AP® Physics B
2007 Scoring Guidelines

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General Notes About 2007 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 1 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. See pages 21–22 of the *AP Physics Course Description* for a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each.

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

AP® PHYSICS B
2007 SCORING GUIDELINES

Question 1

15 points total | **Distribution of points**

(a) 2 points

For using a correct equation relating distance, speed, and time — 1 point

$x = \upsilon \Delta t$

$\Delta t = \dfrac{x}{\upsilon}$

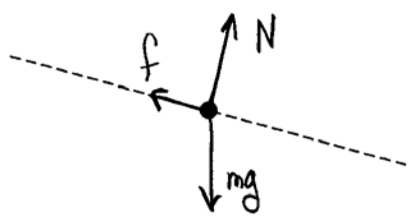
$\Delta t = \dfrac{21\text{ m}}{2.4\text{ m/s}}$

For the correct answer — 1 point

$\Delta t = 8.75\text{ s}$

Note: Only 1 point was awarded for the correct answer with no supporting work.

(b) 3 points



For each correct force that is correctly labeled, is attached to the dot, and has an arrowhead pointing in the correct direction, 1 point was awarded. — 3 points

For each incorrect vector, a point was deducted, with the minimum possible score being 0.

(c) 3 points

For recognizing that the sum of the forces upon the sled is zero — 1 point

$\sum F = 0$

Writing the equation for the forces acting along the slope,

$\sum F = mg\sin 15° - f = 0$, where f represents the force of friction

For equating the force of kinetic friction with the component of weight that acts down the slope — 1 point

$f = mg\sin 15°$

$f = (25\text{ kg})(9.8\text{ m/s}^2)\sin 15°$

For the correct answer — 1 point

$f = 63.4\text{ N}$ (64.7 N if $g = 10\text{ m/s}^2$ is used)

Note: Only 1 point was awarded for the correct answer with no supporting work.

Question 1 (continued)

Distribution of points

(d) 3 points

For equating the force of kinetic friction to the product of the coefficient of friction and the normal force — 1 point

$f = \mu N$

$\sum F = mg\cos 15° - N = 0$

For equating the normal force to the component of the sled's weight that is normal to the slope — 1 point

$N = mg\cos 15°$

$$\mu = \frac{f}{N} = \frac{mg\sin 15°}{mg\cos 15°} = \tan 15°$$

For the correct answer or for an answer consistent with the friction force obtained in (c) — 1 point

$\mu = 0.27$

Note: Only 1 point was awarded for the correct answer with no supporting work.

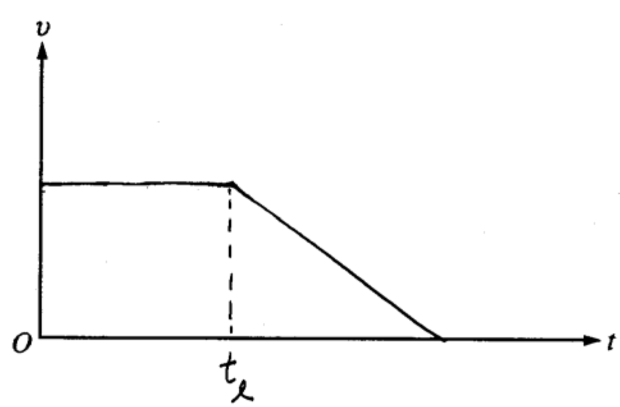
(e)

(i) 2 points

For implicitly or explicitly stating that the velocity of the sled decreases — 1 point

For explicitly stating that the acceleration of the sled is constant — 1 point

(ii) 2 points



For sketching a horizontal non-zero line — 1 point

For sketching a line of constant negative slope that begins at the right-hand end of the previously drawn horizontal line and also indicating the time t_ℓ on the graph — 1 point

Note: The second point was awarded only if the first point was awarded.

Question 2

10 points total — **Distribution of points**

(a) 1 point

For correctly indicating that the direction of the field is INTO the page or in the $-z$ direction. — 1 point

(b) 2 points

For stating that the (magnetic) force is perpendicular to the velocity, or the force is centripetal, or an equivalent concept. — 1 point

Note: The use of the phrase "centripetal force," without stating its source, earned no credit.

For stating that the (magnetic) force or field changes the direction of the velocity but not the speed, or an equivalent concept. — 1 point

(c) 4 points

For a correct expression indicating that the magnetic force provides the centripetal force — 1 point

$$\frac{m\upsilon^2}{R} = q\upsilon B$$

For a correct calculation of the radius of the trajectory — 1 point

$$R = \frac{x}{2} = \frac{1.75\text{ m}}{2} = 0.875\text{ m}$$

For correct substitutions into a correct expression — 1 point

$$\upsilon = \frac{qBR}{m} = \frac{2\left(1.60\times10^{-19}\text{ C}\right)(0.090\text{ T})(0.875\text{ m})}{1.45\times10^{-25}\text{ kg}}$$

For a correct answer with units — 1 point

$$\upsilon = 1.74\times10^{5}\text{ m/s}$$

(d) 3 points

For a correct expression indicating an equivalence of work and energy or electric potential energy and kinetic energy — 1 point

$$q\mathcal{E} = \frac{1}{2}m\upsilon^2$$

For correct substitutions into a correct expression — 1 point

$$\mathcal{E} = \frac{1}{2}\frac{m}{q}\upsilon^2 = \frac{1}{2}\frac{\left(1.45\times10^{-25}\text{ kg}\right)}{2\left(1.60\times10^{-19}\text{ C}\right)}\left(1.74\times10^{5}\text{ m/s}\right)^2$$

For a consistent answer with units — 1 point

$$\mathcal{E} = 6860\text{ V}$$

Question 3

15 points total | **Distribution of points**

(a)

(i) 2 points

For ranking I_A as the greatest — 1 point

For ranking I_C as the second greatest and I_B as the third greatest — 1 point

(ii) 2 points

For a correct statement justifying that I_A is greatest. (For example: The total current flows through R_A and gets divided between the other two resistors.) — 1 point

For a correct statement justifying that I_C is second and I_B is third. (For example: R_B and R_C share the current in the parallel segment, and that current divides between R_B and R_C so that the smaller resistor R_C carries the most current.) — 1 point

(b)

(i) 1 point

For the correct ranking $V_A,\ V_B,\ V_C = 1,\ 2,\ 2$ — 1 point

(ii) 2 points

For a correct justification that V_A is the greatest. (For example, because no resistor is greater than R_A, and R_A has the full current through it. Or, because R_A is greater than the equivalent parallel resistance of R_B and R_C.) — 1 point

For a correct justification that $V_B = V_C$. (For example, since the voltage across the parallel resistors R_B and R_C is the same.) — 1 point

(c) 3 points

Let R_{BC} be the resistance of the parallel combination of R_B and R_C.

For one correct form for determining R_{BC} — 1 point

$$\frac{1}{R_{BC}} = \frac{1}{R_B} + \frac{1}{R_C} = \frac{1}{2R} + \frac{1}{R} = \frac{1}{400\ \Omega} + \frac{1}{200\ \Omega} = \frac{3}{400\ \Omega}$$

$$R_{BC} = \frac{2R}{3} = \frac{400\ \Omega}{3} = 133\ \Omega$$

For one correct form for determining the total resistance — 1 point

$$R_{tot} = R_A + R_{BC} = 2R + \frac{2R}{3} = 400\ \Omega + 133\ \Omega$$

For the correct numerical value — 1 point

$$R_{tot} = 533\ \Omega$$

Question 3 (continued)

Distribution of points

(d) 3 points

For one correct form for the current I_A, using R_{tot} from part (c) — 1 point

$$I_A = \frac{\mathcal{E}}{R_{tot}} = \frac{12\text{ V}}{533\ \Omega} = 0.0225\text{ A}$$

For the correct value of V_C — 1 point

$$V_C = \mathcal{E} - V_A = \mathcal{E} - I_A R_A = 12\text{ V} - (0.0225\text{ A})(400\ \Omega) = 3.0\text{ V}$$

$$I_C = \frac{V_C}{R_C} = \frac{3\text{ V}}{200\ \Omega}$$

For the correct numerical value of I_C — 1 point

$$I_C = 0.015\text{ A}$$

Alternate solution — *Alternate points*

Using $R_B = 2R_C$ *and* $V_B = V_C$ *so that* $I_B R_B = I_C R_C$

$$I_C = \frac{R_B}{R_C} I_B = \frac{2R_C}{R_C} I_B = 2I_B$$

For the correct numerical value for I_{tot} — *1 point*

$$I_{tot} = \mathcal{E}/R_{tot} = 0.0225\text{ A}$$

For correctly relating I_{tot} *to* I_C — *1 point*

$$I_{tot} = I_B + I_C = \frac{I_C}{2} + I_C = \frac{3I_C}{2}$$

For the correct numerical value of I_C — *1 point*

$$I_C = \frac{2I_{tot}}{3} = \frac{2}{3}(0.0225\text{ A}) = 0.015\text{ A}$$

(e) 2 points

In the new circuit, $I_B = 0$ at equilibrium, so the total current goes through each of the two resistors

$$I_{tot} = \frac{\mathcal{E}}{R_A + R_C} = \frac{\mathcal{E}}{2R + R} = \frac{\mathcal{E}}{3R} = \frac{12\text{ V}}{600\ \Omega} = 0.02\text{ A}$$

For the correct value of the voltage across the capacitor — 1 point

$$V_C = I_{tot} R_C = (0.02\text{ A})(200\ \Omega) = 4.0\text{ V}$$

$$Q = CV_C$$

$$Q = \left(2.0 \times 10^{-6}\text{ F}\right)(4.0\text{ V})$$

For the correct numerical value of Q — 1 point

$$Q = 8.0 \times 10^{-6}\text{ C}$$

Question 4

10 points total | **Distribution of points**

(a) 2 points

For any indication that the volume rate of flow is defined as volume/time — 1 point
Define the symbol $\mathcal{V}$ for the volume flow rate
$\mathcal{V} = 7.2 \times 10^{-4}\ \text{m}^3 / [(2.0\ \text{min})(60\ \text{s/min})]$
For the correct answer, including units — 1 point
$\mathcal{V} = 6.0 \times 10^{-6}\ \text{m}^3/\text{s}$

(b) 2 points

For a correct relationship between volume flow rate, speed, and area — 1 point
$\mathcal{V} = \upsilon A$
$\upsilon = \mathcal{V}/A$
$\upsilon = \left(6.0 \times 10^{-6}\ \text{m}^3/\text{s}\right) / \left(2.5 \times 10^{-6}\ \text{m}^2\right)$
For the correct answer, including units — 1 point
$\upsilon = 2.4\ \text{m/s}$
Note: *An attempt to use kinematics with the distance x and height d could earn a maximum of 1 point.*

(c) 3 points

For applying Bernoulli's Equation, either to points at the top of the liquid and the hole or to points just inside and outside of the hole, and recognizing the specific conditions for one of the three variables (pressure, speed, or height) — 1 point
For recognizing the conditions for the remaining two variables — 1 point

Top and hole	Inside and outside
$P_t + \rho g y_t + \frac{1}{2}\rho \upsilon_t^2 = P_h + \rho g y_h + \frac{1}{2}\rho \upsilon_h^2$	$P_{\text{in}} + \rho g y_{\text{in}} + \frac{1}{2}\rho \upsilon_{\text{in}}^2 = P_{\text{out}} + \rho g y_{\text{out}} + \frac{1}{2}\rho \upsilon_{\text{out}}^2$
$P_t = P_h = P_{atm}$	$P_{\text{in}} = P_{atm} + \rho g h$, $P_{\text{out}} = P_{atm}$
$\upsilon_t = 0$	$\upsilon_{\text{in}} = 0$
$y_t = h$, $y_h = 0$	$y_{\text{in}} = y_{\text{out}} = 0$

Both cases simplify to the same equation, where υ_e is the exit speed
$\rho g h = \rho \upsilon_e^2 / 2$
$h = \upsilon_e^2 / 2g = (2.4\ \text{m/s})^2 / 2\left(9.8\ \text{m/s}^2\right)$
For the correct answer, including units — 1 point
$h = 0.29\ \text{m}$

Notes: *Solutions that begin with the equation $\rho g h = \rho \upsilon^2/2$ could earn 2 of the 3 points.*

Solutions that begin with the equation $mgh = m\upsilon^2/2$ could earn 1 of the 3 points.

Question 4 (continued)

Distribution of points

(c) (continued)

Alternate solution 1	*Alternate points*
For explicitly stating by name that Torricelli's theorem applies	*1 point*
For writing the correct expression for the theorem	*1 point*

$\upsilon = \sqrt{2gh}$

$h = \dfrac{\upsilon^2}{2g} = \dfrac{(2.4\ \text{m/s})^2}{2\left(9.8\ \text{m/s}^2\right)}$

For the correct answer, including units	*1 point*

$h = 0.29\ \text{m}$

Alternate solution 2	*Alternate points*
For relating the pressure difference across the hole to the acceleration of the liquid through the hole	*1 point*

$F = ma = \Delta P\, A$

$\Delta P = \rho gh$

$a = \rho ghA/m = ghA/V$, *where V is the volume of the hole*

For applying an appropriate kinematics equation and substituting the expression for acceleration	*1 point*

$\upsilon^2 = \upsilon_0^2 + 2a\ell$, *where* $\upsilon_0 = 0$ *and* ℓ *is the thickness of the container wall*

$\upsilon^2 = 2(ghA/V)\ell = 2gh$

$h = \dfrac{\upsilon^2}{2g} = \dfrac{(2.4\ \text{m/s})^2}{2\left(9.8\ \text{m/s}^2\right)}$

For the correct answer, including units	*1 point*

$h = 0.29\ \text{m}$

(d) 3 points

For correctly indicating that the liquid will hit to the left of the beaker	1 point
For an explanation that relates the decrease in water height to a decrease in the pressure at the hole <u>and</u> a decrease in velocity exiting the hole	2 points

Other explanations, such as relating force and acceleration at the hole, describing changes in potential and kinetic energy, or using a relationship from part (c), could earn full credit.

<u>*Note:*</u> *In the exam booklets, the container was erroneously referred to as the beaker in this part. Answers indicating that the liquid would hit to the right of the beaker received full credit if there was an explanation indicating that the student was now using the container as the reference object.*

Question 5

10 points total | **Distribution of points**

(a) 2 points

Using the relationship between pressure and force
$P = F/A$

For correctly determining the area of the piston — 1 point

$A = \pi R^2 = \pi(0.20\text{ m}/2)^2$

$F = P_{abs}A = P_{abs}\pi R^2$

For correct substitution of values for pressure and area (or for correct answer in the absence of explicitly showing the substitution) — 1 point

$F = \left(4.0 \times 10^5\text{ Pa}\right)\pi(0.20\text{ m}/2)^2$

$F = 1.3 \times 10^4\text{ N}$

(b) 2 points

Using the ideal gas law
$PV = nRT$

$V = \dfrac{nRT}{P}$

For correct substitution of at least three numerical values — 1 point

$V = \dfrac{(2.0\text{ mol})(8.31\text{ J/mol}\bullet\text{K})(300\text{ K})}{4.0 \times 10^5\text{ Pa}}$

For the correct answer — 1 point

$V = 1.2 \times 10^{-2}\text{ m}^3$

(c) 2 points

Using the expression for the work done <u>on</u> the gas
$W_{\text{on}} = -P\,\Delta V$

The work done <u>by</u> the gas has the opposite sign
$W_{\text{by}} = P_{abs}\,\Delta V$

For a correct expression for the change in volume — 1 point

$\Delta V = Ax = \pi R^2 x$

$W_{\text{by}} = P_{abs}\pi R^2 x$

For substituting the correct pressure and a change in volume — 1 point

$W_{\text{by}} = \left(4.0 \times 10^5\text{ Pa}\right)\pi(0.20\text{ m}/2)^2(0.15\text{ m})$

$W_{\text{by}} = 1.9 \times 10^3\text{ J}$

Question 5 (continued)

Distribution of points

(c) (continued)

Alternate solution	*Alternate points*
$W = Fx$	
For substituting the value of force from part (a)	*1 point*
For substituting the correct value for the distance	*1 point*
$W = \left(1.3\times10^4 \text{ N}\right)(0.15 \text{ m})$	
$W = 1.9\times10^3 \text{ J}$	

<u>Note:</u> *One point was deducted for any indication that the final value of the work done by the gas is negative.*

(d) 3 points

For correctly indicating that heat is transferred to the gas.	1 point
For any indication that because the expansion occurs under constant pressure, the temperature or internal energy of the gas increases.	1 point
For correctly applying the first law of thermodynamics to explain why heat is transferred to the gas. For example: Since the internal energy goes up while the gas loses energy by doing work, heat must be added.	1 point

Units point

For including correct units in at least two of the answers in (a) through (c)	1 point

<u>Note:</u> *If a substitution was made using a value with units other than those given in the problem or in the Table of Information, the units used had to be explicitly stated. An exception was part (b), where the commonly used values of pressure in atmospheres and R in* $(liter)(atmospheres)/(moles)(K)$ *were acceptable.*

Question 6

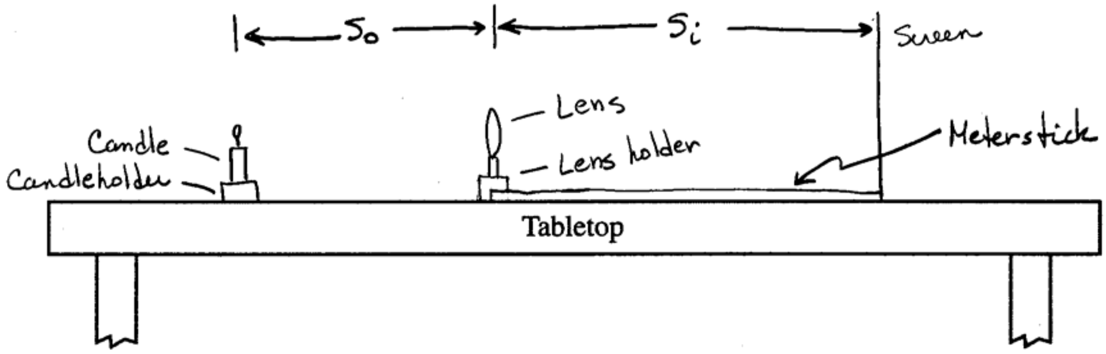
10 points total | **Distribution of points**

(a) 2 points

For a clear and complete method of <u>estimating</u> the focal length by focusing the image of the tree on a screen <u>and</u> stating that the distance between the image and the lens is the focal length — 2 points

<u>Partial credit:</u>
1 point only was awarded if the method above was incomplete.
1 point only was awarded if the distances s_o (tree to lens) and s_i (lens to image) were measured or estimated, and then the numbers were used in the thin lens equation to <u>calculate</u> the focal length.

(b) and (c) 3 points

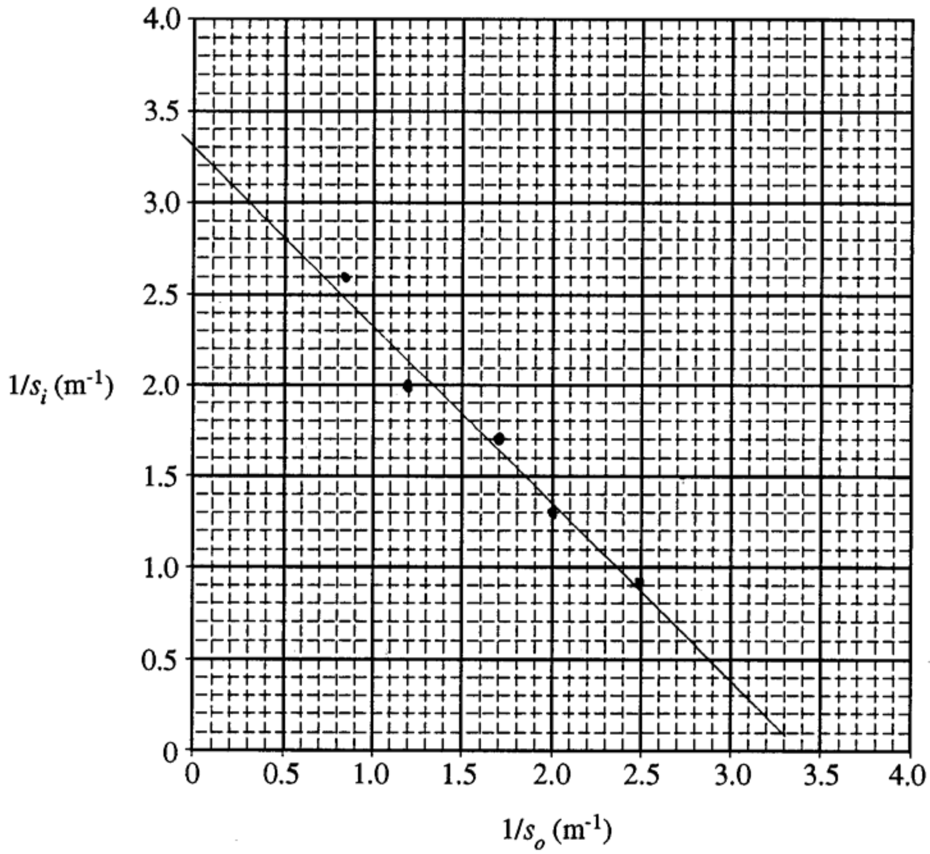


For showing a functional setup involving an object, the lens, and a screen — 1 point
For having the lens and the distances s_o and s_i labeled correctly on the diagram — 1 point
For labeling on the diagram all the equipment checked in (b) (must have a functional setup to earn this point) — 1 point

Question 6 (continued)

Distribution of points

(d) 2 points



For all data points from the table plotted correctly — 1 point

For a best-fit straight line (i.e., two points above and two points below the line <u>and/or</u> intercepts on axes close to $3.35\ \text{m}^{-1}$) — 1 point

Question 6 (continued)

Distribution of points

(e) 3 points

For a clear and accurate solution with the correct answer in the range 0.28 m to 0.32 m with units (The two most common approaches to doing this are illustrated below.) — 3 points

Approach 1:
Pick a point on the best-fit line (not a data point)
For example, for the graph shown in part (d), one point on the line is (1.0, 2.3).

$\frac{1}{s_o} = 1.0\ \text{m}^{-1}, \quad \frac{1}{s_i} = 2.3\ \text{m}^{-1}$

$\frac{1}{f} = \frac{1}{s_i} + \frac{1}{s_o} = 1.0\ \text{m}^{-1} + 2.3\ \text{m}^{-1} = 3.3\ \text{m}^{-1}$

$f = \frac{1}{3.3\ \text{m}^{-1}}$

$f = 0.30\ \text{m}$

Approach 2:

$\frac{1}{s_i} + \frac{1}{s_o} = \frac{1}{f}$

$\frac{1}{s_i} = \frac{1}{f} - \frac{1}{s_o}$

So $\frac{1}{f}$ is the y intercept of a graph of $\frac{1}{s_i}$ versus $\frac{1}{s_o}$

For example, for the graph shown in part (d) the y intercept is $3.3\ \text{m}^{-1}$

So $\frac{1}{f} = 3.3\ \text{m}^{-1}$

$f = \frac{1}{3.3\ \text{m}^{-1}}$

$f = 0.30\ \text{m}$

Partial credit:
2 points only were awarded for a mostly complete solution where either units were missing or it was unclear that the best-fit line was used (e.g., not using numbers from the best-fit line if Approach 1 was used, or not showing the idea of using the intercept if Approach 2 was used).
1 point only was awarded either for a correct answer with units where it was not clear how the answer was obtained, or for using the lens equation with data from the line where there was no final answer.

Question 7

Distribution of points

(a) 3 points

Using the relationship between mass and energy

$E = m_e c^2$

For correct substitutions of the positron mass and the speed of light — 1 point

For the correct value of energy in joules — 1 point

$E = (9.11 \times 10^{-31}\ \text{kg})(3.00 \times 10^{8}\ \text{m/s})^2 = 8.20 \times 10^{-14}\ \text{J}$

For using the correct factor to convert from joules to eVs — 1 point

$E = 8.20 \times 10^{-14}\ \text{J} / 1.60 \times 10^{-19}\ \text{J/eV}$

$E = 5.12 \times 10^{5}\ \text{eV}$

(b) 1 point

Since the electron and positron have the same mass, the energy before annihilation is twice the value found in part (a). That energy goes into creating the two photons of equal energy, so each photon has the energy equivalent of one of the particles.

For any indication that this is the same numerical answer as in part (a) — 1 point

$E_\gamma = 5.12 \times 10^{5}\ \text{eV}$

Note: *Full credit was earned if the student's answer to part (a) was zero and the correct calculation shown for part (a) was done here.*

(c) 3 points

For a correct equation relating energy and wavelength — 1 point

$E_\gamma = hf = \dfrac{hc}{\lambda}$

For substituting the value of energy from part (b), either in eV or joules — 1 point

For substituting a value of *h* or *hc* in units that are consistent with those of the energy used — 1 point

$\lambda = hc/E_\gamma = (1.24 \times 10^{3}\ \text{eV}\bullet\text{nm})/(5.12 \times 10^{5}\ \text{eV})$

$\lambda = 2.42 \times 10^{-3}\ \text{nm} = 2.42 \times 10^{-12}\ \text{m}$

Alternate solution — *Alternate points*

Using the relationship between wavelength and momentum

$\lambda = h/p$

For substituting values for h and p (but not earned if $p = mv$ *was used)* — *1 point*

For using the value of p from part (d) — *1 point*

For substituting a value of h in units that are consistent with those of the momentum used — *1 point*

$\lambda = (6.63 \times 10^{-34}\ \text{J}\bullet\text{s})/(2.73 \times 10^{-22}\ \text{kg}\bullet\text{m/s})$

$\lambda = 2.42 \times 10^{-3}\ \text{nm} = 2.42 \times 10^{-12}\ \text{m}$

Question 7 (continued)

Distribution of points

(d) 2 points

$\lambda = h/p$

For correct substitutions, using the value of λ determined in (c) — 1 point

$$p = h/\lambda = \frac{6.63 \times 10^{-34}\ \text{J}\bullet\text{s}}{2.42 \times 10^{-12}\ \text{m}} \quad \text{or} \quad \frac{4.14 \times 10^{-5}\ \text{eV}\bullet\text{s}}{2.42 \times 10^{-12}\ \text{m}}$$

For correct units in the final answer — 1 point

$$p = 2.74 \times 10^{-22}\ \text{kg}\bullet\text{m/s}\ \ (\text{or N}\bullet\text{s or J}\bullet\text{s/m}) \quad \text{or} \quad 0.0017\ \text{eV}\bullet\text{s/m}$$

Alternate solution — *Alternate points*

$E = pc$

For substituting the value of energy from part (b) — *1 point*

$$p = \frac{E}{c} = \frac{(8.20 \times 10^{-14}\ \text{J})}{3.00 \times 10^{8}\ \text{m/s}} \quad OR \quad \frac{(5.12 \times 10^{5}\ \text{eV})}{3.00 \times 10^{8}\ \text{m/s}}$$

For correct units in the final answer — *1 point*

$$p = 2.73 \times 10^{-22}\ \text{kg}\bullet\text{m/s}\ \ (\text{or N}\bullet\text{s or J}\bullet\text{s/m}) \quad \text{or} \quad 0.0017\ \text{eV}\bullet\text{s/m}$$

(e) 1 point

For indicating that the total momentum is zero — 1 point