CollegeBoard
Advanced Placement Program

AP® Physics B
2004 Scoring Guidelines
Form B

General Notes about 2004 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 $10\ \text{m/s}^2$ 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

15 points total — **Distribution of points**

(a) 4 points

For any indication of conservation of energy — 1 point

For a correct conservation equation for this situation — 1 point

$\frac{1}{2}mv_0^2 + mgh_0 = \frac{1}{2}mv_A^2 + mgh_A$

$v_A^2 = v_0^2 + 2g(h_0 - h_A)$

For the correct substitutions — 1 point

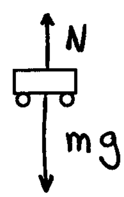
$v_A^2 = (1.5\ \text{m/s})^2 + 2(9.8\ \text{m/s}^2)(2.0\ \text{m} - 1.9\ \text{m})$

$v_A^2 = 4.2(\text{m/s})^2$ (or $4.3(\text{m/s})^2$ using $g = 10\ \text{m/s}^2$)

For the correct answer — 1 point

$v_A = 2.0\ \text{m/s}$ (or $2.1\ \text{m/s}$ if v_A^2 was not rounded or if $g = 10\ \text{m/s}^2$ was used)

(b) 2 points



For each correctly drawn and labeled force — 1 pt each

One point earned for correct forces was deducted for having any extraneous forces.

(c) 3 points

For indicating that the sum of the forces equals the centripetal force — 1 point

$\sum F = \frac{mv_A^2}{r}$

For having the correct relative signs in the application of the above equation — 1 point

$mg - N = \frac{mv_A^2}{r}$

For solving for the normal force, substituting, and solving correctly — 1 point

$N = mg - \frac{mv_A^2}{r}$

$N = (0.50\ \text{kg})(9.8\ \text{m/s}^2) - \frac{(0.50\ \text{kg})(4.21(\text{m/s})^2)}{0.95\ \text{m}}$

$N = 2.7\ \text{N}$

Question 1 (continued)

	Distribution of points
(d) 3 points	
For any indication that the work done must equal the kinetic energy at point *A* in the absence of friction	1 point
$W_{\text{friction}} = -\frac{1}{2}mv_A^2$	
For correct substitution	1 point
$W_{\text{friction}} = -\frac{1}{2}(0.50\text{ kg})\left(4.2(\text{m/s})^2\right)$	
For the correct answer, including the negative sign	1 point
$W_{\text{friction}} = -1.1\text{ J}$	
(e) 3 points	
Method 1:	
For indicating that one should decrease the radius of the curve of the second hill	1 point
The cart will lose contact when $mg - \frac{mv_A^2}{r} \le 0$. Decreasing the radius of the curve will cause the second term to increase and thus meet the condition.	
For referring to the equation $N = mg - \frac{mv_A^2}{r}$	1 point
For indicating that the cart will loose contact when $N \le 0$	1 point
Method 2:	
For indicating that one should make the initial hill higher or the second hill lower	(1 point)
The cart will loose contact when $mg - \frac{mv_A^2}{r} \le 0$. Increasing the difference in heights will cause the speed at *A* to increase, and thus the second term will increase and the condition will be met.	
For referring to the equation $N = mg - \frac{mv_A^2}{r}$ and indicating that the cart will loose contact when $N \le 0$	(1 point)
For indicating that the speed at *A* will increase	(1 point)

Question 2

15 points total | **Distribution of points**

(a) 4 points

For calculating the length of time t_1 that the diving bell is accelerating (i.e. the time it takes to reach the constant speed v_c) — 1 point

$v_c = at_1$

$t_1 = v_c/a$

$t_1 = (2.0\ \text{m/s})/(0.10\ \text{m/s}^2) = 20\ \text{s}$

For calculating the distance the bell descends while accelerating — 1 point

$d_1 = \frac{1}{2}at_1^2$

$d_1 = \frac{1}{2}(0.10\ \text{m/s}^2)(20\ \text{s})^2 = 20\ \text{m}$

The bell therefore descends a distance $d_2 = 80\ \text{m} - 20\ \text{m} = 60\ \text{m}$ at the constant speed.

For calculating the time to descend this 60 m — 1 point

$d_2 = v_c t_2$

$t_2 = d_2/v_c$

$t_2 = (60\ \text{m})/(2.0\ \text{m/s}) = 30\ \text{s}$

For calculating the total time — 1 point

$t_{\text{tot}} = t_1 + t_2 = 20\ \text{s} + 30\ \text{s}$

$t_{\text{tot}} = 50\ \text{s}$

(b) 3 points

For a correct expression for the weight of the water above the cross-sectional area A — 1 point

$w = \rho Vg = \rho Ahg$

For correct substitution — 1 point

$w = (1025\ \text{kg/m}^3)(9.0\ \text{m}^2)(80\ \text{m})(9.8\ \text{m/s}^2)$

For the correct answer, including units — 1 point

$w = 7.2 \times 10^6\ \text{N}$ (or $7.4 \times 10^6\ \text{N}$ using $g = 10\ \text{m/s}^2$)

Full credit could also be earned for determining the pressure due to the water alone, and using $F = PA$ to determine the weight

A maximum of 2 points could be earned for only determining the mass of the water, or for calculating the absolute pressure and using $F = PA$.

Question 2 (continued)

Distribution of points

(c) 3 points

For indicating that the pressure at a depth *h* has a term ρgh, or using $P = w/A$ and the value of the weight from part (b) — 1 point

For indicating that the atmospheric pressure must be added (in correct SI units – otherwise the ρgh term must be converted to atmospheres for full credit) — 1 point

$P = (w/A) + P_{atm}$

$P = \left(7.2 \times 10^6 \text{ N}/9.0 \text{ m}^2\right) + 1.0 \times 10^5 \text{ N/m}^2$

For the correct answer, including units — 1 point

$P = 9.0 \times 10^5 \text{ N/m}^2$ (or $9.2 \times 10^5 \text{ N/m}^2$ using $g = 10 \text{ m/s}^2$)

(d) 3 points

For a correct expression for the force on an area A_{hatch} — 1 point

$F = PA_{\text{hatch}}$

For a correct expression for the area of the hatch — 1 point

$A_{\text{hatch}} = \pi r^2$

Since there is one atmosphere pressure inside the diving bell, the net pressure corresponding to the minimum applied force is that from the water only.

$F_{\text{min}} = \rho g h A_{\text{hatch}}$

Substituting:

$F_{\text{min}} = \left(1025 \text{ kg/m}^3\right)\left(9.8 \text{ m/s}^2\right)(80 \text{ m})\left(\pi (0.25 \text{ m})^2\right)$

For the correct answer — 1 point

$F_{\text{min}} = 1.6 \times 10^5 \text{ N}$

Since the question could have been interpreted as asking for the minimum total force required, full credit was awarded for including atmospheric pressure.

(e) 2 points

For a correct modification that would reduce the force necessary to open the hatch — 1 point

For a correct justification — 1 point

Examples:

- Increase the pressure inside the diving bell. The internal pressure would then compensate for atmospheric pressure plus some of the pressure of the water, reducing the force needed.
- Reduce the size of the hatch. Pressure times a smaller area yields a smaller force.
- Use a tool that gives a mechanical advantage, such as a lever. Such a tool is designed so that one exerts a smaller force over a larger distance than one would without it.

Question 3

15 points total — **Distribution of points**

(a) 4 points

There must be a node at the liquid surface and an antinode near the top of the tube, so the length of consecutive resonances differ by a half wavelength.

For equating the difference in air column lengths to the difference in the number of wavelengths — 3 points

$L_2 - L_1 = \frac{\lambda}{2}$

$\lambda = 2(L_2 - L_1)$

For correct substitution and answer — 1 point

$\lambda = 2(0.80\text{ m} - 0.25\text{ m})$

$\lambda = 1.1\text{ m}$

A maximum of 3 points was awarded for using only one of the air column lengths to calculate a wavelength

A maximum of 2 points was awarded for equating the difference in air column lengths to one or one-quarter wavelength

(b) 2 points

For using the relationship between wavelength, speed, and frequency — 1 point

$f = v_{air}/\lambda$

For correct substitutions (using λ from part (a)) and a corresponding correct answer — 1 point

$f = (343\text{ m/s})/(1.1\text{ m})$

$f = 312\text{ Hz}$

(c) 3 points

For indicating the need to use the values of the wave properties appropriate for water — 1 point

$\lambda_{water} = v_{water}/f_{water}$

For indicating that the frequency in water is the same as in air — 1 point

For correct substitution and answer — 1 point

$\lambda_{water} = \frac{(1490\text{ m/s})}{312\text{ Hz}}$

$\lambda_{water} = 4.8\text{ m}$

Question 3 (continued)

Distribution of points

(d) 3 points

L_3 is approximately $1\frac{1}{4}$ wavelengths, which is one-half wavelength longer than L_2

For any indication that L_3 equals $L_2 + \lambda/2$ or $L_1 + \lambda$ — 2 points

$L_3 = 0.80 \text{ m} + \frac{1.1 \text{ m}}{2}$

For the correct answer (using whatever wavelength was determined previously) — 1 point

$L_3 = 1.35 \text{ m}$

A maximum of 2 points were awarded for using $L_3 = 5\lambda/2$ or $L_3 = L_2 + \lambda$

One point was awarded for a good drawing of the standing wave in the air column with no calculation.

(e) 3 points

For indicating that the calculation of frequency was too low — 2 points

For a correct justification — 1 point

For example: As temperature increases, the speed of sound in air increases, so the speed used in part (b) was too low. Since $f = v_{air}/\lambda$, that lower speed of sound yielded a frequency that was too low.

Question 4

15 points total | **Distribution of points**

(a) 4 points

For a correct expression for the magnitude of the emf per turn in the coil — 1 point

$\mathcal{E} = \dfrac{\Delta\phi}{\Delta t}$ OR $\mathcal{E} = B\ell v$

$\mathcal{E} = \dfrac{A\Delta B}{\Delta t} = \dfrac{w\ell(B-0)}{\Delta t}$ OR $\mathcal{E} = \dfrac{B\ell w}{\Delta t}$

For correct substitutions in either equation (both yield the same value) — 1 point

$\mathcal{E} = \dfrac{(0.25\text{ m})(0.15\text{ m})(0.20\text{ T})}{0.50\text{ s}}$

For correct calculation — 1 point

$\mathcal{E} = 0.015$ V per turn

For recognizing that with 20 turns the total emf in the coil is 20 times the emf per turn — 1 point

$\mathcal{E}_{tot} = 20(0.015\text{ V per turn}) = 0.30\text{ V}$

(b) 2 points

For correct expression for Ohm's law, substitution from part (a), and magnitude — 1 point

$V = IR$

$I = \dfrac{V}{R} = \dfrac{0.30\text{ V}}{5.0\ \Omega} = 0.06\text{ A}$

For correct direction, i.e., counterclockwise — 1 point

(c) 3 points

For a correct expression for the power dissipated in the coil — 1 point

$P = IV$ OR $P = I^2R$ OR $P = V^2/R$

For correct substitution of answers from (a) and/or (b) into one of these expressions (Must recognize that $V = \mathcal{E}_{tot}$) — 1 point

For example, $P = (0.06\text{ A})(0.30\text{ V})$

For correct calculation including correct units — 1 point

$P = 0.018$ W

Question 4 (continued)

Distribution of points

(d) 3 points

The force on the right side is zero, and forces on the top and bottom sides cancel, so the net force is that on the left side.

For the correct expression for the force on a straight wire (force per turn in this situation) in a magnetic field — 1 point

$F = BI\ell\sin\theta$ OR $F = BI\ell$ (recognizing that the wire is perpendicular to the field)

For correct substitutions — 1 point

$F = (0.20\text{ T})(0.60\text{ A})(0.15\text{ m})$

$F = 0.0018\text{ N}$

For recognizing that with 20 turns the total force on the left side of the coil is 20 times the force per turn — 1 point

$F_{\text{tot}} = 0.036\text{ N}$

Alternate Solution — *Alternate points*

For using one of the equations $P = Fv\sin\theta$ OR $P = \dfrac{W}{t} = \dfrac{Fd}{t}$ — *1 point*

$$F = \frac{P}{v\sin\theta} \quad \text{OR} \quad F = \frac{Pt}{d}$$

For correct substitutions (both approaches yield same value) — *1 point*

$$F_{\text{tot}} = \frac{(0.018\text{ W})(0.50\text{ s})}{0.25\text{ m}}$$

For correct answer — *1 point*

$F_{\text{tot}} = 0.036\text{ N}$

(e) 3 points

For recognition that doubling the number of turns doubles the total emf, which would tend to increase the current — 1 point

For recognition that doubling the number of turns doubles the total resistance, which would tend to decrease the current — 1 point

For putting these together to show that the current is unchanged — 1 point

$$I_f = \frac{\varepsilon_f}{R_f} = \frac{2\varepsilon_i}{2R_i} = \frac{\varepsilon_i}{R_i} = I_i$$

<u>Note</u>: The third point was awarded for an indication that the current is unchanged, even if the justification was wrong.

Question 5

10 points total | **Distribution of points**

(a) 2 points

For recognizing that $P_A = P_B$ — 1 point

At point A: $P_1V_1 = nRT_1$

At point B: $P_1\frac{V_1}{2} = nRT_2$

Dividing these equations and solving for T_2:

$$\frac{P_1V_1}{P_1\frac{V_1}{2}} = \frac{T_1}{T_2}$$

$$2 = \frac{T_1}{T_2}$$

For the correct answer — 1 point

$T_2 = T_1/2$

(b) 2 points

Answer can be obtained by either comparing points B & C or points A & C using the ideal gas law at each point

For recognizing that $T_C = 2T_B$ OR $T_C = T_A$ — 1point

<u>Comparing points B & C</u>

At point B: $P_1\frac{V_1}{2} = nR\frac{T_1}{2}$

At point C: $P_2\frac{V_1}{2} = nRT_1$

Dividing the equations and solving for P_2:

$$\frac{P_1\frac{V_1}{2}}{P_2\frac{V_1}{2}} = \frac{nR\frac{T_1}{2}}{nRT_1}$$

$$\frac{P_1}{P_2} = \frac{1}{2}$$

For the correct answer

$P_2 = 2P_1$

<u>Comparing points C & A</u>

At point A: $P_1V_1 = nRT_1$

At point C: $P_2\frac{V_1}{2} = nRT_1$

Dividing the equations and solving for P_2:

$$\frac{P_1V_1}{P_2\frac{V_1}{2}} = 1$$

$$\frac{2P_1}{P_2} = 1$$

For the correct answer — 1 point

$P_2 = 2P_1$

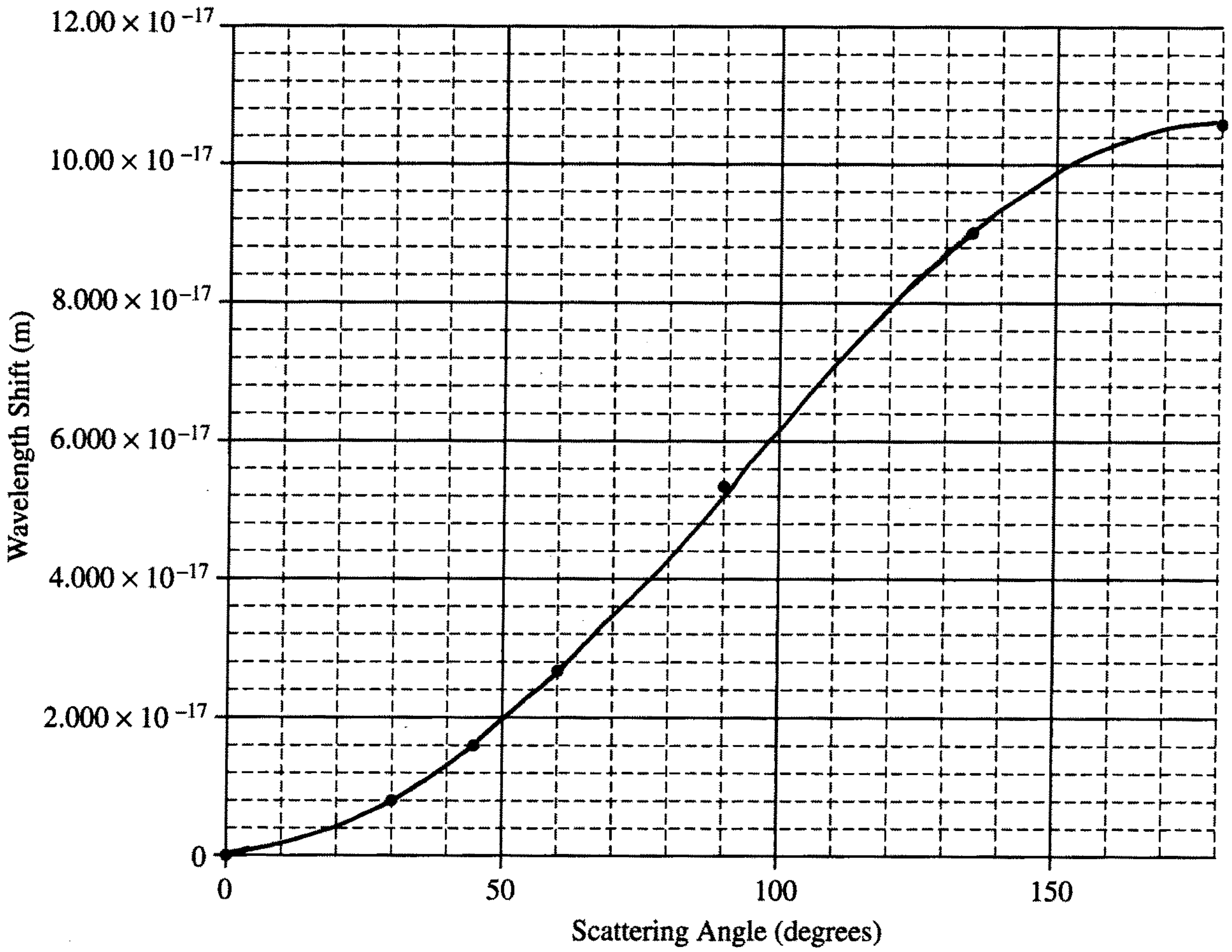
Question 5 (continued)

		Distribution of points
(c)	2 points	
	For correct equation for work done on the gas (regardless of sign) OR for recognition that work is the area under the line *AB* on the graph. (No work is done from *B* to *C* because the change in volume is zero.) $W = -P\,\Delta V$ $W = -P_1\left(\frac{V_1}{2} - V_1\right)$	1 point
	For the correct answer including correct sign $W = \frac{P_1V_1}{2}$	1 point
(d)	4 points	
	Heat was added to the gas in processes *BC* and *CA*, but not in *AB*. For two or three correct indications of whether or not heat was added to the gas in each process (The absence of a check mark was taken as in indication that heat was not added.)	1 point
	For a reasonable justification for process *AB.* This point was awarded only if this process was indicated correctly (i.e., not checked) <u>Example</u>: The volume decreases so the work done on the gas is positive. The temperature decreases so the change in internal energy is negative. Therefore $Q = \Delta U - W$ is negative. Heat is expelled from the gas. (Note: Answer must mention work for credit.)	1 point
	For a reasonable justification for process *BC.* This point was awarded only if this process was indicated correctly (i.e., checked) <u>Example</u>: There is no change in volume so no work is done. The temperature increases so the internal energy increases. Therefore $Q = \Delta U - W$ is positive. (This point also awarded for only referring to increasing temperature or for referring to increasing speed of the molecules.)	1 point
	For a reasonable justification for process *CA*. This point was awarded only if this process was indicated correctly (i.e., checked). <u>Example</u>: There is no change in temperature or internal energy. The volume increases so work is done by the gas. Heat needs to be added to the gas to do this work.	1 point

Question 6

10 points total **Distribution of points**

(a) 3 points



For a smooth curve passing through or very close to all plotted points — 3 points

Partial credit points could be awarded for curves of lesser quality.

<u>For example:</u>

Showing all the data points connected by straight-line segments earned 2 points.

Curves that generally fit the data points at small angles, but are concave upward for the whole range earned 1 or 2 points depending on how badly the curve misses the points at higher angles.

A single straight "best fit" line or really bad curve earned 1 point.

A curve that was monotonically decreasing earned no points.

Question 6 (continued)

Distribution of points

(b) 3 points

For reading the wavelength shift from the graph	1 point
From the graph shown, the wavelength shift at $120°$ is 8.000×10^{-17} m .	
The photon loses energy, which means the wavelength increases.	
For adding (not subtracting) the wavelength shift to the original wavelength	1 point
$\lambda_s = 1.400 \times 10^{-14}\ \text{m} + 8.000 \times 10^{-17}\ \text{m}$	
For correct answer	1 point
$\lambda_s = 140.8 \times 10^{-16}\ \text{m} = 1.41 \times 10^{-14}\ \text{m}$	

(c) 2 points

For using the de Broglie equation to calculate momentum (even if a value from (b) that was actually $\Delta\lambda$ was substituted)	1 point
$\lambda_s = h/p_s$ OR $p = h/\lambda$	
$p_s = h/\lambda_s$	
$p_s = \left(6.63 \times 10^{-34}\ \text{J•s}\right)/\left(1.408 \times 10^{-14}\ \text{m}\right)$	
For consistent answer including correct units	1 point
$p_s = 4.71 \times 10^{-20}\ \text{kg•m/s}$	

Note: The answer point could also be awarded if the value of $\lambda_s = \lambda_i - \Delta\lambda$ was used instead of the correct relationship.

(d) 2 points

For use of conservation of energy	1 point

$\Delta E_{nuc} = -\Delta E_{photon}$

$$\Delta E_{photon} = \Delta(hf) = \Delta\left(\frac{hc}{\lambda}\right) \text{ OR } \Delta E_{photon} = \Delta(pc) = \Delta\left(\frac{hc}{\lambda}\right)$$

$$\Delta E_{nuc} = -\left(\frac{hc}{\lambda_s} - \frac{hc}{\lambda_i}\right) = hc\left(\frac{1}{\lambda_i} - \frac{1}{\lambda_s}\right)$$

$$\Delta E_{nuc} = \left(1.99 \times 10^{-25}\ \text{J} \cdot \text{m}\right)\left(\frac{1}{1.400 \times 10^{-14}\ \text{m}} - \frac{1}{1.408 \times 10^{-14}\ \text{m}}\right)$$

For the correct answer	1 point

$\Delta E_{nuc} = 8.08 \times 10^{-14}$ J (or 510 keV)

Note: The answer point was awarded for correct use of whatever λ_s was obtained from part (b), but not for using the value of $\Delta\lambda$.