled force — 1 point each

One point was deducted if any extraneous forces were shown.

(b) 2 points

For correctly applying conservation of energy — 1 point

$$\frac{1}{2}mv^2 = mg\,\Delta h$$

$$v = \sqrt{2g\,\Delta h}$$

$$v = \sqrt{2\left(9.8\ \text{m/s}^2\right)(0.08\ \text{m})} = \sqrt{1.568}\ \text{m/s}$$

For the correct answer — 1 point

$$v = 1.3\ \text{m/s}$$

Question 2 (continued)

Distribution of points

(c) 3 points

For using $\sum \mathbf{F} = m\mathbf{a}$ — 1 point

For a correct expression for the net force that is equated to a centripetal force — 1 point

$T - mg = mv^2/r$

$T = m\left(g + v^2/r\right)$

$T = (0.085\ \text{kg})\left[9.8\ \text{m/s}^2 + (1.3\ \text{m/s})^2/(1.5\ \text{m})\right]$

For the correct answer with units — 1 point

$T = 0.93\ \text{N}$ (or equivalent answer depending on rounding or use of $g = 10\ \text{m/s}^2$)

(d) 1 point

For a correct modification — 1 point

For example: Make the string four times longer.

Question 3

15 points total | **Distribution of points**

(a) 4 points

For any mathematical statement indicating that the force on the $-Q$ charge is obtained by the addition of forces due to the other two charges — 1 point

For any of the following three statements or expressions — 1 point

- The y components of the forces due to the two $-2Q$ charges cancel.
- The magnitude of the net force equals the sum of the magnitudes of the x components.
- $r_{+a} = r_{-a} = \sqrt{a^2 + (2a)^2} = \sqrt{5}a$

$$F_x = 2\frac{kQ(2Q)}{r^2}\cos\theta$$

$$\cos\theta = \frac{2a}{r} = \frac{2a}{\sqrt{5}a} = \frac{2}{\sqrt{5}}$$

$$F_x = 2\frac{kQ(2Q)}{5a^2}\frac{2}{\sqrt{5}}$$

For the correct expression for the magnitude of the net force — 1 point

$$F_x = \frac{8kQ^2}{5\sqrt{5}a^2}$$

For the correct indication of direction — 1 point

Force is directed to the right, OR force is in the $+x$ direction, OR explicit use of an arrow to show direction.

(b) 3 points

For any indication that the contributions to the field from the $-2Q$ charges cancel — 1 point

For the correct expression for the magnitude of the field due to the $-Q$ charge — 1 point

$$E = \left|\frac{kq}{r^2}\right| = \left|\frac{k(-Q)}{(2a)^2}\right|$$

$E = \dfrac{kQ}{4a^2}$ (point awarded even with a minus sign)

For the correct indication of direction — 1 point

Field is directed to the right, OR field is in the $+x$ direction, OR explicit use of an arrow to show direction.

Question 3 (continued)

Distribution of points

(c) 5 points

$$V = k\sum_i \frac{q_i}{r_i}$$

For any indication of the need to use superposition for the electrical potential (or showing three terms in the expression) — 1 point

One point awarded for each correct term, including the minus sign, in the following expression — 3 points

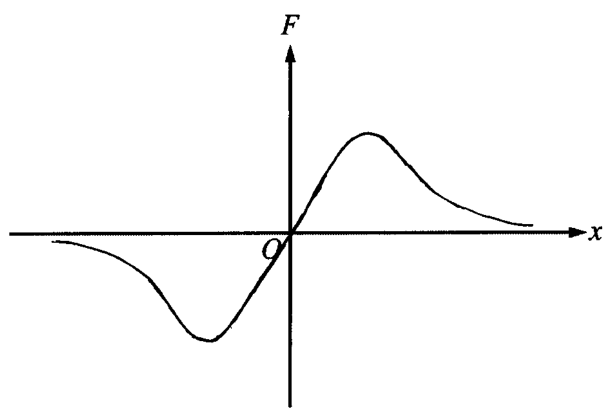
$$V = \frac{k(-2Q)}{a} + \frac{k(-2Q)}{a} + \frac{k(-Q)}{2a}$$

$$V = -\frac{4kQ}{a} - \frac{kQ}{2a} = -\frac{8kQ}{2a} - \frac{kQ}{2a}$$

For the correct simplified answer with correct sign — 1 point

$$V = -\frac{9kQ}{2a}$$

(d) 3 points



For having $F = 0$ at $x = 0$ with $|F|$ increasing gradually going away from the origin — 1 point

This point was not given for a spike function at the origin.

For having the graph positive on the right and negative on the left — 1 point

For having a single maximum of $|F|$ on each side of the origin and having the curve monotonically and asymptotically decreasing to zero as $x \to \infty$ — 1 point

Question 4

15 points total — **Distribution of points**

Credit for each part of this problem was awarded if the response, when judged holistically, showed reasonable understanding of a correct experimental method. Responses that showed little understanding could not receive full credit.

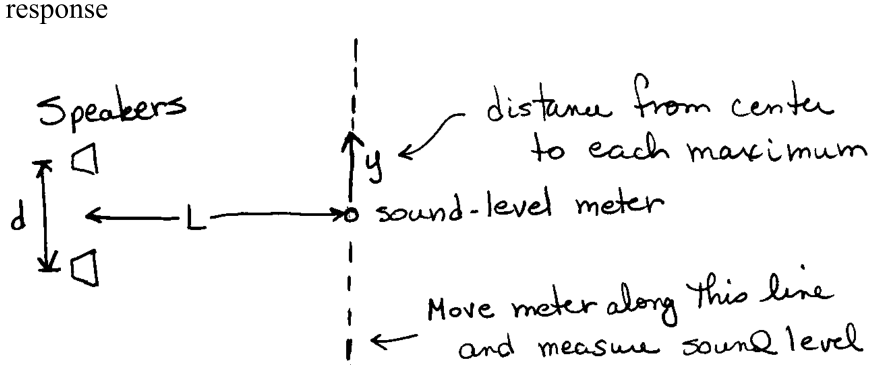
(a) 2 points

For using in parts (b) and (c) every piece of equipment marked in part (a)	1 point
For marking every piece of equipment used in parts (b) and (c)	1 point

(b) 4 points

For drawing an appropriate setup	1 point
For completely labeling the equipment	1 point
For indicating the measurements to be made	1 point
For complete labeling of the measurements, including symbols for them	1 point

Sample response



(c) 4 points

For a description of the setup of equipment	2 points
For a description of how to determine maxima or minima in the interference pattern	1 point
For indicating what measurements to take	1 point

Example response for the figure above:

Set the speakers a fixed distance d apart, pointing perpendicular to the line along which d is measured.

Determine a line parallel to the speaker line and a distance L away.

Use the sound meter to locate the maxima of the interference pattern along this line.

Record the locations of these maxima along the line.

Question 4 (continued)

	Distribution of points
(d) 4 points	
The solution shown below is for the example given above. Solutions for other methods also received appropriate credit.	
For the condition for a maximum	1 point
$m\lambda = d\sin\theta$	
For using the condition for small angles and eliminating θ	1 point
$\sin\theta \approx y/L$	
$m\lambda \approx dy/L$	
For using successive maxima (i.e., $\Delta m = 1$) to get $\lambda \approx d\,\Delta y/L$	1 point
For an appropriate expression for frequency	1 point
$f = \upsilon_{sound}/\lambda$	
$f \approx L\upsilon_{sound}/d\,\Delta y$	
(e) 1 point	
For a correct description	1 point
For the example given: Decreasing frequency results in increasing wavelength. Thus the distance between successive maxima will increase.	

Question 5

10 points total | **Distribution of points**

(a) 4 points

For including atmospheric pressure in the expression for total pressure	1 point
For the correct expression for the term for the pressure due to the saltwater	1 point

$P = P_{atm} + \rho_{sw}gh$

$P = 1\times10^5 \text{ Pa} + \left(1025 \text{ kg/m}^3\right)\left(9.8 \text{ m/s}^2\right)(20 \text{ m})$

$P = 1\times10^5 \text{ Pa} + 2.0\times10^5 \text{ Pa}$

$P = 3.0\times10^5 \text{ Pa}$ (or $3.1\times10^5 \text{ Pa}$ using $g = 10 \text{ m/s}^2$)

For the correct relationship between force and pressure — 1 point

$F = PA$

$F = \left(3.0\times10^5 \text{ Pa}\right)\left(4.0\times10^{-5} \text{ m}^2\right)$

For the correct answer with units — 1 point

$F = 12 \text{ N}$

(b) 4 points

For applying Bernoulli's principle at the top of the tank and the height of the drain — 1 point

$P_{0top} + \rho g y_{top} + \frac{1}{2}\rho \upsilon_{top}^2 = P_{0drain} + \rho g y_{drain} + \frac{1}{2}\rho \upsilon_{drain}^2$

For realizing that $P_{0top} = P_{0drain} = P_{atm}$ — 1 point

For realizing that $\upsilon_{top} = 0$ — 1 point

Substituting and simplifying

$\rho g y_{top} = \rho g y_{drain} + \frac{1}{2}\rho \upsilon_{drain}^2$

$\frac{1}{2}\rho \upsilon_{drain}^2 = \rho g y_{drain} - \rho g y_{top} = \rho g\left(y_{drain} - y_{top}\right)$

$\upsilon_{drain} = \sqrt{2g\left(y_{drain} - y_{top}\right)}$

$\upsilon_{drain} = \sqrt{2\left(9.8 \text{ m/s}^2\right)(20 \text{ m})}$

$\upsilon_{drain} = \sqrt{392} \text{ m/s}$

For the correct answer with units — 1 point

$\upsilon_{drain} = 20 \text{ m/s}$

Question 5 (continued)

Distribution of points

(c) 2 points

For a correct expression for the volume rate of flow — 1 point

$V/t = \upsilon A$

$V/t = (20\ \text{m/s})\left(4.0 \times 10^{-5}\ \text{m}^2\right)$

For the correct answer with units — 1 point

$V/t = 8.0 \times 10^{-4}\ \text{m}^3/\text{s}$

Question 6

10 points total **Distribution of points**

(a) 1 point

For a correct expression relating P and V — 1 point

$PV = nRT$ OR $P = nRT\dfrac{1}{V}$

(b) 2 points

The total pressure is atmospheric pressure plus the pressure due to the added mass.

$$P = P_{atm} + \frac{mg}{A}$$

$$P = 1.0 \times 10^{5} \text{ Pa} + \frac{m\left(9.8 \text{ m/s}^2\right)}{3.0 \times 10^{-4} \text{ m}^2}$$

m (kg)	$V\left(\text{m}^3\right)$	$1/V$ $\left(\text{m}^{-3}\right)$	P (Pa)
0	6.0×10^{-5}	1.7×10^{4}	1.0×10^{5}
1	4.5×10^{-5}	2.2×10^{4}	1.3×10^{5}
2	3.6×10^{-5}	2.8×10^{4}	1.7×10^{5}
3	3.0×10^{-5}	3.3×10^{4}	2.0×10^{5}
4	2.6×10^{-5}	3.8×10^{4}	2.3×10^{5}

For two or three correct values of pressure — 1 point
For an additional one or two correct values (i.e., four or five correct received two points) — 1 point
If atmospheric pressure was left out, only one point could be earned.

Question 6 (continued)

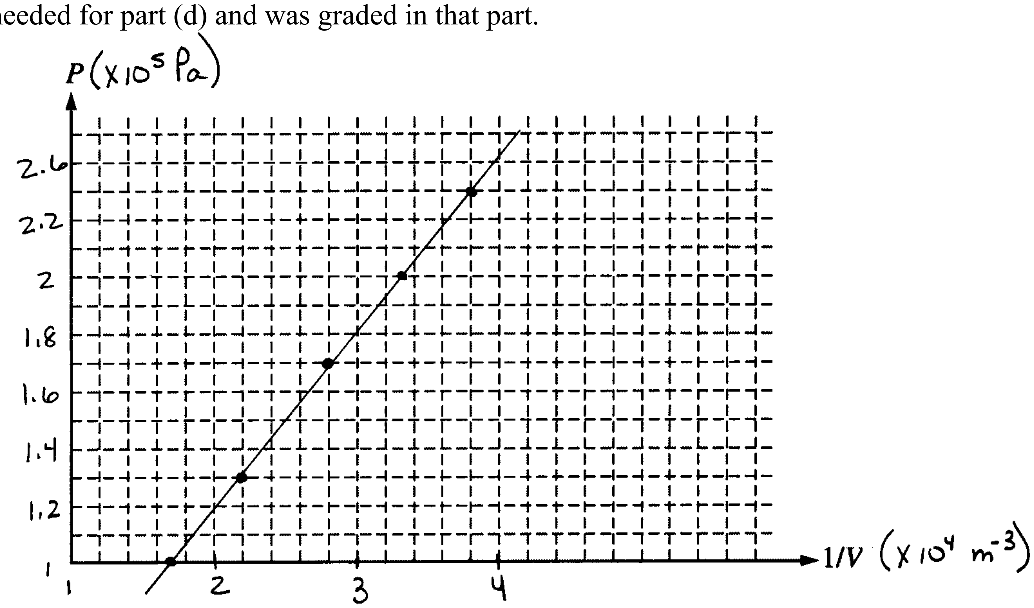
Distribution of points

(c) 3 points

For correctly labeling the horizontal axis	1 point
For correctly labeling the vertical axis	1 point
For accurately plotting the points	1 point

Full credit could be earned for correctly plotting incorrect data from the table.

Example answer shown below. This part of the question did not ask for the best-fit line, but it was needed for part (d) and was graded in that part.



(d) 4 points

For drawing a reasonable best-fit line through the data, given that the data could yield a value for n — 1 point

$P = nRT(1/V)$

For calculating the slope of the line — 1 point

From the example graph shown above, where the line goes through the first and last data points

$$\text{slope} = \frac{\left(2.3\times10^5 - 1.0\times10^5\right)\ \text{Pa}}{\left(3.8\times10^4 - 1.7\times10^4\right)\ \text{m}^{-3}}$$

For a reasonable value for the slope — 1 point

For the values shown above, $\text{slope} = 6.19\ \text{Pa}\bullet\text{m}^3$

$n = \text{slope}/RT$

$$n = \frac{6.19\ \text{Pa}\bullet\text{m}^3}{(8.31\ \text{J}/(\text{mol}\bullet\text{K}))(300\ \text{K})}$$

For the correct answer — 1 point

$n = 0.0025$ mol

Question 7

10 points total | **Distribution of points**

(a) 2 points

For a correct expression for the energy of a photon — 1 point

$E = hf$ OR $E = hc/\lambda$

Substituting into the second equation

$E = \left(1.99 \times 10^{-25}\ \text{J•m}\right)/\left(450 \times 10^{-9}\ \text{m}\right)$ OR $\left(1.24 \times 10^{3}\ \text{eV•nm}\right)/(450\ \text{nm})$

For the correct answer with units — 1 point

$E = 4.4 \times 10^{-19}\ \text{J}$ (or 2.8 eV)

(b) 3 points

For a correct relationship for the number of photons N — 1 point

$$N = \frac{\text{(energy emitted in 5 minutes)}}{\text{(energy per photon)}}$$

For correct substitutions — 1 point

$$N = \frac{\text{(power)(time)}}{\text{(energy per photon)}} = \frac{\left(2.5 \times 10^{-3}\ \text{J/s}\right)(5\ \text{min})(60\ \text{s/min})}{4.4 \times 10^{-19}\ \text{J}}$$

For the correct answer — 1 point

$N = 1.7 \times 10^{18}$

(c) 3 points

For relating the maximum kinetic energy of an electron to the stopping potential (i.e., 0.86 eV or qV) — 1 point

$$\frac{1}{2}mv_{\text{max}}^2 = qV$$

For obtaining the correct expression for the maximum speed — 1 point

$v_{\text{max}} = \sqrt{2qV/m}$

$v_{\text{max}} = \sqrt{2\left(1.6 \times 10^{-19}\ \text{C}\right)(0.86\ \text{V})/\left(9.11 \times 10^{-31}\ \text{kg}\right)}$

For the correct answer with units — 1 point

$v_{\text{max}} = 5.5 \times 10^{5}\ \text{m/s}$

Question 7 (continued)

Distribution of points

(d) 2 points

For a correct relationship for the wavelength — 1 point

$$\lambda = \frac{h}{p_{\max}}$$

$$\lambda = \frac{h}{mv_{\max}}$$

$$\lambda = \frac{6.63 \times 10^{34}\ \text{J}\bullet\text{s}}{\left(9.11 \times 10^{-31}\ \text{kg}\right)\left(5.5 \times 10^{5}\ \text{m/s}\right)}$$

For the correct answer with units — 1 point

$\lambda = 1.3$ nm