AP® Physics B
2002 Scoring Guidelines
Form B

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General Notes About
2002 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 approximate value $g = 10 \text{ m/s}^2$ for ease of calculation, but use of 9.8 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, in calculations of mass differences in a nuclear reaction, rounding to too few digits can lose the accuracy required to determine a mass difference.

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Question 1

15 points total **Distribution of points**

(a) 4 points

For any statement indicating that impulse equals change in momentum — 1 point

For any statement indicating that impulse can be determined from the area under the graph — 1 point

$\Delta p = F\Delta t =$ area under the curve

$$\Delta p = 2\left(\frac{1}{2}\right)\left(0.5\times10^{-3}\ \text{s}\right)\left(10\times10^{3}\ \text{N}\right) = 5\ \text{N}\cdot\text{s}$$

For recognizing that the impulse on the 2 kg cart is negative, and subtracting it from the initial momentum of the cart — 1 point

$$p_{2\ \text{kg after}} = (2.0\ \text{kg})(3.0\ \text{m/s}) - 5\ \text{N}\cdot\text{s} = 1\ \text{N}\cdot\text{s}$$

$$p_{2\ \text{kg after}} = (2\ \text{kg})v_{2\ \text{kg after}} = 1\ \text{N}\cdot\text{s}$$

For the correct answer — 1 point

$v_{2\ \text{kg after}} = 0.5\ \text{m/s}$ to the right

(b) 3 points

For any statement of conservation of momentum — 1 point

$p_{2\ \text{kg before}} = p_{2\ \text{kg after}} + p_{m\ \text{after}}$

For correct substitutions — 1 point

$6\ \text{N}\cdot\text{s} = 1\ \text{N}\cdot\text{s} + m(1.6\ \text{m/s})$

For the correct answer — 1 point

$m = 3.1$ kg

Alternate solution — *Alternate points*

The average acceleration is the average force divided by the mass

$\bar{a} = \bar{F}/m$

For calculating the average acceleration — *1 point*

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{1.6\ \text{m/s}}{1\times10^{-3}\ \text{s}} = 1600\ \text{m/s}^2$$

For calculating the average force — *1 point*

$$\bar{F} = \frac{1}{2}(0 + 10{,}000)\ \text{N} = 5000\ \text{N}$$

$$m = (5000\ \text{N})/(1600\ \text{m/s}^2)$$

For the correct answer — *1 point*

$m = 3.1$ kg

Note: An alternate solution is to do part (b) first using impulse, in which case the first two points noted above for part (a) could be earned. Then conservation of momentum can be used to solve part (a), so the first point noted above for part (b) could be earned.

Question 1 (cont'd.)

Distribution of points

(c) 2 points

For using the slope of the graph to determine the acceleration — 1 point

$a = \text{ slope } = \dfrac{(0.5 - 1.6)\ \text{m/s}}{(3.5 - 2)\ \text{s}}$

For the correct answer — 1 point

$a = -0.73\ \text{m/s}^2$

(d) 3 points

For using the area under the curve or one of the equations $d = vt$ or $d = \bar{v}t$ — 1 point

For calculating a distance for each segment of the graph — 1 point

$d_1 = (1.6\,\text{m/s})(2\ \text{s}) = 3.2\ \text{m}$

$d_2 = \dfrac{(1.6 + 0.5)\ \text{m/s}}{2}(1.5\ \text{s})$ or $(1.6\ \text{m/s})(1.5\ \text{s}) + \dfrac{1}{2}(-0.73\ \text{m/s}^2)(1.5\ \text{s})^2$

$d_2 = 1.6\ \text{m}$

$d_3 = (0.5\ \text{m/s})(1.5\ \text{s}) = 0.8\ \text{m}$

$d_{\text{tot}} = d_1 + d_2 + d_s$

For the correct answer — 1 point

$d_{\text{tot}} = 5.5\ \text{m}$

(e) 3 points

The acceleration is negative, so the cart must be moving opposite to the force of gravity, which is the only force acting on it.

For indicating that the ramp goes up — 1 point

For using conservation of energy — 1 point

$mgh = \dfrac{1}{2}m\left(v_i^2 - v_f^2\right)$

$h = \dfrac{1}{2(10\ \text{m/s}^2)}\left((1.6\ \text{m/s})^2 - (0.5\ \text{m/s})^2\right)$

For the correct answer — 1 point

$h = 0.12\ \text{m}$

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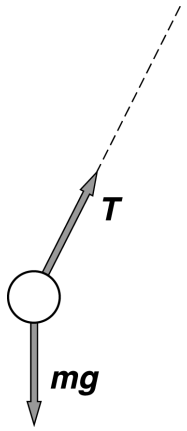
Question 2

15 points total **Distribution of points**

(a) 3 points



1 point for each correctly drawn and appropriately labeled force — 2 points
For no incorrect forces — 1 point

The horizontal and vertical components of the tension were acceptable if properly labeled

(b) 3 points

For indicating that the sum of the vertical forces is zero — 1 point
$\sum F_y = 0$

For correctly substituting the applicable forces — 1 point
$T\cos\theta - mg = 0$

For the correct answer — 1 point
$m = \dfrac{T\cos\theta}{g}$

Question 2 (cont'd.)

Distribution of points

(c) 4 points

The centripetal force is supplied by the horizontal component of the tension
$F_c = T\sin\theta$

For using a correct expression for the centripetal force F_c — 1 point

$\frac{mv^2}{r} = T\sin\theta$

For eliminating the tension or the mass using the answer to part (b) — 1 point

$\frac{mv^2}{r} = mg\frac{\sin\theta}{\cos\theta} = mg\tan\theta$ OR $\frac{T\cos\theta\ v^2}{gr} = T\sin\theta$

For using the substitution $r = \ell\sin\theta$ — 1 point

$\frac{mv^2}{\ell\sin\theta} = mg\tan\theta$ OR $\frac{T\cos\theta\ v^2}{g\ell\sin\theta} = T\sin\theta$

For the correct answer — 1 point

$v = \sqrt{g\ell\sin\theta\tan\theta}$ or $\sqrt{\frac{g\ell\sin^2\theta}{\cos\theta}}$

(d) 3 points

For using a correct expression for period or frequency — 1 point

$T = \frac{2\pi r}{v}$ or $f = \frac{v}{2\pi r}$

For substituting the velocity from part (c) — 1 point

For the correct answer (unsimplified acceptable) — 1 point

$f = \frac{\sqrt{g\ell\sin\theta\tan\theta}}{2\pi\ell\sin\theta}$ or $\frac{1}{2\pi}\sqrt{\frac{g\tan\theta}{\ell\sin\theta}}$ or $\frac{1}{2\pi}\sqrt{\frac{g}{\ell\cos\theta}}$

(e) 2 points

For any indication that the initial velocity of the ball is horizontal — 1 point

For any indication that the subsequent trajectory is parabolic — 1 point

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Question 3

15 points total **Distribution of points**

(a) 6 points

For the correct expression for the total resistance in the parallel branch — 1 point

$\frac{1}{R_p} = \frac{1}{6\ \Omega} + \frac{1}{3\ \Omega}$

For the correct value for the parallel branch — 1 point

$R_p = 2\ \Omega$

For correctly combining R_p in series with the remaining resistance — 1 point

$R_t = 2\ \Omega + 3\ \Omega$

For the correct total resistance — 1 point

$R_t = 5\ \Omega$

For using Ohm's law — 1 point

$I = V/R = 9\ \text{V}/5\ \Omega$

For the correct answer — 1 point

$I = 1.8\ \text{A}$

(b) 3 points

For indicating that bulb *A* is brightest — 1 point

For a correct justification based on the power expended by each bulb (either quantitative reasoning or direct calculations) — 2 points

For example:

$P = I^2 R$

$P_A = (1.8\ \text{A})^2 (3\ \Omega) = 9.7\ \text{W}$

One third of the current flows through bulb *B* and two-thirds through bulb *C*

$P_B = \left(\frac{1.8\ \text{A}}{3}\right)^2 (6\ \Omega) = 2.2\ \text{W}$ and $P_C = \left(\frac{2(1.8\ \text{A})}{3}\right)^2 (3\ \Omega) = 4.3\ \text{W}$

One justification point was awarded for only discussing the relative currents in the bulbs or the relative voltages across them.

Question 3 (cont'd.)

Distribution of points

(c)

i. 2 points

For indicating that the brightness of bulb *A* decreases — 1 point
For a correct justification — 1 point
For example: The total resistance increases so the current through bulb *A* decreases, thus decreasing its power output

ii. 2 points

For indicating that the brightness of bulb *B* increases — 1 point
For a correct justification — 1 point
For example: The current through bulb *B* increases, thus increasing its power output

iii. 2 points

For indicating that the brightness of bulb *C* decreases — 1 point
For a correct justification — 1 point
For example: The current through bulb *C* is now zero, so the bulb goes out

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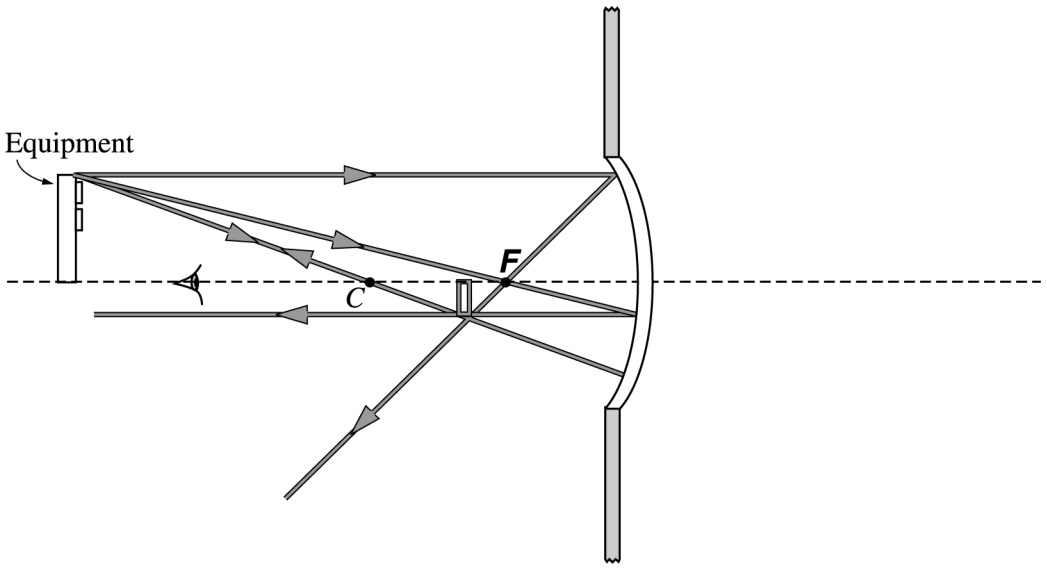
Question 4

15 points total **Distribution of points**

(a) 3 points

For indicating that the focal length is half the radius of curvature 3 points

(b) 3 points



1 point each for any two correct principal rays (the three principal rays are shown above) 2 points
For a correctly drawn image 1 point

(c)

i. 1 point

For indicating the image is inverted 1 point

ii. 1 point

For indicating the image is real 1 point

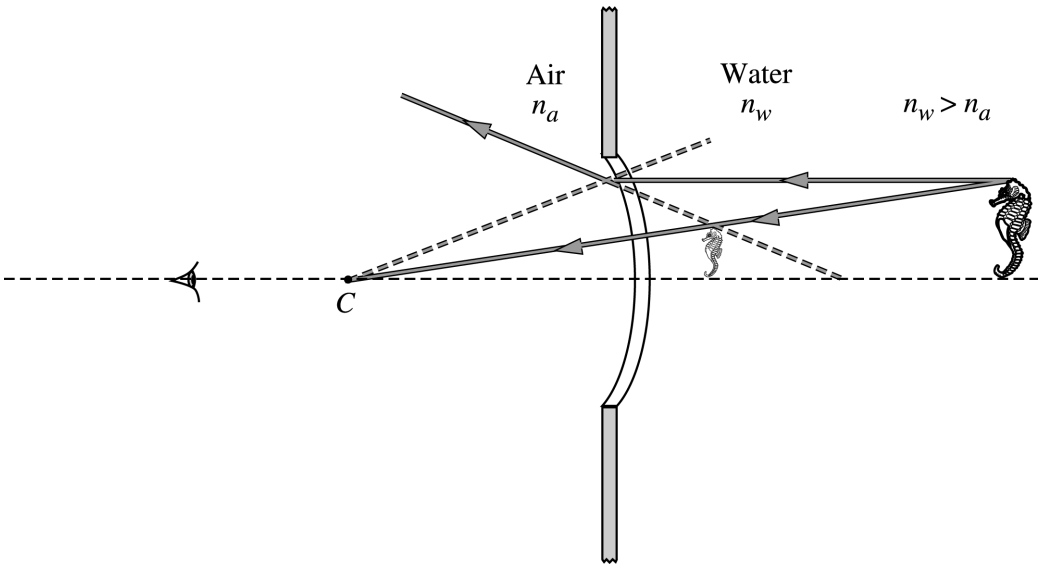
iii. 1 point

For indicating the image is smaller than the object 1 point

Question 4 (cont'd.)

Distribution of points

(d) 3 points



1 point each for any two correct rays (i.e. showing no refraction for normal incidence and refraction away form the normal for non-normal incidence) — 2 points

For a correctly drawn image — 1 point

(e)

i. 1 point

For indicating the image is upright — 1 point

ii. 1 point

For indicating the image is virtual — 1 point

iii. 1 point

For indicating the image is smaller than the object — 1 point

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Question 5

10 points total **Distribution of points**

(a) 2 points

For indicating the correct polarity, negative on the left and positive on the right 2 points

(b) 2 points

Using the expression for the magnitude of the electric field between two parallel plates:
$E = V/d$

For correct substitutions 1 point
$V = (5000\ \text{N/C})(0.02\ \text{m})$

For the correct answer 1 point
$V = 100\ \text{V}$

(c) 2 points

Using the expression for the capacitance of a parallel-plate capacitor:
$C = \frac{\epsilon_0 A}{d}$

For correct substitutions 1 point
$C = \frac{\left(8.85 \times 10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}\right)\left(0.3\ \text{m}^2\right)}{0.02\ \text{m}}$

For the correct answer 1 point
$C = 1.3 \times 10^{-10}\ \text{F}$

(d) 2 points

Using the expression for the force and substituting:
$F = qE = \left(1.6 \times 10^{-19}\ \text{C}\right)(5000\ \text{N/C})$

For the correct magnitude of the force 1 point
For the correct direction 1 point
$F = 8.0 \times 10^{-16}\ \text{N}$ to the right

Question 5 (cont'd.)

Distribution of points

(e) 2 points

The potential difference between the center and one of the plates is 50 V

For correctly equating the work to the kinetic energy, and using 50 V for the potential difference — 1 point

$$W = qV = \frac{1}{2}mv^2$$

Solving for v:

$$v = \sqrt{2qV/m} = \sqrt{2\left(1.6\times10^{-19}\text{ C}\right)(50\text{ V})\Big/\left(9.11\times10^{-31}\text{ kg}\right)}$$

For the correct answer — 1 point

$$v = 4.2\times10^{6}\text{ m/s}$$

Alternate solution — *Alternate points*

For determining the acceleration — *1 point*

$$a = F/m = \left(8\times10^{-16}\text{ N}\right)\Big/\left(9.11\times10^{-31}\text{ kg}\right) = 8.8\times10^{14}\text{ m/s}^2$$

Using an applicable kinematic equation

$$v_f^2 = v_0^2 + 2ad$$

$$v_f^2 = 0 + 2\left(8.8\times10^{14}\text{ m/s}^2\right)(0.01\text{ m})$$

For the correct answer — *1 point*

$$v = 4.2\times10^{6}\text{ m/s}$$

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Question 6

10 points total | **Distribution of points**

(a) 3 points

For using the equation for an ideal gas — 1 point

$pV = nRT$

$p = nRT/V$

For correct substitutions — 1 point

$p = (4.5 \text{ mol})(8.31 \text{J/mol} \cdot \text{K})(300 \text{ K}) \big/ \left(8 \times 10^{-3} \text{ m}^3\right)$

For the correct answer — 1 point

$p = 1.40 \times 10^6 \text{ Pa}$

(b) 3 points

For the correct relationship between pressures and temperatures at constant volume — 1 point

$\frac{p_1}{T_1} = \frac{p_2}{T_2}$

Solving for p_2:

$p_2 = \frac{p_1 T_2}{T_1}$

For substituting the value of p_1 from part (a) — 1 point

$p_2 = \frac{\left(1.40 \times 10^6 \text{ Pa}\right)(273 \text{ K})}{300 \text{ K}}$

For the correct answer — 1 point

$p_2 = 1.28 \times 10^6 \text{ Pa}$

Alternate solution | *Alternate points*

For using the equation for an ideal gas — *1 point*

$pV = nRT$

$p = nRT/V$

For correct substitutions — *1 point*

$p = (4.5 \text{ mol})(8.31 \text{J/mol} \cdot \text{K})(273 \text{ K}) \big/ \left(8 \times 10^{-3} \text{ m}^3\right)$

For the correct answer — *1 point*

$p = 1.28 \times 10^6 \text{ Pa}$

Question 6 (cont'd.)

Distribution of points

(c) 4 points

For using the mass of the water times its heat of fusion as the total heat used in melting ice — 1 point

For using the correct expressions for the heat lost by the canister and neon — 1 point

$m_w L_w = nc_n \Delta T + m_s c_s \Delta T$

$m_w = \dfrac{\left(nc_n \Delta T + m_s c_s \Delta T\right)}{L_w}$

For using the correct ΔT — 1 point

$m_w = \dfrac{(4.5 \text{ mol})(12.5 \text{ J/mol} \cdot \text{K})(300 \text{ K} - 273 \text{ K}) + (12.0 \text{ kg})(448 \text{ J/kg} \cdot \text{K})(300 \text{ K} - 273 \text{ K})}{3.33 \times 10^5 \text{ J/kg}}$

For the correct answer — 1 point

$m_w = 0.440 \text{ kg}$

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Question 7

10 points total | **Distribution of points**

(a) 5 points

For using the expression for deBroglie wavelength — 1 point
$\lambda = h/p$ or h/mv

Determining the speed from the kinetic energy K:

$K = \frac{1}{2}mv^2$

$v = \sqrt{2K/m}$

For including the conversion of K from eV to joules — 1 point

For correctly determining the velocity — 1 point

$v = \sqrt{2(3.70\text{ eV})\left(1.6\times10^{-19}\text{ J/eV}\right)\Big/\left(9.11\times10^{-31}\text{ kg}\right)} = 1.14\times10^{6}\text{ m/s}$

For correctly substituting this velocity into the equation for the wavelength — 1 point

$\lambda = \left(6.63\times10^{-34}\text{ J}\cdot\text{s}\right)\Big/\left(9.11\times10^{-31}\text{ kg}\right)\left(1.14\times10^{6}\text{ m/s}\right)$

For the correct answer — 1 point

$\lambda = 6.38\times10^{-10}\text{ m}$

(b) 2 points

For using the correct equation relating wavelength to energy, or an equivalent combination of equations — 1 point

$\lambda = hc/E$ (or a combination such as $E = hf$ and $f = c/\lambda$)

The energy E is equal to the kinetic energy of the electrons. Substituting for hc and E:

$\lambda = \left(1.24\times10^{3}\text{ eV}\cdot\text{nm}\right)\Big/(3.70\text{ eV})$ or equivalent calculation using joules

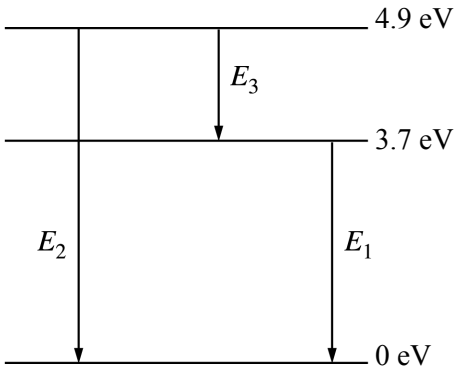
For the correct answer

$\lambda = 335\text{ nm}$

Question 7 (cont'd.)

Distribution of points

(c) 3 points



$E_1 = 3.7$ eV
$E_2 = 4.9$ eV
$E_3 = 1.2$ eV

For a diagram with correctly labeled levels or some identification of the relative energies 1 point
For an indication of the additional transition of 1.2 eV 2 points