# AP® Physics B
# 2012 Scoring Guidelines

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# AP® PHYSICS
# 2012 SCORING GUIDELINES

## General Notes About 2012 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 in part (b). One exception to this practice may occur in cases where the numerical answer to a later part should easily be recognized as wrong, for example, a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if the use of an 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 sheets. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections — Student Presentation" in the *AP Physics Course Description*.

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. 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 owing 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 eliminate the level of accuracy required to determine the difference in the numbers, and some credit may be lost.

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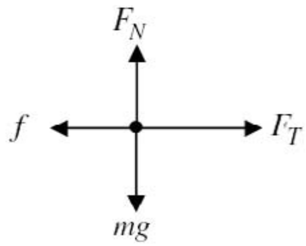
## Question 1

**15 points total** | **Distribution of points**

(a) 2 points




For showing a complete vector diagram in the horizontal direction with proper labels and vectors pointing in the correct directions — 1 point

For showing a complete vector diagram in the vertical direction with proper labels and vectors pointing in the correct directions — 1 point

(b) 3 points

For any use of Newton's second law to sum the forces in the horizontal direction — 1 point

$F_T - f = ma$

$a = \dfrac{F_T - f}{m}$

For a correct expression for, or value of, the frictional force — 1 point

$$a = \frac{F_T - \mu mg}{m} = \frac{(15\text{ N}) - (0.25)(2.0\text{ kg})\left(9.8\ \text{m/s}^2\right)}{(2.0\text{ kg})}$$

For a correct answer, with units — 1 point

$a = 5.1\ \text{m/s}^2$ (or $5.0\ \text{m/s}^2$ using $g = 10\ \text{m/s}^2$)

(c) 4 points

For a proper summation of forces on block *A* in the *x*-direction — 1 point

$\sum F_{m_A} = m_A a = F_T - f$

For a proper summation of forces on block *B* in the *y*-direction — 1 point

$\sum F_{m_B} = m_B a = m_B g - F_T$

For a reasonable attempt to combine these two relationships — 1 point

$(m_A + m_B)a_{system} = m_B g - f$

$$a_{system} = \frac{m_B g - f}{(m_A + m_B)} = \frac{(1.5\text{ kg})\left(9.8\ \text{m/s}^2\right) - (0.25)(2.0\text{ kg})\left(9.8\ \text{m/s}^2\right)}{(3.5\text{ kg})}$$

For a correct answer with units — 1 point

$a = 2.8\ \text{m/s}^2$ (or $2.9\ \text{m/s}^2$ using $g = 10\ \text{m/s}^2$)

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**Question 1 (continued)**

**Distribution of points**

(c) (continued)

*Alternate solution* — *Alternate points*

*Treating the two blocks as one system with a total mass of* $M_T = m_A + m_B$

*For a correct statement of the net force on the system* — *1 point*

*For a correct expression for total mass of the system* — *1 point*

$m_B g - f = (m_A + m_B)a$

*For agreement between the sign of the net force and the direction of acceleration* — *1 point*

$$a = \frac{m_B g - \mu m_A g}{(m_A + m_B)} = \frac{(1.5\text{ kg})\left(9.8\text{ m/s}^2\right) - (0.25)(2.0\text{ kg})\left(9.8\text{ m/s}^2\right)}{(2.0\text{ kg} + 1.5\text{ kg})}$$

*For a correct answer* — *1 point*

$a = 2.8\text{ m/s}^2$ (or $2.9\text{ m/s}^2$ using $g = 10\text{ m/s}^2$ )

(d) 2 points

For a correct expression of the summation of forces on either block $A$ or block $B$ — 1 point

$F_T - \mu m_A g = m_A a$ or $m_B g - F_T = m_B a$

For correct substitution of the acceleration determined in part (c) and the given masses — 1 point

$$F_T = m_A(a + \mu g) = (2.0\text{ kg})\left(2.8\text{ m/s}^2 + (0.25)\left(9.8\text{ m/s}^2\right)\right)$$

or

$$F_T = m_B(g - a) = (1.5\text{ kg})\left(9.8\text{ m/s}^2 - 2.8\text{ m/s}^2\right)$$

$F_T = 10.5\text{ N}$

(e) 2 points

For any proper kinematic approach to determine the displacement of block $B$ — 1 point

$$\Delta y = \frac{1}{2}at^2$$

For a correct substitution of the acceleration found in part (c) into the kinematic relationship — 1 point

$$\Delta y = \frac{1}{2}\left(2.8\text{ m/s}^2\right)(0.40\text{ s})^2$$

$\Delta y = 0.22\text{ m}$

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## Question 1 (continued)

| | Distribution of points |
|---|---|
| (f) 2 points | |
| For any reasonable statement of a physical factor that would alter the measured value of the acceleration | 1 point |

The following are some common acceptable responses:

- The pulley has an appreciable amount of friction in the bearings.
- The string has an appreciable mass.
- The pulley has an appreciable rotational inertia.
- A small uphill incline exists in the horizontal surface.

Note: If a response contains both correct and incorrect factors, this point can be earned only if a correct justification for a correct factor is given.

| | |
|---|---|
| For a proper justification of how the physical factor listed causes the measured value of the acceleration to be smaller than the theoretical value of the acceleration | 1 point |

The following are examples of some common correct justifications:

- The friction in the bearings of the pulley does negative work on the system, leaving less energy available for the system's kinetic energy. This will result in a slightly smaller final velocity and therefore a slightly smaller acceleration than the theoretical value.
- The slightly inclined surface creates a small downward component of gravity, which works in opposition to the acceleration. This small opposing force will create a smaller net force and a decrease in the measured acceleration of block *B*.

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## Question 2

**10 points total** | **Distribution of points**

(a) 2 points

For a statement that shows the conservation of energy for the large sphere — 1 point

$\Delta U_{3M} = \Delta K_{3M}$

$3MgH = \frac{1}{2}(3M)v_b^2$

For a correct answer (or equivalent expression for $v_b$) — 1 point

$v_b = \sqrt{2gH}$

*Alternate solution* — *Alternate points*

*For using a proper kinematic approach* — *1 point*

$v_f^2 = v_0^2 + 2a\Delta y$

$v_b^2 = 2gH$

*For a correct answer* — *1 point*

$v_b = \sqrt{2gH}$

(b) 2 points

For stating or showing the conservation of momentum applied to the collision — 1 point

$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$

For stating or showing that the spheres are initially traveling in opposite directions — 1 point

$3Mv_b + M(-v_b) = 3Mv_L + Mv_S$

$2v_b = 3v_L + v_S$

(c) 1 point

Substituting the given zero value into the answer from part (b)

$2v_b = 3v_L + v_S$

$2v_b = 0 + v_S$

For a correct answer — 1 point

$v_S = 2v_b$

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**Question 2 (continued)**

**Distribution of points**

(d) 3 points

For any correct attempt to compare total kinetic energy before the collision to total kinetic energy after the collision — 1 point

$K_i = K_{3Mi} + K_{Mi}$ and $K_f = K_{3Mf} + K_{Mf}$

For correct substitutions of $\upsilon_b$, the expression for $\upsilon_S$ from part (c), and the correct masses in the kinetic energy terms — 1 point

$$K_i = \frac{1}{2}(3M)(\upsilon_b)^2 + \frac{1}{2}(M)(-\upsilon_b)^2 = 2M\upsilon_b^2$$

$$K_f = \frac{1}{2}(M)(2\upsilon_b)^2 = 2M\upsilon_b^2$$

For correctly stating that the collision is elastic (or inelastic if consistent with the comparison of initial and final kinetic energies) — 1 point

(e) 2 points

For a statement of conservation of energy for ball $M$ as it rises to the new height $h$ — 1 point

$$U_{gf} = K_0$$

$$Mgh = \frac{1}{2}M\upsilon_S^2$$

$$h = \frac{(2\upsilon_b)^2}{2g} = \frac{4\upsilon_b^2}{2g} = \frac{2\left(\sqrt{2gH}\right)^2}{g}$$

For a correct answer consistent with the expression for $\upsilon_b$ obtained in part (a) — 1 point

$h = 4H$

*Alternate solution* — *Alternate points*

*For using a correct kinematic approach to solve for maximum height of ball M* — *1 point*

$$\upsilon_f^2 = \upsilon_0^2 + 2a\Delta y$$

$$\upsilon_0 = \upsilon_S = 2\upsilon_b = 2\sqrt{2gH}$$

$$0 = \left(2\left(\sqrt{2gH}\right)\right)^2 - 2gh$$

*For a correct answer consistent with the expression for* $\upsilon_b$ *obtained in part (a)* — *1 point*

$h = 4H$

<u>Note</u>: Both points are awarded for any correctly determined value of $h$ without any written justification.

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## Question 3

**10 points total** — **Distribution of points**

(a) 3 points

For a statement or equation that the pressures at interfaces $A$ and $B$ are equal — 1 point

$P_{atm} + \rho_o g h_o = P_{atm} + \rho_w g h_w$

For a substitution of the correct density and the correct heights — 1 point

$\rho_o = \rho_w h_w / h_o = \left(1000\ \text{kg/m}^3\right)(24.5\ \text{cm})/(27.2\ \text{cm})$

For the correct answer — 1 point

$\rho_o = 901\ \text{kg/m}^3$

(b) 2 points

Use equation for absolute pressure

$P = P_0 + \rho g h$

For using atmospheric pressure for $P_0$ — 1 point

For using the correct height (in meters) with the correct density and a correct acceleration owing to gravity — 1 point

$P = P_0 + \rho g h = \left(1.0 \times 10^5\ \text{Pa}\right) + \left(1000\ \text{kg/m}^3\right)\left(9.8\ \text{m/s}^2\right)(0.245\ \text{m})$

$P = 1.02 \times 10^5\ \text{Pa}$

Note: The use of $1.013 \times 10^5\ \text{Pa}$ and $10\ \text{m/s}^2$ is acceptable.

(c) 3 points

For selecting "Below $A$" — 1 point

For a statement that the height of the oil above the mercury is now lower — 1 point

For a statement that the pressure is lower at interface $A$ owing to the lower height — 1 point

(d) 1 point

For selecting "Increases" — 1 point

Units 1 point

For correct units in both numerical answers of parts (a) and (b) — 1 point

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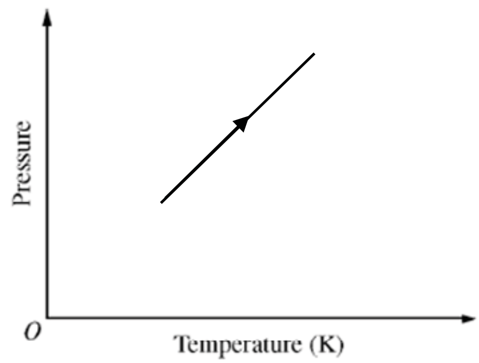
## Question 4

**10 points total** | **Distribution of points**

(a) 3 points




For a graph showing pressure proportional to temperature (i.e., a straight line segment that, if extended, would pass through the origin) — 1 point

For showing that the initial pressure and initial temperature are not zero — 1 point

For a final state that is at a higher pressure and temperature than the initial state (regardless of the shape of the path) — 1 point

(b) 2 points

For selecting "Moves down" — 1 point

For recognition of the piston's mass, which is pulled down by the force of gravity — 1 point

<u>Note</u>: One point could be earned for selecting "Remains stationary" with a clear explanation that the internal and external pressures are equal or that the system returned to the original pressure $P_0$

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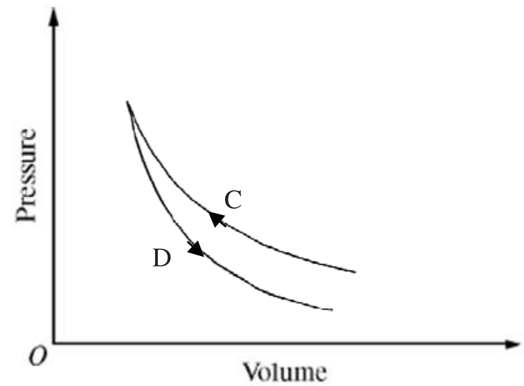
**Question 4 (continued)**

**Distribution of points**

(c) and (d) 5 points

These two parts are closely linked; therefore they are scored as a unit.




| | |
|---|---|
| For drawing curve C as concave up, with a negative slope | 1 point |
| For drawing curve D as concave up, with a negative slope | 1 point |
| For drawing the final state of curve C and the initial state of curve D as the only point where the two curves intersect | 1 point |
| For drawing curve C above curve D | 1 point |
| For correct labels and directions of arrows on both processes | 1 point |

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## Question 5

| **15 points total** | **Distribution of points** |
|---|---|

(a)

(i) 2 points

For substituting the electron charge into the equation for potential energy — 1 point

$\Delta U = -W = -q\Delta V = -\left(-1.6 \times 10^{-19}\text{ C}\right)(0 - 24\text{ V})$

For the correct answer, with units — 1 point

$\Delta U = -3.8 \times 10^{-18}\text{ J} = -24\text{ eV}$

Note: Full credit is given for the correct answer, with units, with no supporting calculations.

(ii) 1 point

For selecting "Loses energy" — 1 point

(b) 4 points

For recognizing that the equivalent resistance is a series sum of two parallel combinations — 1 point

For the correct calculation of $R_{AB}$ — 1 point

$\frac{1}{R_{AB}} = \frac{1}{R_A} + \frac{1}{R_B} = \frac{1}{6\ \Omega} + \frac{1}{3\ \Omega}$

$R_{AB} = 2\ \Omega$

For the correct calculation of $R_{CD}$ — 1 point

$\frac{1}{R_{CD}} = \frac{1}{R_C} + \frac{1}{R_D} = \frac{1}{12\ \Omega} + \frac{1}{24\ \Omega}$

$R_{CD} = 8\ \Omega$

For the correct calculation of $R_T$ — 1 point

$R_T = R_{AB} + R_{CD} = 2\ \Omega + 8\ \Omega$

$R_T = 10\ \Omega$

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**Question 5 (continued)**

**Distribution of points**

(c)

(i) 3 points

For calculation of the total current, with calculations consistent with the value of $R_T$ found in part (b) — 1 point

$$I_T = \frac{V_T}{R_T} = \frac{(24\ \text{V})}{(10\ \Omega)}$$

$I_T = 2.4\ \text{A}$

For the use of $V_{AB} = I_T R_{AB}$ to find $V_{AB}$ — 1 point

$V_{AB} = I_T R_{AB} = (2.4\ \text{A})(2\ \Omega)$

$V_{AB} = 4.8\ \text{V}$

For the use of $I_Y = V_{AB}/R_B$ to find $I_Y$ — 1 point

$$I_Y = \frac{V_{AB}}{R_B} = \frac{(4.8\ \text{V})}{(3\ \Omega)}$$

$I_Y = 1.6\ \text{A}$

*Alternate solution* — *Alternate points*

*For calculation of total current with calculations consistent with calculation of $R_T$ found in part (b)* — *1 point*

$$I_T = \frac{V_T}{R_T} = \frac{(24\ \text{V})}{(10\ \Omega)}$$

$I_T = 2.4\ \text{A}$

*For indicating that the current splits at the juncture* — *1 point*

*For correct calculations of the current at Y using the correct ratio* — *1 point*

$V_B = V_{AB}$

$I_Y R_B = I_{AB} R_{AB}$

$$I_Y = \frac{R_{AB}}{R_B} I_T = \frac{2}{3}(2.4\ \text{A})$$

$I_Y = 1.6\ \text{A}$

(ii) 1 point

For an arrow drawn at point $Y$ pointing to the right — 1 point

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**Question 5 (continued)**

**Distribution of points**

(d) 3 points

For a correct calculation of $P_C$ — 1 point

$$P_C = \frac{V_C^2}{R_C} = I_C^2 R_C$$

Note: Because the ratios of resistances in the two parallel segments are the same, the current in bulb *C* is the same as at point *Y*.

$$P_C = (1.6\text{ A})^2 (12\ \Omega)$$

$$P_C = 30.7\text{ W}$$

For using $U_C = P_C t$ or an equivalent statement with consistent values — 1 point

$$U_C = P_C t = (30.7\text{ W})(5\text{ s})$$

For a consistent answer, with units — 1 point

$$U_C = 154\text{ J}$$

(e) 1 point

For a correct ranking of the bulbs in order of brightness, with 1 being the brightest — 1 point

Bulb *A* = 4 Bulb *B* = 3 Bulb *C* = 1 Bulb *D* = 2

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## Question 6

**10 points total** | **Distribution of points**

(a) and (b) — 6 points

These two parts are closely linked; therefore they are scored as a unit.

| | |
|---|---|
| For indicating the use of the sine-wave generator to send a sound wave of a given frequency into the glass tube | 1 point |
| For indicating adjustment of the movable piston until the sound picked up by the microphone and shown on the waveform display indicates that resonance occurs (maximum amplitude of standing wave) or until resonance is heard by ear | 1 point |
| For indicating the use of the meterstick to measure the distance $L$ from the piston to the left-hand end of the tube at resonance | 1 point |
| For a statement indicating that $L$ is proportional, but not equal, to the wavelength | 1 point |
| For defining variables for frequency and wavelength | 1 point |
| For indicating that $v = \lambda f$ should be used with the measurements to determine an experimental value of the speed of sound | 1 point |

<u>Example</u>

Send a sound wave of frequency $f$ into the glass tube using the sine-wave generator and speaker. Move the piston all the way to the left end of the tube. Pull the piston to the right until the sound picked up by the microphone and shown on the waveform display indicates that resonance occurs. Use the meterstick to measure the distance $L$ between the piston and the left-hand end of the tube. For a tube closed at one end, the wavelength $\lambda$ is equal to $4L/n$, with the first resonance at $n = 1$. Using the above measurements, an experimental value of the speed of sound can be determined using the equation $v = \lambda f$.

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## Question 6 (continued)

| | Distribution of points |
|---|---|
| (c) 4 points | |
| For indicating an appropriate variable that can be varied to obtain multiple sets of data | 1 point |
| For correctly identifying appropriate independent and dependent variables to be graphed | 1 point |
| For indicating an appropriate plot that will produce a linear graph | 1 point |
| For stating how the slope of this graph can be used to determine the speed of sound $v$ | 1 point |

Examples

One of the measured variables that could be varied in order to obtain multiple sets of data is the frequency $f$. If $f$ is varied, this means it is the independent variable, and the dependent variable is the wavelength $\lambda$. A plot of $\lambda$ versus $1/f$ will produce a linear graph, the slope of which is the speed of sound.

One of the measured variables that could be varied in order to obtain multiple sets of data is the wavelength $\lambda$. If $\lambda$ is varied, this means it is the independent variable, and the dependent variable is the frequency $f$. A plot of $f$ versus $1/\lambda$ will produce a linear graph, the slope of which is the speed of sound.

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## Question 7

**10 points total** | **Distribution of points**

(a) 2 points

For correct substitution of the momentum value into the de Broglie wavelength relationship — 1 point

$$\lambda = \frac{h}{p} = \frac{\left(6.63 \times 10^{-34}\ \text{J•s}\right)}{\left(5.5 \times 10^{-20}\ \text{kg•m/s}\right)}$$

For a correct answer, with units — 1 point

$\lambda = 1.2 \times 10^{-14}$ m

(b) 2 points

For correct substitution of the momentum into an equation to compute the speed of the proton and substituting the speed into the equation for kinetic energy — 1 point

$$\upsilon = \frac{p}{m_p} = \frac{5.5 \times 10^{-20}\ \text{kg•m/s}}{1.67 \times 10^{-27}\ \text{kg}} = 3.3 \times 10^{7}\ \text{m/s}$$

$$K = \frac{1}{2}m\upsilon^2 = \frac{1}{2}\left(1.67 \times 10^{-27}\ \text{kg}\right)\left(3.3 \times 10^{7}\ \text{m/s}\right)^2$$

For a correct answer, with units — 1 point

$K = 9.1 \times 10^{-13}$ J (or $9.0 \times 10^{-13}$ J , depending on earlier rounding)

*Alternate solution* — *Alternate points*

*Derive formula for kinetic energy*

$$K = \frac{1}{2}m\upsilon^2 = \frac{1}{2}m\left(\frac{p}{m}\right)^2 = \frac{p^2}{2m}$$

*For using* $K = \frac{p^2}{2m}$ *to find the kinetic energy* — *1 point*

$$K = \frac{\left(5.5 \times 10^{-20}\ \text{kg•m/s}\right)^2}{(2)\left(1.67 \times 10^{-27}\ \text{kg}\right)}$$

*For a correct answer, with units* — *1 point*

$K = 9.1 \times 10^{-13}$ J


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**Question 7 (continued)**

**Distribution of points**

(c) 3 points

For an attempt to apply conservation of energy to the system — 1 point

$U_1 + K_1 = U_2 + K_2$

$U_1$ is approximately zero (the proton is initially far away from the uranium nucleus)

$K_2 = 0$ (the proton is instantaneously at rest)

Therefore $K_1 = U_2$

For any correct expression that shows the electrostatic potential energy of the system at the proton's closest approach equal to the kinetic energy determined in part (b), using either symbols or values from the problem — 1 point

$$K_1 = U_2 = \frac{kq_1q_2}{r} = \frac{k(92e)(e)}{D}$$

$$K_1 = \frac{92ke^2}{D}$$

$$D = \frac{92ke^2}{K} = \frac{(92)\left(9 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2\right)\left(1.6 \times 10^{-19}\ \text{C}\right)^2}{\left(9.06 \times 10^{-13}\ \text{J}\right)}$$

For a correct answer, with units — 1 point

$D = 2.3 \times 10^{-14}$ m

(d) 3 points

For selecting "Greater" — 1 point

For using the mass-energy relationship $E = mc^2$ in an attempt to solve for the mass defect of the uranium decaying into the daughter particles plus excess energy — 1 point

$$E = \Delta mc^2$$

$$\Delta m = \frac{E}{c^2} = \frac{\left(2.5 \times 10^{-11}\ \text{J}\right)}{\left(3.0 \times 10^8\ \text{m/s}\right)^2}$$

For an answer with any proper units of mass — 1 point

$\Delta m = 2.8 \times 10^{-28}$ kg or $\Delta m = 0.17$ amu

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