CollegeBoard
Advanced Placement Program

AP® Physics B
2004 Scoring Guidelines

AP® PHYSICS B
2004 SCORING GUIDELINES

General Notes about 2004 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 value $g = 9.8 \text{ m/s}^2$, but use of 10 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, 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.

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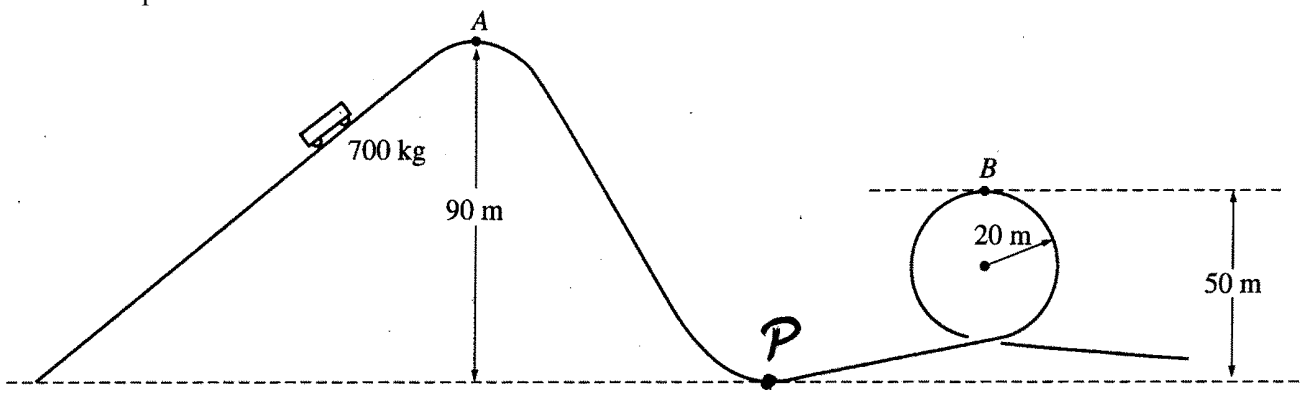
Question 1

15 points total **Distribution of points**

(a)

i. 1 point



For correctly locating point P at the low point between the hill and the loop 1 point

ii. 3 points

For any indication that energy is conserved 1 point

Setting the kinetic energy at P equal to the potential energy at A:

$$\frac{1}{2}mv_{max} = mgy_A$$

$$v_{max} = \sqrt{2gy_A}$$

For correct substitution 1 point

$$v_{max} = \sqrt{2\left(9.8 \text{ m/s}^2\right)(90 \text{ m})}$$

For the correct answer 1 point

$v_{max} = 42$ m/s (or 42.4 m/s using $g = 10$ m/s^2)

A maximum of 2 points could be earned for applying the kinematics equation $v_{max}^2 = v_A^2 + 2a\,\Delta y$ without an explicit statement that since energy is conserved, anything "falling" from A to P will achieve the same speed as something that is dropped.

Question 1 (continued)

Distribution of points

(b) 3 points

For any indication that energy is conserved — 1 point

Equating the total energy at point B to the potential energy at point A:

$$\frac{1}{2}mv_B + mgy_B = mgy_A$$

Solving for the speed at point B:

$$v_B = \sqrt{2g(y_A - y_B)}$$

For correct substitution — 1 point

$$v_B = \sqrt{2\left(9.8\ \text{m/s}^2\right)(90\ \text{m} - 50\ \text{m})}$$

For the correct answer — 1 point

$v_B = 28$ m/s (or 28.3 m/s using $g = 10\ \text{m/s}^2$)

As in (a) ii above, a maximum of 2 points could be earned for using the kinematics equation.

(c)

i. 3 points

For each correctly drawn and labeled vector — 1 pt each

For no extraneous vectors, given that the two vectors above are drawn correctly — 1 point

ii. 3 points

For determining the correct value of the weight — 1 point

$$mg = (700\ \text{kg})\left(9.8\ \text{m/s}^2\right)$$

$mg = 6860$ N (or 7000 N using $g = 10\ \text{m/s}^2$)

For indicating there is a centripetal force on the car, either separately or by setting the sum of the forces equal to the centripetal force — 1 point

$$N + mg = \frac{mv_B^2}{r}$$

$$N = \frac{mv_B^2}{r} - mg = \frac{(700\ \text{kg})(28\ \text{m/s})^2}{20\ \text{m}} - 6860\ \text{N}$$

For the correct answer — 1 point

$N = 20{,}580$ N (or 21,000 N using $g = 10\ \text{m/s}^2$)

Question 1 (continued)

Distribution of points

(d) 2 points

For any clear description of both a modification that will lower the height of point *B* and a correct justification — 2 points

For example: Flatten out the track on either side of the loop so the bottom of the loop is on the ground, and thus point *B* is lower. The work done by friction will reduce the total mechanical energy available at point *B*, so if the kinetic energy at point *B* is to remain the same, the potential energy at that point must be reduced.

Only one point was awarded for an answer that showed some understanding but was not totally clear or complete.

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Question 2

15 points total **Distribution of points**

(a) 2 points

For work showing $p_{absolute} - p_{atm}$ in an appropriate equation or calculation 1 point

$p_g = p_{absolute} - p_{atm}$

$p_g = 413 \text{ atm} - 1 \text{ atm}$

For the correct answer 1 point

$p_g = 412 \text{ atm}$

Note: An answer with no work shown only received 1 point total

(b) 3 points

For showing $p = \rho gh$ in any of the following equations or during calculation 1 point

$p = p_0 + \rho gh$ OR $p_g = \Delta p = \rho gh$ OR $p = \rho gh$

For correct substitutions in any of these equations 1 point

For example, $D = \dfrac{p_g}{\rho g} = \dfrac{(412 \text{ atm})\left(1 \times 10^5 \text{ N}/\left(\text{m}^2 \cdot \text{atm}\right)\right)}{\left(1025 \text{ kg}/\text{m}^3\right)\left(9.8 \text{ m}/\text{s}^2\right)}$

For answer consistent with (a), with a reasonable number of significant figures (1 to 4) 1 point

$D = 4100$ m (or 4020 m using $g = 10 \text{ m}/\text{s}^2$). Any negative sign was ignored.

Note: A range of answers was possible depending on the value used for g (9.8 or $10 \text{ m}/\text{s}^2$) and on the conversion factor used to convert atmospheres to N/m^2 (the approximate value in the equation sheet or the more precise value found in some calculators).

(c) 2 points

For correct substitution of numerical values into a correct relationship 1 point

$F = p_g A = (412 \text{ atm})\left(1 \times 10^5 \text{ N}/\left(\text{m}^2 \cdot \text{atm}\right)\right)\left(0.0100 \text{ m}^2\right)$

Note: Since "force due to the water" might have been interpreted as due to the total pressure instead of the gauge pressure, 413 atm was also accepted for the pressure.

For the correct answer with units consistent with calculation using 412 atm, 413 atm, or answer to (a) 1 point

$F = 4.12 \times 10^5$ N

Note: In the absence of explicit indication of numerical substitution, a correct answer with a correct equation could earn 2 points.

Also accepted was $F = \rho Vg$, where $\rho = 1025 \text{ kg/m}^3$ and $V = \left(0.0100 \text{ m}^3\right)$(answer to (b))

Question 2 (continued)

Distribution of points

(d) 2 points

For substitution in the correct equation OR for the correct numerical answer 1 point
Negative sign was ignored.
For a correct numerical answer with correct units 1 point
$a = \Delta v/t = (10.0 \text{ m/s} - 0 \text{ m/s})/(30.0 \text{ s})$
$a = 0.333 \text{ m/s}^2$

(e) 2 points

For correct substitution into a correct equation 1 point
For correct answer (using acceleration from (d) in the first two of the following solutions) 1 point
$v^2 = v_0^2 + 2a\Delta x$
$d = v_f^2/2a = (10.0 \text{ m/s})^2/2(0.333 \text{ m/s}) = 150 \text{ m}$

OR

$d = \frac{1}{2}at^2$
$d = \frac{1}{2}(0.333 \text{ m/s}^2)(30.0 \text{ s})^2 = 150 \text{ m}$

OR

$v_{\text{avg}} = \Delta x/t$
$d = v_{avg}t = (30 \text{ s})(10.0 \text{ m/s} + 0 \text{ m/s})/2 = 150 \text{ m}$

Note: In the absence of explicit indication of numerical substitution, a correct answer with a correct equation could earn 2 points. Negative sign was ignored.

(f) 4 points

For computing the distance Δy that the ship falls at constant velocity using D from part (b) and d from part (e) 1 point
$\Delta y = D - d = 4100 \text{ m} - 150 \text{ m}$
$\Delta y = 3950 \text{ m}$
For consistent substitution in a correct equation to find t_2, the time the ship falls at constant velocity 1 point
$\Delta y = v_f t_2$
$t_2 = \Delta y/v_f = (3950 \text{ m})/(10 \text{ m/s}) = 395 \text{ s}$
For finding the total time by adding t_2 to the given time t_1 to reach terminal velocity 1 point
$t_{\text{tot}} = t_2 + t_1 = 395 \text{ s} + 30 \text{ s}$
For the correct total time 1 point
$t = 425 \text{ s}$ (or answer consistent with previous answers)

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Question 3

15 points total **Distribution of points**

(a) 3 points

For using the correct expression for the magnetic flux 1 point
$\phi = BA$

For correct substitution 1 point
$\phi = (0.030\ \text{T})(0.20\ \text{m})^2$

For the correct answer
$\phi = 1.2 \times 10^{-3}\ \text{T}\cdot\text{m}^2$ 1 point

(b) 4 points

For using the correct expression for the magnitude of the emf 1 point
$\mathcal{E} = \dfrac{\Delta\phi}{\Delta t}$

For recognizing that one needs to calculate a change in the magnetic field or the flux 1 point

For a correct determination of the change in magnetic field or the flux 1 point
$\mathcal{E} = \dfrac{\Delta B\, A}{\Delta t}$

$\mathcal{E} = \dfrac{(0.20\ \text{T} - 0.030\ \text{T})(0.20\ \text{m})^2}{0.50\ \text{s}}$

For the correct answer 1 point
$\mathcal{E} = 0.014\ \text{V}$ (with or without a negative sign)

(c)

i. 2 points

For using a correct expression for Ohm's law 1 point
$I = \mathcal{E}/R$

For correct substitution 1 point
$I = (0.014\ \text{V})/(0.60\ \Omega)$
$I = 0.023\ \text{A}$

Question 3 (continued)

Distribution of points

(c) (continued)

ii. 3 points

For correctly indicating that the current is counterclockwise 1 point

The remaining points were only awarded if the point above was earned

For indicating that Lenz's law or a hand rule applies 1 point

For correctly explaining how Lenz's law or a hand rule leads to the answer 1 point

For example: The magnetic field is increasing into the page. Current will be induced to oppose that change. By the right-hand rule, to create a field out of the page the current must be counterclockwise.

(d) 2 points

For any description of a correct method to induce a current in a constant magnetic field 2 points

For example: Change the area of the loop
Pull the loop out of the field
Rotate the loop about an axis in the plane of the loop

No points were awarded if items such as batteries, capacitors, etc. were added to the loop

Units: 1 point

For correct units on at least two of the three answers to parts (a), (b), and (c) 1 point

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Question 4

15 points total **Distribution of points**

(a) 3 points

For a correct equation 1 point

$v = f\lambda$

$\lambda = v/f$

For correct substitutions 1 point

$\lambda = (343 \text{ m/s})/(2500 \text{ Hz})$

For the correct answer with units 1 point

$\lambda = 0.1372 \text{ m} \approx 0.14 \text{ m}$

(b) 3 points

For demonstrating a correct approach to the problem using any of the following methods. 1 point

Method 1

$$x_m \approx \frac{m\lambda L}{d} = \frac{\frac{1}{2}\lambda L}{d} = \frac{\frac{1}{2}(0.1372 \text{ m})(5.0 \text{ m})}{0.75 \text{ m}}$$

$Y = x_m = 0.457 \text{ m}$

Method 2

$d\sin\theta = m\lambda$ and $Y = L\tan\theta$

$$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{\frac{1}{2}(0.1372 \text{ m})}{0.75 \text{ m}}\right) = 5.25°$$

$Y = L\tan\theta = (5.0 \text{ m})\tan(5.25°) = 0.459 \text{ m}$

Method 3

Computing the actual path difference and setting it equal to $\lambda/2$:

$$\sqrt{\left(Y + \frac{d}{2}\right)^2 + L^2} - \sqrt{\left(Y - \frac{d}{2}\right)^2 + L^2} = \frac{\lambda}{2}$$

$$\sqrt{(Y + 0.375 \text{ m})^2 + (5 \text{ m})^2} - \sqrt{(Y - 0.375 \text{ m})^2 + (5 \text{ m})^2} = \frac{0.1372 \text{ m}}{2}$$

By algebraic solution or by using a calculator

$Y = 0.460 \text{ m}$

Assignment of points for each of the three methods:

For using $m = 1/2$ or for using path difference $= \lambda/2$ 1 point

For substitution of λ from (a), $d = 0.75$ m, and $L = 5.0$ m 1 point

Question 4 (continued)

Distribution of points

(c) 3 points

For correct identification of another minimum — 1 point
Examples:
$Y = 0.46$ m along the line PQ but on the opposite side of P than Q
OR
At 3, 5, 7, … times the answer from (b) along the line PQ. Could be on either side of P, but it was not necessary to mention which side.

For a complete explanation of the placement of the minimum cited — 2 points
This explanation may include a clear statement of the symmetry of the problem, a description of the path differences for sound from the speakers, or a mathematical derivation of the new distance from P to the new minimum. One point only was awarded for justifications that were not complete or less clear.

(d)

i. 3 points

For an indication that Y increases — 1 point
For a clear correct justification — 2 points
Examples:
A statement that the distance d between the speakers decreases and Y is inversely proportional to the separation of the speakers
OR
A mathematical calculation of the value of Y for a value of $d < 0.75$ m
Note: The justification points were awarded based on the quality of the explanation. One point only was awarded for justifications that were not complete or less clear.

ii. 3 points

For an indication that Y decreases — 1 point
For a clear correct justification — 2 points
Examples:
A statement that includes the inverse proportion between wavelength and frequency and the direct proportion between Y and wavelength
OR
A mathematical calculation that demonstrates these relationships starting with $f > 2500$ Hz and ending with $Y < 0.46$ m.
Note: The justification points were awarded based on the quality of the explanation. One point only was awarded for justifications that were not complete or less clear.

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Question 5

10 points total **Distribution of points**

(a)

i. 2 points

For a correct calculation of the work done on the gas 1 point

$W_{on} = -P\Delta V$

$W_{on} = -\left(600\ \text{N/m}^2\right)\left(9.0\ \text{m}^3 - 3.0\ \text{m}^3\right)$

$W_{on} = -3600\ \text{J}$

For recognition that the work done by the gas is the negative of the work done on the gas 1 point

$W_{by} = 3600\ \text{J}$

ii. 3 points

For a correct expression or derivation of the expression for ΔU 1 point

$\Delta U = \frac{3}{2} nR\ \Delta T$

For correct calculation of T's or ΔT using the ideal gas law, $PV = nRT$ 1 point

$\Delta U = \frac{3}{2}(2\ \text{moles})\left(8.31 \frac{\text{J}}{\text{mol K}}\right)(325\ \text{K} - 108\ \text{K})$

OR since $P\ \Delta V = nR\ \Delta T$, $\Delta U = \frac{3}{2} P\ \Delta V = \frac{3}{2}\left(600\ \text{N/m}^2\right)\left(9\ \text{m}^3 - 3\ \text{m}^3\right)$

For the correct answer 1 point

$\Delta U = 5400\ \text{J}$

Note: The equation $\Delta U = \frac{3}{2} nR\ \Delta T$ can be derived from the expressions for K_{avg} and υ_{rms} found in the equation sheet as follows:

$U = NK_{avg}$, where N = number of molecules in the gas = nN_0

$U = nN_0 \frac{3}{2} k_B T$

$\upsilon_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_B T}{\mu}}$, so $\frac{R}{M} = \frac{k_b}{\mu}$

$R = k_B \frac{M}{\mu} = k_B N_0$

$U = \frac{3}{2} nRT$

$\Delta U = \frac{3}{2} nR\ \Delta T$

Question 5 (continued)

Distribution of points

(a) continued

iii. 1 point

For correct substitution of answers from parts i. and ii. into the first law of thermodynamics — 1 point

$\Delta U = Q + W_{on}$

$Q = \Delta U - W_{on}$

$Q = 5400 \text{ J} - (-3600 \text{ J})$

$Q = 9000 \text{ J}$

Alternate Solutions for parts ii. and iii. — *Alternate points*

Solving part iii. first:

$$Q = nc_P \Delta T = n\frac{5}{2}R\,\Delta T = (2 \text{ moles})\frac{5}{2}\left(8.31\frac{\text{J}}{\text{mol K}}\right)(325 \text{ K} - 108 \text{ K}) = 9000 \text{ J}$$

For a correct equation — *1 point*

For correct calculation of T's or ΔT — *1 point*

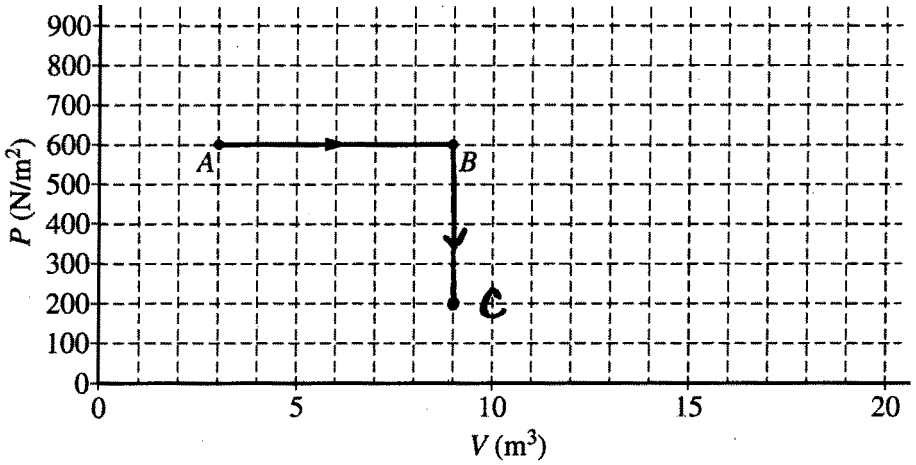
For the correct answer — *1 point*

Returning to solve part ii.:

$\Delta U = Q + W_{on} = 9000 \text{ J} + (-3600 \text{ J}) = 5400 \text{ J}$

For correct substitutions into the first law of thermodynamics of answers from parts i. and iii. — *1 point*

(b) 1 point



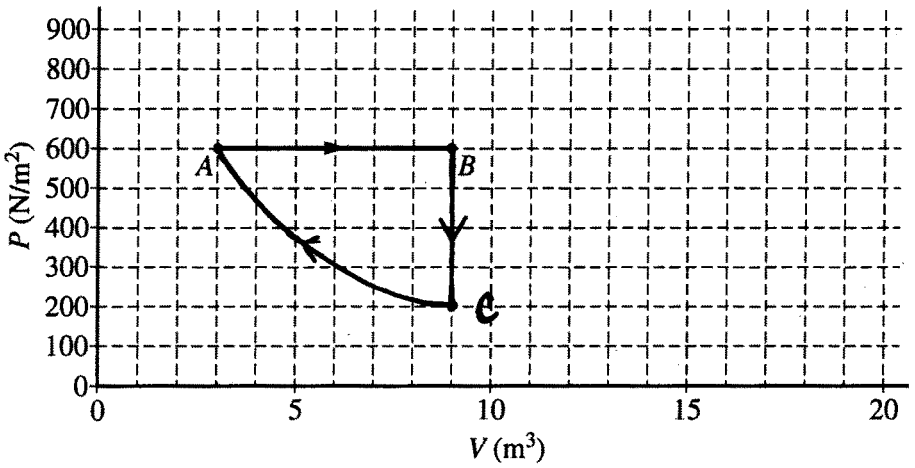
For point C plotted and labeled correctly as above, and for a correct straight line from point B to point C — 1 point

Question 5 (continued)

Distribution of points

(c)

i. 1 point



For a correct curve from point *C* to point *A*. Curve must be concave upward. 1 point

ii. 2 points

For correctly indicating that heat is removed from the gas 1 point

For a correct justification such as explaining in words or symbols that the change in internal energy is zero, so from first law of thermodynamics $Q = -W$. Since the work done on the gas is greater than zero, Q is negative. Therefore heat is removed from the gas. 1 point

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Question 6

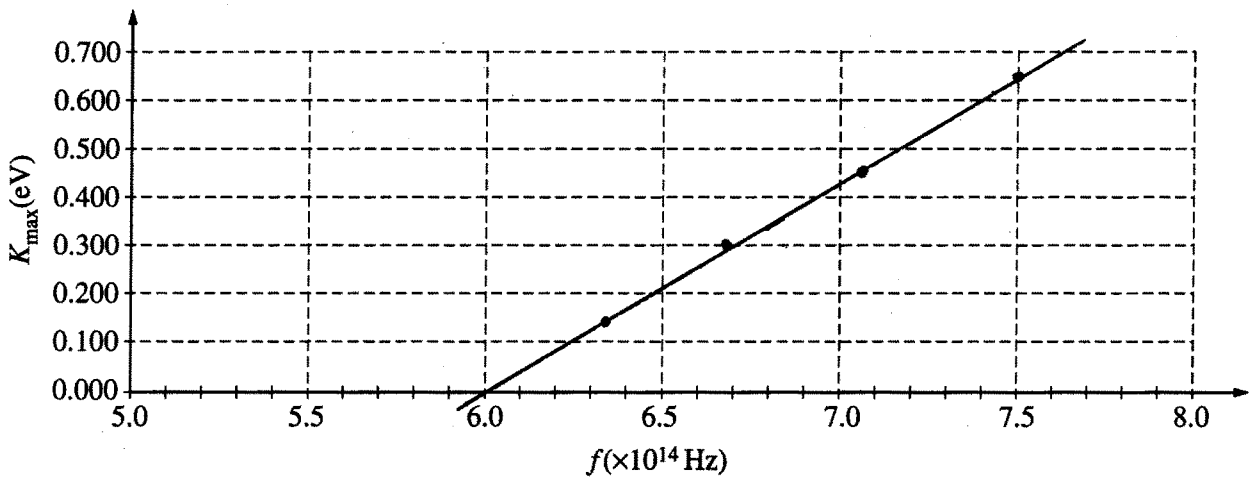
10 points total **Distribution of points**

(a) 2 points

For indicating that the ammeter is M_2 1 point

For indicating that the voltmeter is M_1 1 point

(b) 2 points



For correctly plotting all 4 points 1 point

For a correct straight line based on the points that were plotted 1 point

(c) 2 points

$K_{max} = hf - \phi$, so h equals the slope of the line

Taking two points from the graph, for example

$(6 \times 10^{14}\ \text{Hz}, 0\ \text{eV})$ and $(7.5 \times 10^{14}\ \text{Hz}, 0.65\ \text{eV})$:

$$h = \frac{\Delta y}{\Delta x} = \frac{\Delta K_{max}}{\Delta f} = \frac{0.65\ \text{eV} - 0\ \text{eV}}{7.5 \times 10^{14}\ \text{Hz} - 6.0 \times 10^{14}\ \text{Hz}}$$

$h = 4.3 \times 10^{-15}$ eV•s

For any indication of $\frac{\Delta y}{\Delta x}$ or $\frac{\Delta K_{max}}{\Delta f}$ or $\frac{y}{x}$ or $\frac{K_{max}}{f}$ 1 point

For a value of h consistent with the plotted data. 1 point

Note: For correctly plotted points, a range of values from 3.73×10^{-15} eV•s to 4.55×10^{-15} eV•s was accepted. This range is ±10% of the actual value of h.

Question 6 (continued)

Distribution of points

(c) (continued)

Alternate Solutions *Alternate points*

Method 1 By simultaneous equations
Set up two equations with two unknowns using $K_{\max} = hf - \phi$ and two points on the graph. Solve the equations for *h*.
For indicating $K_{\max} = hf - \phi$ *1 point*
For the correct value of *h* from the two equations *1 point*

Method 2 By calculator program
Enter the data into a calculator and run a program to determine the best-fit line for $K_{\max}$ as a function of *f*. Then recognize that *h* is the coefficient of f in the equation.
For the correct equation $y \approx 4.2 \times 10^{-15} x - 2.51$ or $K_{\max} \approx 4.2 \times 10^{-15} f - 2.51$ (*1 point*)
For the statement that $h = 4.2 \times 10^{-15}$ eV•s from the equation (*1 point*)

(d) 4 points

For a statement that the graph moves to the right or down, OR for a sketch of a second parallel line to the right of the first graph and labeled as the second graph. 2 points
Note: 1 point was deducted for an indication that the slope of the graph changes.
For a correct explanation that relates to a graph or to the physical situation, such as one of the following: 2 points

- A larger work function means a larger *y*-intercept (no penalty for not including a minus sign before the *y*-intercept)
- A larger work function means a larger *x*-intercept or threshold frequency
- A larger work function means that greater energy is needed in order for an electron to escape from the surface