AP® Physics B
2007 Scoring Guidelines
Form B

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AP® PHYSICS B (Form B)
2007 SCORING GUIDELINES

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 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. However, when students are asked to derive and 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. 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* .

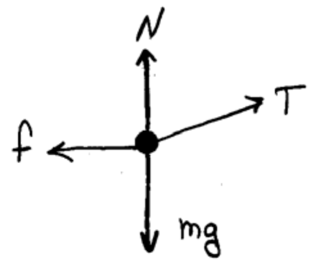
4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

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.

Question 1

15 points total **Distribution of points**

(a) 4 points



For each of the forces above with arrow correctly drawn and labeled, 1 point was awarded — 4 points

Notes:
The force vector T could be shown in component form or as one force, but not both.
For extraneous forces, 1 point was deducted.

(b) 4 points

$\sum F_y = 0$

$N + T\sin\theta - mg = 0$

For a correct force equation — 1 point

$N = mg - T\sin\theta$

For calculating the *mg* term correctly — 1 point

For calculating the $T\sin\theta$ term correctly — 1 point

$N = (15 \text{ kg} + 5 \text{ kg})(9.8 \text{ m/s}^2) - (55 \text{ N})\sin 20°$

For the correct numerical answer with units — 1 point

$N = 177 \text{ N}$ (181 N if $g = 10 \text{ m/s}^2$ is used)

(c) 3 points

$\sum F_x = ma$

For a correct Newton's second law equation involving horizontal forces — 1 point

$T\cos\theta - f = ma$

$$a = \frac{T\cos\theta - f}{m}$$

For the correct relationship between the frictional and normal forces — 1 point

$f = \mu N$

For correct calculation of the frictional force using the value of *N* from part (b) — 1 point

$f = (0.22)(177 \text{ N}) = 38.9 \text{ N}$ (39.8 N if $g = 10 \text{ m/s}^2$ is used)

$$a = \frac{(55 \text{ N})\cos 20° - 38.9 \text{ N}}{20 \text{ kg}}$$

$a = 0.64 \text{ m/s}^2$ (0.59 m/s^2 if $g = 10 \text{ m/s}^2$ is used)

Question 1 (continued)

Distribution of points

(d) 2 points

For the correct work equation — 1 point

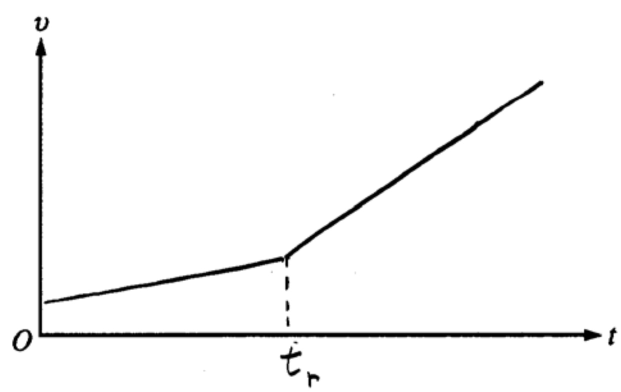
$W = (T\cos\theta)d$

For substituting the correct displacement — 1 point

$W = (55\text{ N})\cos 20°(7.0\text{ m})$

$W = 360\text{ J}$

(e) 2 points



For each section of the graph correctly drawn as above, 1 point was awarded. — 2 points

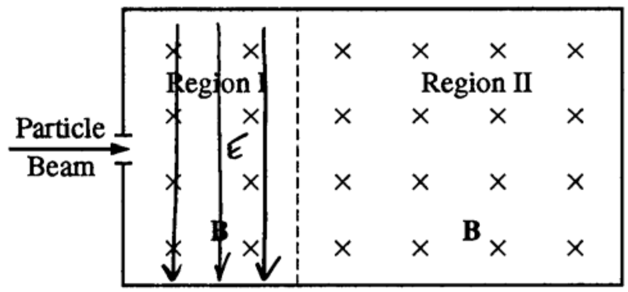
<u>Note:</u> *The second point was awarded only if the change at* t_r *was abrupt.*

Question 2

10 points total | **Distribution of points**

(a)

(i) 2 points



For at least two correct electric field lines in the right directions — 1 point

For the lines going through the entire Region I from top to bottom — 1 point

<u>Note:</u> *A single line going from top to bottom could earn a maximum of 1 point.*

(ii) 2 points

For either of the first two equations below — 1 point

$$qvB = qE$$

$$v = E/B$$

$$v = (4800\ \text{N/C})/(0.12\ \text{T})$$

$$v = 4.0 \times 10^4\ \text{m/s}$$

For the correct answer with units — 1 point

(b) 2 points

$$qvB = \frac{mv^2}{r}$$

For the correct equation for the radius — 1 point

$$r = \frac{mv}{qB}$$

For correct substitutions consistent with the answer to (a)(ii) — 1 point

$$r = \frac{(6.68 \times 10^{-26}\ \text{kg})(4.0 \times 10^4\ \text{m/s})}{(3.2 \times 10^{-19}\ \text{C})(0.12\ \text{T})}$$

$$r = 0.070\ \text{m}$$

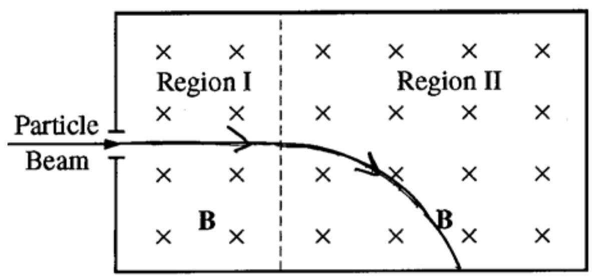
Question 2 (continued)

Distribution of points

(c) 2 points

For indicating that the initial force is "Toward the bottom of the page"	1 point
For a correct justification indicating that the magnetic force ($F_B = qvB$) decreases as velocity decreases, while the electric force ($F_E = qE$) remains the same, so $F_E > F_B$.	1 point

(d) 2 points



For the path in Region I being straight and horizontal	1 point
For the path in Region II being a circular arc, curving downward	1 point

Question 3

15 points total **Distribution of points**

(a) 3 points

For a statement of Ohm's law, recognizing that $I_C = 0$ — 1 point

$V = IR$

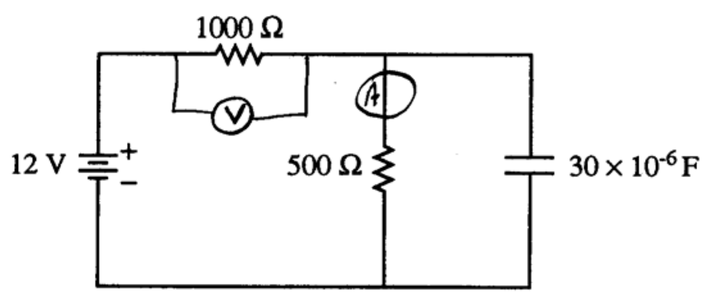
For the calculation of the total resistance — 1 point

$R_{\text{total}} = 1000\ \Omega + 500\ \Omega = 1500\ \Omega$

For the correct answer, including units — 1 point

$$I = \frac{12\text{ V}}{1500\ \Omega} = 8.0 \times 10^{-3}\text{ A}$$

(b)



(i) 2 points

For the ammeter in series anywhere in the circuit except the capacitor branch — 2 points

(ii) 2 points

For the voltmeter in parallel across the $1000\ \Omega$ resistor — 2 points

(c) 3 points

For a correct equation relating the charge, voltage, and capacitance — 1 point

$Q = CV_C$ or $C = \dfrac{Q}{V_C}$

For recognizing that the voltage drop across the capacitor is the same as the voltage drop across the $500\ \Omega$ resistor — 1 point

$$V_C = IR_{500} = \left(8.0 \times 10^{-3}\text{ A}\right)(500\ \Omega) = 4.0\text{ V}$$

For the correct answer with the correct units — 1 point

$$Q = \left(30 \times 10^{-6}\text{ F}\right)(4.0\text{ V})$$

$$Q = 1.2 \times 10^{-4}\text{ C}$$

Question 3 (continued)

	Distribution of points
(d) 2 points	
For a correct equation for the power dissipated	1 point
$P = I^2R_{1000}$ or $V_{1000}I$ or $\dfrac{V_{1000}^2}{R_{1000}}$	
Calculation for the second two relationships	
$V_{1000} = IR_{1000} = \left(8.0 \times 10^{-3}\ \text{A}\right)(1000\ \Omega) = 8.0\ \text{V}$	
For the correct substitutions	1 point
$P = \left(8.0 \times 10^{-3}\ \text{A}\right)^2(1000\ \Omega)$ or $(8.0\ \text{V})\left(8.0 \times 10^{-3}\ \text{A}\right)$ or $\dfrac{(8.0\ \text{V})^2}{1000\ \Omega}$	
$P = 6.4 \times 10^{-2}\ \text{W}$	
(e) 3 points	
For choosing "Larger"	1 point
For correct justification in words or with numerical example. For example:	2 points

"Replacing the $500\ \Omega$ resistor with a larger resistor lowers the steady state current, causing the voltage across the $1000\ \Omega$ resistor to decrease and the voltage across the replacement resistor to increase." (1 point)

"The capacitor is in parallel with the replacement resistor, and so its voltage increases and therefore its charge increases since $Q = CV$." (1 point)

Question 4

10 points total — **Distribution of points**

(a) 3 points

Applying Bernoulli's equation
For example, taking point 1 to be at the top of the liquid and point 2 at the hole

$$P_1 + \rho g y_1 + \frac{1}{2}\rho \upsilon_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho \upsilon_2^2$$

$$P_1 = P_2 = P_{atm}$$

$$\upsilon_1 = 0$$

$$\rho g(y_1 - y_2) = \frac{1}{2}\rho \upsilon_2^2$$

For a correct expression for the speed — 1 point

$$\upsilon_2 = \sqrt{2g(y_1 - y_2)}$$

For correct substitutions — 1 point

$$\upsilon_2 = \sqrt{2\left(9.8\ \text{m/s}^2\right)(0.70\ \text{m})}$$

For the correct answer, including units — 1 point

$$\upsilon_2 = 3.7\ \text{m/s}$$

(b) 2 points

For any indication that the volume rate of flow is the area multiplied by the speed — 1 point

Define the symbol $\mathcal{V}$ for the volume flow rate.

$$\mathcal{V} = \upsilon A$$

For correct substitutions — 1 point

$$\mathcal{V} = (3.7\ \text{m})\pi(0.0010\ \text{m})^2$$

$$\mathcal{V} = 1.2 \times 10^{-5}\ \text{m}^3/\text{s}$$

(c) 2 points

For any indication that the volume is the volume rate multiplied by the time — 1 point

$$V = \mathcal{V}t$$

For correct substitutions — 1 point

$$V = \left(1.2 \times 10^{-5}\ \text{m}^3/\text{s}\right)(2\ \text{min})(60\ \text{s/min})$$

$$V = 1.4 \times 10^{-3}\ \text{m}^3$$

Question 4 (continued)

Distribution of points

(d) 3 points

For using the kinematic equation for distance as a function of time — 1 point

$$y = y_0 + \upsilon_0 t + \frac{1}{2}at^2$$

Taking down as the positive direction, and using $a = g$ and $y = h$

$$\frac{1}{2}gt^2 + \upsilon_0 t - h = 0$$

For solving the equation for *t* using the quadratic formula — 1 point

$$t = \frac{-\upsilon_0 \pm \sqrt{\upsilon_0{}^2 + 2gh}}{g}$$

For correct substitutions — 1 point

Using the + sign to avoid negative time

$$t = \frac{-3.7\ \text{m/s} + \sqrt{(3.7\ \text{m/s})^2 + 2\left(9.8\ \text{m/s}^2\right)(0.25\ \text{m})}}{9.8\ \text{m/s}^2}$$

$$t = 0.062\ \text{s}$$

Alternate solution — *Alternate points*

For using the kinematic equation relating speed, acceleration, and distance — *1 point*

$$\upsilon^2 = \upsilon_0^2 + 2a(x - x_0)$$

For using the kinematic equation for speed as a function of time — *1 point*

$$\upsilon = \upsilon_0 + at$$

$$t = \frac{\upsilon - \upsilon_0}{a}$$

Substituting for υ *from the initial equation into the above equation for t*

$$t = \frac{\sqrt{\upsilon_0^2 + 2a(x - x_0)} - \upsilon_0}{a}$$

For correct substitutions — *1 point*

$$t = \frac{\sqrt{(3.7\ \text{m/s})^2 + 2\left(9.8\ \text{m/s}^2\right)(0.25\ \text{m})} - 3.7\ \text{m/s}}{9.8\ \text{m/s}^2}$$

$$t = 0.062\ \text{s}$$

Question 5

10 points total | **Distribution of points**

(a)

(i) 3 points

For recognition that one component of the force is $P_{atm}A$ — 1 point

For recognition that another component of the force is Mg — 1 point

$F = P_{atm}A + Mg$

For $A = \pi\left(\dfrac{D}{2}\right)^2 = \dfrac{\pi D^2}{4}$ — 1 point

$$F = \frac{P_{atm}\pi D^2}{4} + Mg$$

(ii) 1 point

For $P = \dfrac{F}{A}$, with answer to (a) substituted for F — 1 point

$$P_{abs} = \frac{\dfrac{P_{atm}\pi D^2}{4} + Mg}{\dfrac{\pi D^2}{4}}$$

$$P_{abs} = P_{atm} + \frac{4Mg}{\pi D^2}$$

(b) 3 points

For checking the "Pressure goes up" answer space — 1 point

For a correct and complete justification, 2 points were awarded, with partial credit given where appropriate

Example:

For indicating that if heat is added, then the temperature must increase, recognizing that the volume is constant — 1 point

For then using the ideal gas law to show that with the volume constant, an increase in temperature implies an increase in pressure — 1 point

Alternate example — *Alternate points*

For indicating that if heat is added, then the internal energy and thus the kinetic energy of the gas molecules must increase, recognizing that the volume is constant — *1 point*

For then indicating that as the kinetic energy of the gas molecules increase, they exert more force on the walls of the cylinder, thus increasing the pressure — *1 point*

Question 5 (continued)

Distribution of points

(c) 3 points

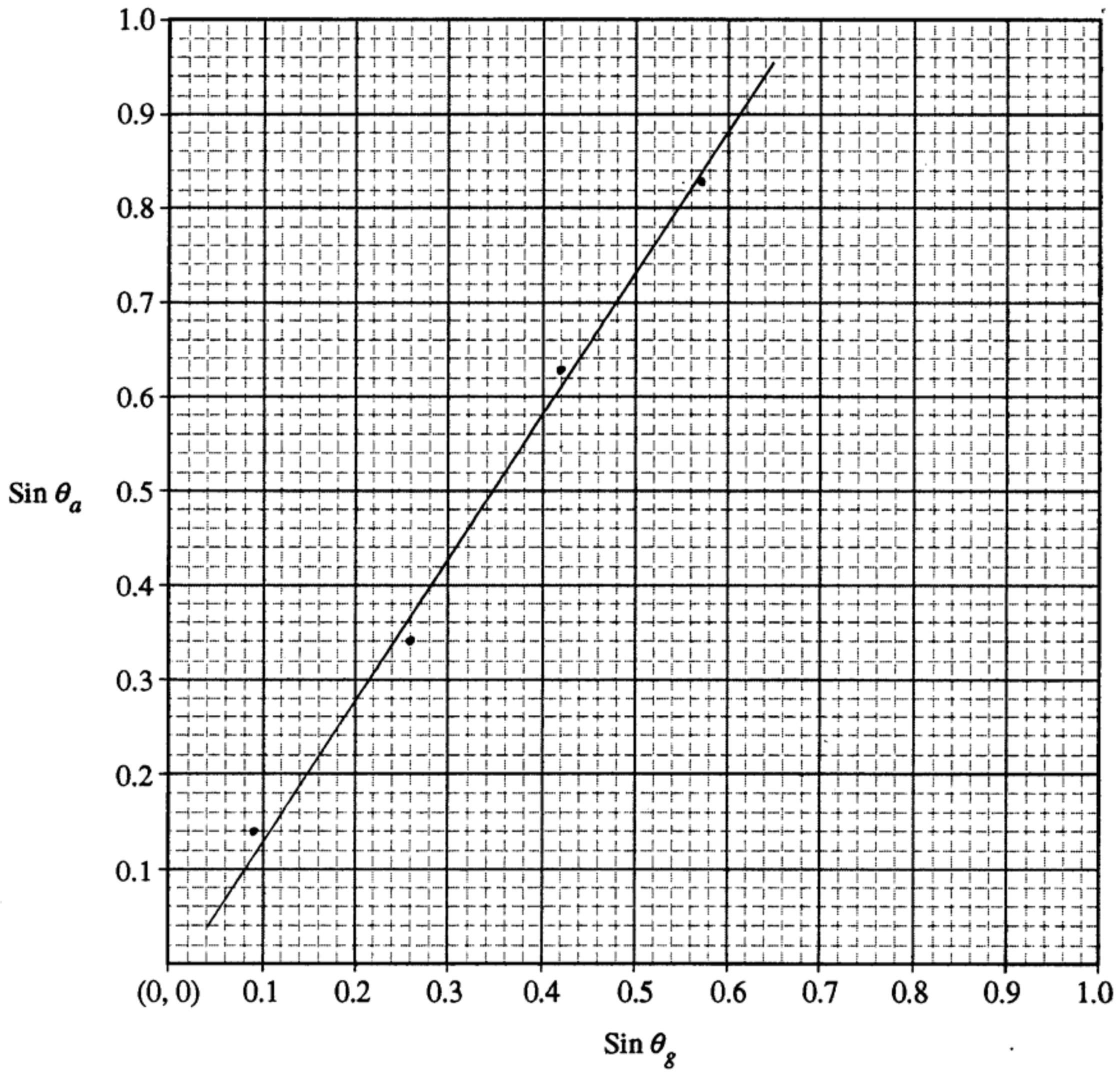
For correct equation for work in terms of force and distance	1 point
$W = Fx$	
For correct substitution of x_0 for x	1 point
$W = Fx_0$	
For substitution of force from part (a)(i)	1 point
$W = \left(\dfrac{P_{atm}\pi D^2}{4} + Mg\right)x_0$	

Alternate solution	*Alternate points*
For correct equation for work in terms of pressure and volume change	*1 point*
$W = P_{abs}\,\Delta V$	
For correct expression for ΔV	*1 point*
$\Delta V = x_0 A = x_0 \dfrac{\pi D^2}{4}$	
$W = P_{abs} x_0 \left(\dfrac{\pi D^2}{4}\right)$	
For substitution of absolute pressure from part (a)(ii)	*1 point*
$W = \left(P_{atm} + \dfrac{4Mg}{\pi D^2}\right)x_0\left(\dfrac{\pi D^2}{4}\right)$	
$W = \left(\dfrac{P_{atm}\pi D^2}{4} + Mg\right)x_0$	

Question 6

10 points total | **Distribution of points**

(a) 3 points



For at least three data points plotted correctly — 1 point

For a straight line drawn — 1 point

For the line being a "best fit" to the data points (with equal number of points above and below the line) — 1 point

Question 6 (continued)

Distribution of points

(b) 3 points

$n_a \sin\theta_a = n_g \sin\theta_g$

$n_a = 1$

For recognizing that n_g is the slope of the graph of $\sin\theta_a$ versus $\sin\theta_g$. — 1 point

$\sin\theta_a = n_g \sin\theta_g$

For using at least two widely separated points on the best-fit line (not two data points) — 1 point

For example, selecting two points on the line in the graph above, such as (0.08,0.10) and (0.60,0.88)

$$\text{Slope} = \frac{\Delta y}{\Delta x} = \frac{0.88 - 0.10}{0.60 - 0.08} = 1.5$$

For the correct slope value, hence the value for n_g — 1 point

$n_g = 1.5$

(c) 2 points

The critical angle θ_c is equal to θ_g when $\sin\theta_a = 1$

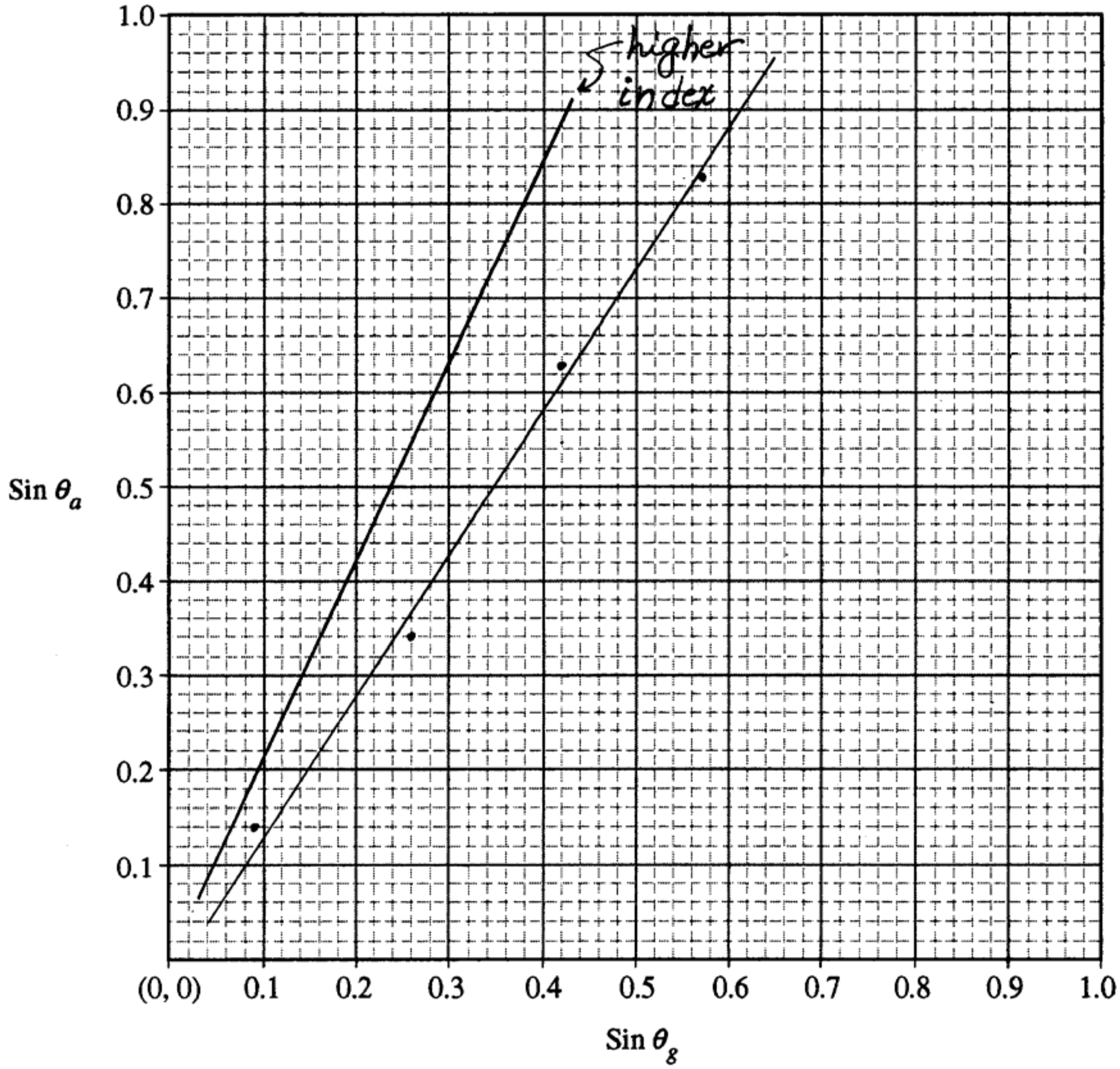
For extending the best-fit line to the point at the top of the graph where $\sin\theta_a = 1$ — 1 point

For indicating that $\theta_c = \sin^{-1}\left(\sin\theta_g\right)$ at this point. (<u>*Note:*</u> *To earn this point it was not required to calculate the actual value for* θ_c.) — 1 point

Question 6 (continued)

Distribution of points

(d) 2 points



For a line with a slope greater than the best-fit line of part (a)	1 point
For the line intercepting the origin (0,0)	1 point

Question 7

10 points total | **Distribution of points**

(a) 3 points

For using the correct equation for energy — 1 point

$E_e = m_e c^2$

For a correct calculation of the energy in joules — 1 point

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

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

For the correct answer in eV as instructed in the question — 1 point

$E_e = 5.12 \times 10^5 \text{ eV}$ (answers in keV and MeV also accepted)

(b) 2 points

For recognizing that the photon energy must be twice that of one of the particles — 1 point

$E_\gamma = 2E_e$

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

$E_\gamma = 2(5.12 \times 10^5 \text{ eV})$

$E_\gamma = 1.02 \times 10^6 \text{ eV}$

(c) 2 points

For a correct relationship between photon energy and wavelength — 1 point

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

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

$\lambda = \dfrac{hc}{E_\gamma} = \dfrac{1.24 \times 10^3 \text{ eV} \bullet \text{nm}}{1.02 \times 10^6 \text{ eV}}$

$\lambda = 1.22 \times 10^{-3} \text{ nm} = 1.22 \times 10^{-12} \text{ m}$

Question 7 (continued)

Distribution of points

(d) 3 points

For a correct relationship between photon wavelength and momentum — 1 point

$$\lambda = \frac{h}{p}$$

For substituting the value of wavelength from part (c) — 1 point

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}\ \text{J}\bullet\text{s}}{1.22 \times 10^{-12}\ \text{m}}$$

For the correct answer with units consistent with the values substituted — 1 point

$p = 5.43 \times 10^{-22}\ \text{kg}\bullet\text{m/s}$ or equivalent (such as $3.39 \times 10^{-3}\ \text{eV}\bullet\text{s/m}$)

Alternate solution — *Alternate points*

For a correct relationship between photon energy and momentum — *1 point*

$$E_\gamma = pc$$

$$p = \frac{E_\gamma}{c} \quad \left(= \frac{2E_e}{c} = \frac{2m_e c^2}{c} = 2m_e c \right)$$

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

$$p = \frac{\left(1.02 \times 10^{6}\ \text{eV}\right)\left(1.6 \times 10^{-19}\ \text{J/eV}\right)}{3.00 \times 10^{8}\ \text{m/s}} \qquad \left(\text{or}\quad 2\left(9.11 \times 10^{-31}\ \text{kg}\right)\left(3 \times 10^{8}\ \text{m/s}\right)\right)$$

For units on the final answer consistent with the values substituted — *1 point*

$p = 5.44 \times 10^{-22}\ \text{kg}\bullet\text{m/s}$ $\left(\text{or } 5.46 \times 10^{-22}\ \text{kg}\bullet\text{m/s}\right)$ *or equivalent*