AP Physics B
1999 Scoring Guidelines

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1999 Physics B Solutions — **Distribution of points**

Question 1 (15 points)

(a) 3 points

For a correct expression of Newton's Gravitation law — 1 point

$F = \frac{GM_1M_2}{R^2}$

For correct substitution/calculation in formula — 1 point

$g_{Mars} = \frac{GM_M}{R_M^2} = \frac{G(0.11)M_E}{(0.53R_E)^2} = \frac{0.11}{(0.53)^2} g_E$

For expressing g_M in terms of g_E — 1 point

$g_M = \frac{0.11}{(0.53)^2} g_E$ OR $g_M = 0.39 g_E$

However, the third point for expressing g_M in terms of g_E is not awarded if no points have been awarded up to that part.

(b) 2 points

For the correct formula for weight: $W = Mg$ — 1 point

For the correct value of g for Mars, where any value of g signifying Mars is acceptable, such as $0.39g_E$, 3.8 m/s^2, g_{Mars}, $\frac{0.11}{(0.53)^2} g_E$, etc. — 1 point

$W = (11.5\,\text{kg})(3.8\,\text{m/s}^2) = 44\,\text{N}$

(Alternate solution) — *(Alternate points)*

For correct calculation using $F = \frac{GM_1M_2}{R^2}$, where the student has calculated the mass of Mars, the radius of Mars and uses the correct mass of Sojourner. (A student needs to have memorized the mass of the Earth and its radius to do this.) — *2 points*

(c) 2 points

For indication that sine or cosine is needed as a necessary factor for computation of N — 1 point

For correct formula and calculation — 1 point

$N = Mg_M \cos\theta$

$N = (11.5\text{ kg})(3.8\text{ m/s}^2)\cos 20° = 41\text{ N}$

OR $N = (11.5\text{ kg})(3.8\text{ m/s}^2)\sin 70° = 41\text{ N}$

Question 1 (continued)

(d) 2 points

For correct statement that $F_{net} = 0$ — 1 point
For a correct reason such as $a = 0$, OR v = constant, OR Newton's First law — 1 point

(e) 3 points

For a correct formula for power — 1 point
$P = \frac{W}{t}$
For a correct formula for distance — 1 point
$d = vt$
For a correct calculation of distance — 1 point
$d = \frac{vW}{P} = \frac{(6.7 \times 10^{-3}\ \text{m/s})(5.4 \times 10^{5}\ \text{J})}{10\ \text{W}}$
$d = 362\ \text{m}$

(Alternate solution) — *(Alternate points)*

For correct formulas for work and power — *1 point*
$W = Fd$ and $P = Fv$
For combining these to yield a correct formula for the distance — *1 point*
$d = \frac{vW}{P}$
For a correct calculation — *1 point*
$d = \frac{(6.7\times10^{-3}\ \text{m/s})(5.4\times10^{4}\ \text{J})}{10\ \text{W}} = 362\ \text{m}$

(f) 3 points

For correct formula $P = Fv$, so $F = \frac{P}{v}$ — 1 point
For correct substitutions using the correct percentage of 0.01% — 1 point
$F = \frac{(0.0001)(10\text{W})}{6.7\times10^{-3}\ \text{m/s}}$
For correct calculation of force — 1 point
$F = 0.15$ N (0.149 N and 0.1 N were acceptable)

Question 2 (15 points)

(a) 3 points

For the expression $V = W/q$ — 1 point
For the expression $W = \Delta K = \frac{1}{2}mv^2$ — 1 point
For correct substitutions and answer — 1 point
$V = \frac{mv^2}{2q} = \frac{(9.31\times10^{-31}\ \text{kg})(6.0\times10^{7}\ \text{m/s})^2}{2(1.6\times10^{-19}\ \text{C})}$
$V = 1.0\times10^{4}\ \text{V}$

(b) 2 points

For correct answer, i.e., upper plate indicated as the one at the higher potential — 1 point

For proper justification for correct answer — 1 point
Examples: F_e is up, therefore E is down; E points in the direction of decreasing potential.
Electrons travel toward higher potential.
The justification point was not awarded if the lower plate was indicated as being at the higher potential

(c)

i. 1 point

For $v_x = \frac{x}{t}$ — 1 point
$t = \frac{x}{v_x} = \frac{0.04\,\text{m}}{6.0\times10^{7}\ \text{m/s}} = 6.7\times10^{-10}\ \text{s}$

ii. 5 points

For each of the following relationships necessary in the solution:
$V = Ed$ — 1 point
$E = F/q$ — 1 point
$F = ma$ — 1 point
$y = \frac{1}{2}at^2$, $v_{0y} = 0$ — 1 point
For correct substitutions and answer — 1 point
$y = \frac{qVt^2}{2dm} = \frac{(1.6\times10^{-19}\ \text{C})(200\ \text{V})(6.7\times10^{-10}\ \text{s})^2}{2(0.012\ \text{m})(9.1\times10^{-31}\ \text{kg})}$
$y = 6.5\times10^{-4}\ \text{m}$

1999 Physics B Solutions — **Distribution of points**

Question 2 (continued)

(d) 2 points

For a correct qualitative comparison of F_g *vs* F_E, or g *vs* a_E, or the distances traveled — 1 point
Examples: F_g is much less than F_E
g is much less than a_E

For additional quantitative comparison of F_g *vs.* F_E or g *vs.* a_E by computing actual numerical values — 1 point
Example: $F_g = mg = (9.1 \times 10^{-31}\ \text{kg})(9.8\ \text{m/s}^2) = 8.9 \times 10^{-30}\ \text{N}$

$$F_E = qE = \frac{qV}{d} = \frac{(1.6 \times 10^{-19}\ \text{C})(200\ \text{V})}{0.012\ \text{m}} = 1.9 \times 10^{-14}\ \text{N}$$

so $F_g \ll F_E$

(e) 2 points

For indicating that the path is a straight line, not horizontal — 1 point
For correct reason, such as an indication that $F = 0$, or $a = 0$. — 1 point

1998 Physics B Solutions — **Distribution of points**

Question 3 (15 points)

(a) 4 points

As the cart rolls down the ramp, potential energy is changed to kinetic energy.
For indicating conservation of energy — 1 point
Initial energy = final energy
For indicating the proper energies — 1 point
This point given for either of the following two equations
P.E. = K.E.

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

For making the proper substitution of y_0 for h — 1 point

$$mgy_0 = \frac{1}{2}mv^2$$

For the correct answer — 1 point

$$v = \sqrt{2gy_0}$$

Alternate solution — (*Alternate points*)
Find acceleration using Newton's 2nd law and use kinematic equations
For making the proper substitution for the distance traveled — *1 point*
For the correct answer — *3 points*

(b)
i. 2 points

As the loop enters the field, the magnetic flux changes, resulting in an induced emf, which can be found using Faraday's law or more simply from the given equation $\mathcal{E} = B\ell v$
For correct substitution of one value, h for ℓ, or $\sqrt{2gy_0}$ for v from part (a) — 1 point
For the correct answer, which requires both substitutions into this equation — 1 point

$$\mathcal{E} = Bh\sqrt{2gy_0}$$

(b)
ii. 2 points

The current in the loop is related to the resistance and voltage by the equation $V = IR$, or $I = \frac{V}{R}$
For the correct substitution of $Bh\sqrt{2gy_0}$ for V — 1 point
For the correct answer — 1 point

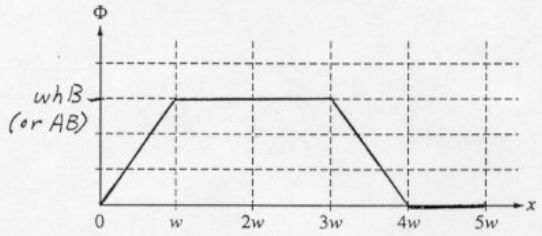
$$I = \frac{Bh\sqrt{2gy_0}}{R}$$

Question 3 (continued)

(c) 1 point

As the loop enters the field, a current is induced in the loop so as to oppose the change in flux.
For an indication that the current is counterclockwise, as shown by arrows or words. 1 point

(d)
i. 3 points



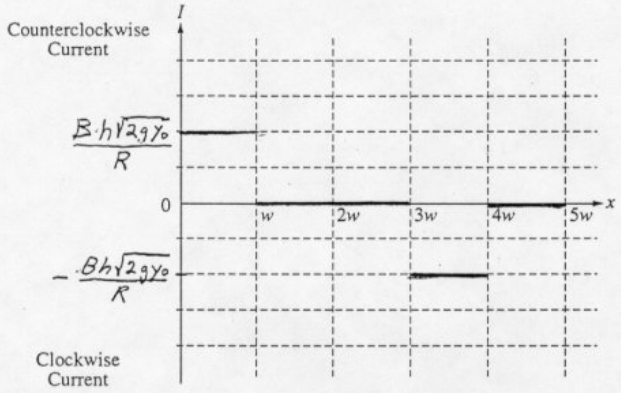
For giving the correct label on the vertical axis as *whB* or *BA* 1 point
(The label could be at any point on the vertical axis as long as it was consistent with the graph drawn.)
For drawing a horizontal, non-zero line between *w* and 3*w* 1 point
For straight lines of constant and proper slope between 0 and *w* and between 3*w* and 4*w* 1 point
(The first has positive slope; the second has negative slope.)
The flux is zero from 4*w* to 5*w*, but it was not required to show this on the graph.

(If the last two points above were not awarded, 1 point was given if the shape of the graph was a trapezoid with parallel top and bottom lines. For example, this point would be given if the graph were horizontal between *w* and 2*w* with straight sloped lines between 0 and *w* and between 2*w* and 3*w*.)

1999 Physics B Solutions **Distribution of points**

Question 3 (continued)

(d)
ii. 3 points

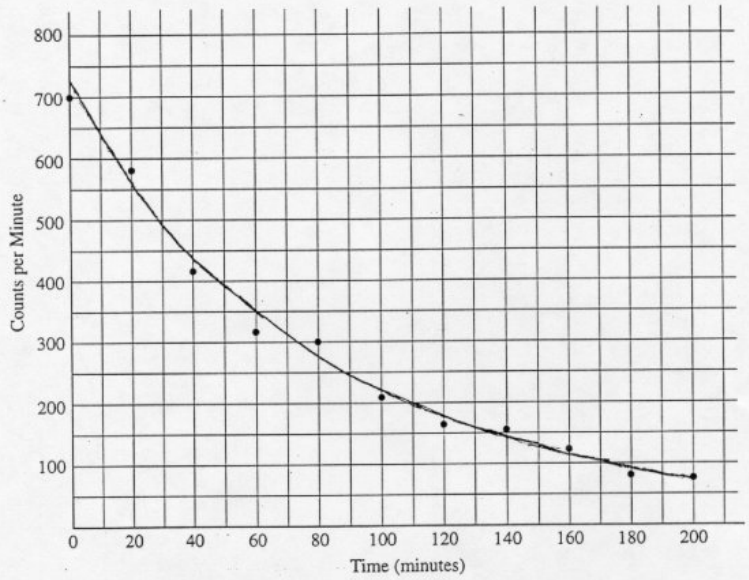


For proper labeling of the graph with $I = \frac{Bh\sqrt{2gy_0}}{R}$ or the answer found in part (b)ii. 1 point
(The label could be at any point on the vertical axis as long as it was consistent with the graph drawn.)
For recognizing that the current was zero between *w* and 3*w* and showing it with a horizontal line 1 point
For showing horizontal, non-zero lines of opposite sign between 0 and *w* and between 3*w* and 4*w* 1 point
The current is zero from 4*w* to 5*w*, but it was not required to show this on the graph.

(Because of the labeling of the axis "Counterclockwise Current" as positive, which was confusing to some, starting negative (from 0 to *w*) and ending positive (from 3*w* to 4*w*) was also acceptable for the third point above. Using slopes consistent with (d)i. also received the two graphing points.)

Question 4 (15 points)

(a) 2 points



For a smooth curve — 1 point
For reasonable best fit (with dots above and below curve) — 1 point

(No points awarded for (a) for a straight line or a "point-to-point" curve)

(b) 2 points

For answer between 50 and 64 minutes, or for answer consistent with incorrect curve, including straight line — 1 point
For showing or explaining that one can read from the graph the time at which the count is halved, or by use of the equation $N = N_0 e^{-\lambda t}$ and two points (data points or points on curve) — 1 point

Question 4 (continued)

(c) 3 points

For indicating the atomic mass and mass number of the alpha particle: ${}^{4}_{2}\alpha$ — 1 point
For showing $Z = 81$ — 1 point
For showing $A = 208$ — 1 point
(Full credit awarded for $Z = 81$ and $A = 208$ alone)

(Alternate partial credit answers) — *(Alternate points)*
$Z = 208$ $A = 81$ — *2 points*
$Z = 79$ $A = 210$ — *2 points*
$Z = 210$ $A = 79$ — *1 point*
Show incorrect values for the alpha particle, but consistent Z and A given those values — *2 points*
Show incorrect values for the alpha particle, consistent Z and A given those values, but Z and A reversed — *1 point*

(d)

i. 4 points

For conversion to like units — 1 point
$6.09 \text{ MeV} = 9.7 \times 10^{-13} \text{ J}$
For use of both the kinetic energy and the momentum equation — 1 point

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

$$p = mv$$

Solving for v_α and substituting

$$v_\alpha = \sqrt{2K/m}$$

$$p = m\sqrt{2K/m} = \sqrt{2Km}$$

$$p_\alpha = \sqrt{2\left(9.7 \times 10^{-13} \text{ J}\right)\left(6.64 \times 10^{-27} \text{ kg}\right)}$$

For consistent answer — 1 point
For correct units — 1 point

$p_\alpha = 1.1 \times 10^{-19}$ kg·m/s

Question 4 (continued)

(d)

ii. 2 points

For showing conservation of momentum of Tl and α — 1 point

$p_{Tl} = |-p_\alpha|$

$m_{Tl} v_{Tl} = 1.1 \times 10^{-19}$ kg·m/s

For showing the mass of Tl: (208)(1.67×10^{-27} kg) — 1 point

(This point also given for alternate ways of showing Tl mass, such as $v_{Tl} = \frac{4}{208} v_\alpha$)

$v_{Tl} = 3.28 \times 10^5$ m/s

$K_{Tl} = \frac{1}{2} m v_{Tl}^2 = \frac{1}{2}(208)(1.67 \times 10^{-27}\text{ kg})(3.28 \times 10^5\text{ m/s})^2$

$K_{Tl} = 1.9 \times 10^{-14}$ J

(e) 2 points

$K_{tot} = (K_\alpha + K_{Tl}) N_0 = (9.7 \times 10^{-13}\text{ J} + 1.9 \times 10^{-14}\text{ J})(6.02 \times 10^{23}\text{ mol}^{-1})$

$K = 6 \times 10^{11}$ J or 3.7×10^{24} MeV

For summing $K_\alpha + K_{Tl}$ — 1 point

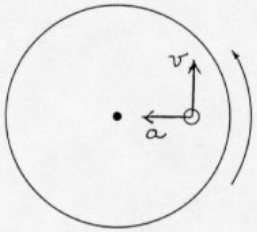
For multiplying total energy by Avogadro's number — 1 point

Alternatively, 1 point awarded for using equation $\Delta E = (\Delta m)c^2$ and mentioning binding energy or mass difference

1999 Physics B Solutions **Distribution of points**

Question 5 (10 points)

(a) 2 points



For any properly labeled, vertical vector pointing upward — 1 point

For any properly labeled, horizontal vector pointing to the left — 1 point

(b) 2 points

$v = \frac{\text{circumference}}{\text{period}} = \frac{2\pi R}{T} = \frac{2\pi(0.14\text{ m})}{1.5\text{ s}} = 0.60$ m/s

For indicating use of circumference for distance traveled in one revolution, such as $\frac{\text{circumference}}{\text{period}}$ OR $\frac{2\pi R}{T}$ — 1 point

For correct answer — 1 point

Answer ranges accepted: $0.187\pi \rightarrow 0.190\pi$ m/s OR $0.58 \rightarrow 0.60$ m/s

(c) 4 points

$F_t = F_c$

$\mu mg = \frac{mv^2}{r}$

$v = \sqrt{\mu r g} = \sqrt{(0.5)(0.14\text{ m})(9.8\text{ m/s}^2)} = 0.83$ m/s

For correct expression of centripetal force — 1 point

For correct expression of frictional force — 1 point

For equating centripetal force to frictional force — 1 point

For correct answer — 1 point

Answer range: 0.80 m/s → 0.84 m/s

Question 5 (continued)

(d) 2 points

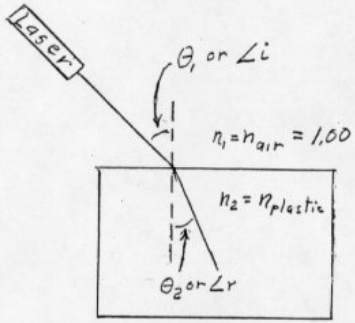
For indicating no change to answer in part (c) 1 point
For any reasonable explanation, such as the masses cancel 1 point

(No points awarded for explanation if it is without statement of no change.)

Question 6 (10 points)

(a) 6 points

For a verbal description of the procedure 1 point
An example of a complete procedure would be: Place the laser on the table so that the beam will travel along the white screen placed on the tabletop. Locate the plastic block so that the light enters it at an angle to the normal to the surface of the plastic. Draw a line representing the surface of the block and the incident ray. Mark where the ray exits the block and remove the block. Draw a ray from the exit point back to the normal and incident ray. Measure the angle of incidence and the angle of refraction. Use Snell's law and the fact that the index of refraction in air is unity to calculate the index of refraction of the plastic.
(Shorter descriptions were also acceptable for this point.)

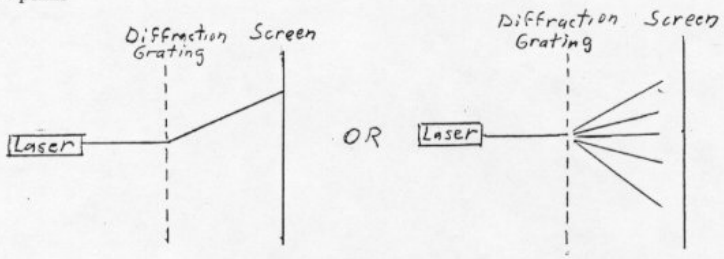


Points awarded for diagram
For all the correct rays drawn and meeting at the interface 1 point
For both θ_1 and θ_2 measured from the normal 1 point
For $\theta_2 < \theta_1$ 1 point
For all quantities being labeled on the diagram, including n_1 and n_2 1 point
(n_1 and n_2 could also be described in the text.)
For the correct equation 1 point

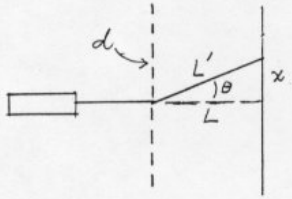
$n_1 \sin\theta_1 = n_2 \sin\theta_2$ OR $\dfrac{\sin\angle i}{\sin\angle r} = n$

Question 6 (continued)

(b) 4 points



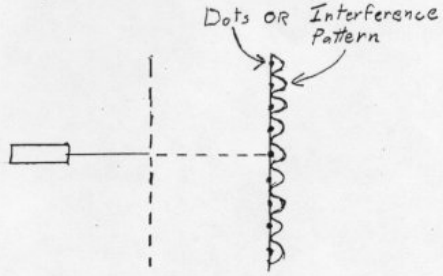
For diagram that must include laser, diffraction grating, screen, and some indication of bending or spreading of light at the grating, as shown above — 1 point



For the labels on the diagram as shown above that correspond to those in the equation used — 1 point
For the equation and any necessary assumptions made — 1 point
The equation could be any one of the following three.

- $n\lambda = d\sin\theta$; d and θ must also be shown in the diagram
- $n\lambda = xd/L'$; d and L' must be shown in the diagram
- $n\lambda = xd/L$; only for small angles using the approximation $\sin\theta \approx \tan\theta$, and d and L must be shown in the diagram

For indicating in some fashion that n is equal to the number of a particular bright line. — 1 point
This could be with a verbal description or by showing successive dots or an interference pattern, as shown in the example below.



Note: Only one diagram was necessary if it included all the features described. For purposes of these standards several diagrams were used to clearly illustrate how the points were awarded.

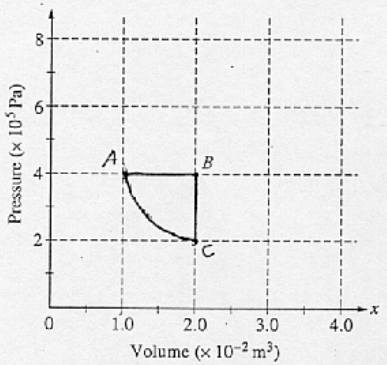
1999 Physics B Solutions **Distribution of points**

Question 7 (10 points)

(a) 2 points

For relating the thermodynamic states at point A and point C — 1 point
Examples: $\frac{p_A V_A}{T_A} = \frac{p_C V_C}{T_C}$ OR $p_A V_A = p_C V_C$
For finding the pressure at point C — 1 point
$p_C = p_A \frac{V_A}{V_C} = (4 \times 10^5\ \text{Pa})\left(\frac{1.0 \times 10^{-2}\ \text{m}^3}{2.0 \times 10^{-2}\ \text{m}^3}\right)$
$p_C = 2.0 \times 10^5\ \text{Pa}$ OR $p_C = 2.0\ \text{atm}$

(b) 4 points



For correctly plotting and labeling Point A — 1 point
For correctly plotting and labeling Point C — 1 point
For indicating that path CA is along an isotherm — 1 point
For drawing a complete cycle with path AB shown as an isobaric process and path BC shown as an isochoric process. — 1 point

Question 7 (continued)

(c) 2 points

For statement that net work done by the gas is positive	1 point
For correct justification	1 point

Examples:

1. Work is related to area and the net area is positive.
2. More heat is absorbed in the cycle that is exhausted.
3. Expansion occurs at a higher pressure while compression occurs at a lower pressure.
4. Thermodynamic cycle is clockwise.

(d) 2 points

For statement that the device is a heat engine	1 point
For correct justification	1 point

Examples:

1. Work done by the system is positive.
2. Work done by the system is done at a higher temperature.
3. Heat is absorbed at a higher temperature and exhausted at a lower temperature.
4. Thermodynamic cycle is clockwise.