AP® Physics B
2010 Scoring Guidelines
Form B

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AP® PHYSICS B
2010 SCORING GUIDELINES (Form B)

General Notes

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for the 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 — for example, 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 Exams 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 $10\ \text{m/s}^2$ 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 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.

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Question 1

10 points total **Distribution of points**

(a) 2 points

For a correct conservation of energy equation for this situation 1 point

$mgh_i = mgh_f + \frac{1}{2}mv_f^2$

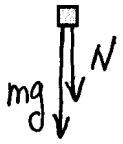
$v_f = \sqrt{2g(h_i - h_f)}$

$v_f = \sqrt{2(9.8\ \text{m/s}^2)(2.0\ \text{m} - 0.50\ \text{m})}$

For the correct answer 1 point

$v_f = 5.4\ \text{m/s}$ (or 5.5 using $g = 10\ \text{m/s}^2$)

(b) 3 points



For correctly drawing and appropriately labeling the weight of the block 1 point

For correctly drawing and appropriately labeling the normal force 1 point

For no extraneous forces 1 point

(c) 2 points

At the top of the track, the net force on the block is the centripetal force

$ma = mv^2/r = mg + N$

The condition for minimum speed is that the normal force is zero.

For a correct equation that can be solved for the minimum speed 1 point

$mv_{\text{min}}^2/r = mg$

$v_{\text{min}} = \sqrt{rg}$

$v_{\text{min}} = \sqrt{(0.60\ \text{m})(9.8\text{m/s}^2)}$

For the correct answer 1 point

$v_{\text{min}} = 2.4\ \text{m/s}$

Question 1 (continued)

Distribution of points

(d) 3 points

For a correct conservation of energy equation for this situation — 1 point

$mgh_{\text{min}} = mg(2r) + \frac{1}{2}mv_{\text{min}}^2$

$h_{\text{min}} = 2r + \left(v_{\text{min}}^2 / 2g\right)$

For correctly substituting the value of v_{min} from part (c) — 1 point

$h_{\text{min}} = 2(0.60 \text{ m}) + \left((2.4 \text{ m/s})^2 / 2\left(9.8 \text{ m/s}^2\right)\right)$

For the correct answer — 1 point

$h_{\text{min}} = 1.5 \text{ m}$

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Question 2

15 points total **Distribution of points**

(a) 3 points

To determine the frequency, all that is needed is a stopwatch to measure the period.
For choosing only the stopwatch 3 points
OR choosing the stopwatch and other equipment, using the stopwatch correctly in part (b), and indicating there a plausible use of the other equipment that does not interfere with correctly using the stopwatch (e.g., using the protractor to set the initial angle)

Partial credit was awarded if part (b) did not use the stopwatch or, in addition to the stopwatch, used other equipment incorrectly. For choosing one item in addition to the stopwatch, 2 points were awarded; for choosing two additional items, 1 point was awarded.

(b) 3 points

For a reasonable and complete procedure that correctly measures time and allows determination of the frequency, either by calculating the period and indicating the correct relationship between the period and frequency, or by directly determining the frequency from the measurements. Some mention of error reduction (e.g., measuring over multiple cycles) was expected as part of a complete experimental procedure. 3 points

(c) 3 points

For indicating that one of the following is a parameter that can be varied: mass of bob, length of string, angle of release or height of release 1 point
For a reasonable and complete experimental procedure and description of data analysis 2 points

(d) 3 points

For correctly indicating that the temperature of the room would slightly increase 1 point
For stating that the pendulum loses kinetic energy 1 point
For stating that the lost kinetic energy is converted to heat energy 1 point

(e) 3 points

For correctly indicating that the period of the pendulum would increase 1 point
For indicating that the length of the rod increases 1 point
For using the relationship between pendulum length and period, $T = 2\pi\sqrt{\ell/g}$, to show that the increase in length leads to an increase in period 1 point

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Question 3

15 points total **Distribution of points**

(a) 2 points

Applying Newton's second law to one of the objects

$ma = T - kq^2/r^2 = 0$

For a correct expression for the tension T 1 point

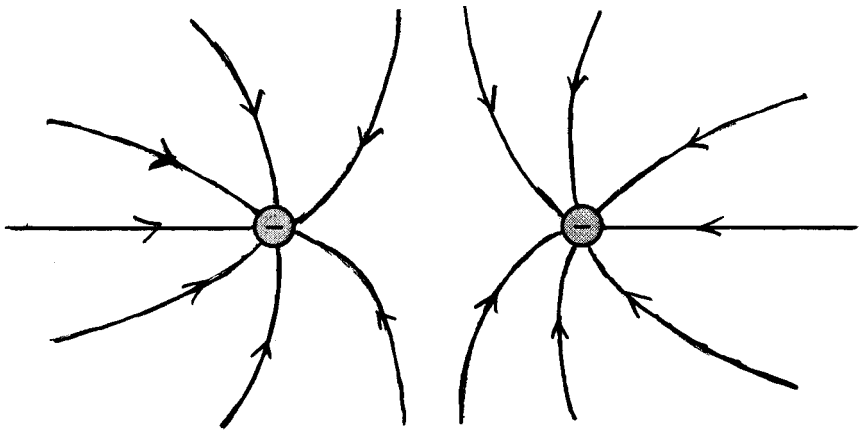
$T = kq^2/r^2$

$T = \left(9.0 \times 10^9 \text{ N•m}^2/\text{C}^2\right)\left(-4.0 \times 10^{-9} \text{ C}\right)^2 / \left(0.020 \text{ m}\right)^2$

For the correct answer, with units 1 point

$T = 3.6 \times 10^{-4}$ N

(b) 4 points



For a full representation of the field in the vicinity of the objects 1 point

For field lines that begin or end on the objects 1 point

For having curved or bent field lines in the region between the objects that indicate an asymptotic approach to a vertical line midway between the objects 1 point

For showing the direction of the field as inward (toward the objects) 1 point

Question 3 (continued)

Distribution of points

(c) 3 points

The acceleration is caused by the electrostatic force, and initially that force has the same magnitude calculated in part (a).

$ma = kq^2/r = T$

For a correct force equation — 1 point

$ma = T$

$a = T/m$

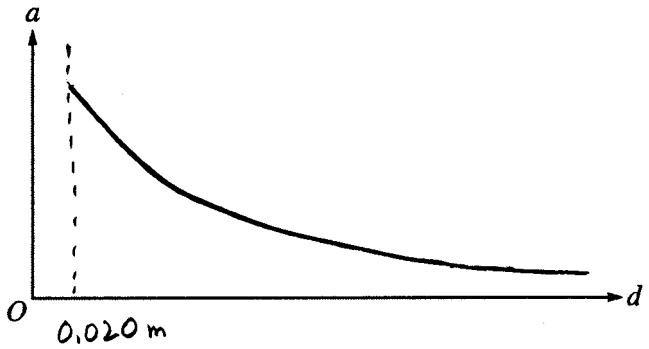
For correctly substituting the value of T from part (a), and mass m_1 — 1 point

$a_1 = \left(3.6 \times 10^{-4}\ \text{N}\right)/(0.030\ \text{kg}) = 1.2 \times 10^{-2}\ \text{m/s}^2$

For correctly substituting the value of T from part (a), and mass m_2 — 1 point

$a_1 = \left(3.6 \times 10^{-4}\ \text{N}\right)/(0.060\ \text{kg}) = 6.0 \times 10^{-3}\ \text{m/s}^2$

(d) 3 points



For beginning the graph at a value d that is clearly greater than zero — 1 point

For a concave upward curve — 1 point

For acceleration approaching zero as d approaches infinity — 1 point

(e) 3 points

For indicating that the speeds increase — 1 point

For indicating that as the objects move apart, their speeds increase at a slower rate (i.e., the acceleration decreases) — 1 point

For indicating that the speeds approach a constant value as d approaches infinity — 1 point

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Question 4

10 points total **Distribution of points**

(a) 2 points

For correctly determining the equivalent resistance of the two parallel resistors 1 point

$$\frac{1}{R_p} = \frac{1}{R_2} + \frac{1}{R_2} = \frac{2}{R_2}$$

$$R_p = \frac{1}{2}R_2$$

For correctly determining the total equivalent resistance of the circuit 1 point

$$R_T = R_1 + R_1 + R_p$$

$$R_T = 2R_1 + \frac{1}{2}R_2$$

(b) 2 points

For a correct expression for the power in terms of emf and resistance 1 point

$$P = \mathcal{E}^2 / R_T$$

For correctly substituting the value of total resistance from part (a) 1 point

$$P = \mathcal{E}^2 \Big/ \left(2R_1 + \frac{1}{2}R_2\right)$$

(c) 3 points

For correctly indicating that the field is directed out of the plane of the page 1 point

For using the right-hand rule to determine the direction of the field at point *P* from each wire (into the page from the top wire, out of the page from the bottom wire) 1 point

For indicating that the magnitude of the field at point *P* from the bottom wire is greater because it is closer to point *P* 1 point

(d) 3 points

For correctly indicating that the force is directed toward the bottom of the page 1 point

For indicating that the magnetic field at the bottom wire due to the top wire is directed into the page 1 point

For using the right-hand rule to determine the direction of the force on the bottom wire due to the magnetic field 1 point

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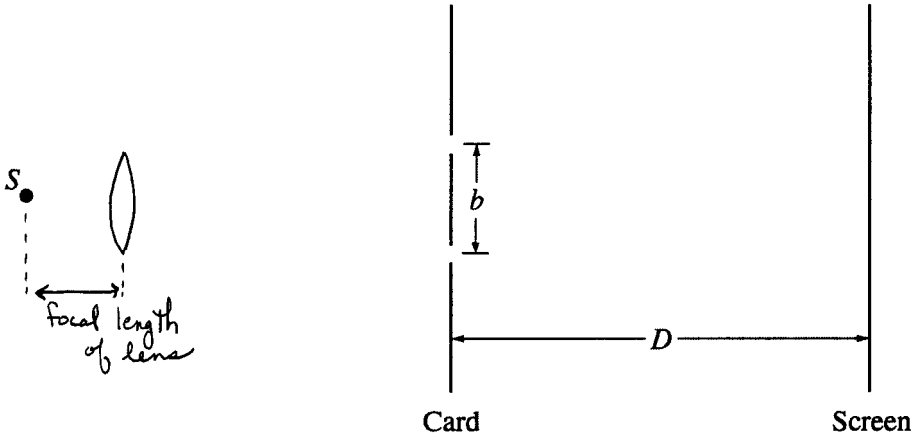
Question 5

10 points total **Distribution of points**

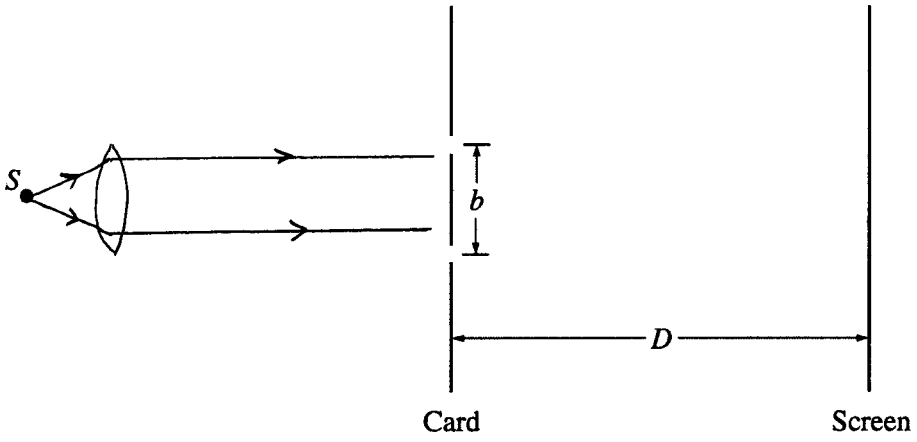
(a) 1 point



Note: Figure not drawn to scale.

For drawing the lens between the source and the card, and indicating that the lens is one focal length from the source — 1 point

(b) 2 points



Note: Figure not drawn to scale.

For drawing diverging rays from the source to the lens — 1 point
For drawing parallel rays from the lens to the card — 1 point
One earned point was deducted if a diverging lens was drawn, if it was obvious that a mirror was being used, or if the lens was set right next to the card.

Question 5 (continued)

Distribution of points

(c) 4 points

For using the correct equation 1 point
$b\sin\theta = m\lambda$

For the correct approximation for $\sin\theta$ 1 point
$\sin\theta \approx y_3/D$

For correctly substituting $m = 3$ 1 point
$b(y_3/D) = 3\lambda$

For the correct answer 1 point
$\lambda = by_3/3D$

Notes:

The first 2 points could also be earned by starting directly with the equation $x_m \approx \frac{m\lambda L}{d}$ from the equation table.

The second point was also earned for use of either of the exact relationships $\sin\theta = y_3/\sqrt{y_3^2 + D^2}$ or $\theta = \tan^{-1}(y_3/D)$.

(d) 3 points

For indicating that the fringe spacing would decrease 1 point
For a clear, correct justification 2 points
For example: If the index of refraction increases, the wavelength in that region decreases. From the relationship in part (c), one can see that that means a decrease in fringe spacing.
No credit was awarded when multiple choices were marked unless they were affirmative and negative marks (e.g., a checkmark for the intended choice and an x for the others).

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Question 6

10 points total **Distribution of points**

(a) 2 points

For indicating that the buoyant force is the difference between the scale readings 1 point
$F_b = 17.8\text{ N} - 16.2\text{ N}$
For the correct answer with units 1 point
$F_b = 1.6\text{ N}$

(b) 3 points

For indicating that the buoyant force equals the weight of the displaced water 1 point
$F_b = m_w g$
For indicating the correct relationship between mass and volume 1 point
$m = \rho V$
The volume of displaced water equals the volume of the object.
$F_b = \rho_w V_w g = \rho_w V_o g$
$V_o = F_b / \rho_w g$
For substituting the value of buoyant force from part (a) 1 point
$V_o = (1.6\text{ N}) / \left(1000\text{ kg/m}^3\right)\left(9.8\text{ m/s}^2\right)$
$V_o = 1.6 \times 10^{-4}\text{ m}^3$

(c) 2 points

For using the relationship between mass and density 1 point
$\rho_o = m_o / V_o$
$\rho_o = \dfrac{w_o / g}{V_o} = w_o / g V_o = (17.8\text{ N}) / \left(9.8\text{ m/s}^2\right)\left(1.6 \times 10^{-4}\text{ m}^3\right)$
For the correct answer 1 point
$\rho_o = 1.1 \times 10^4\text{ kg/m}^3$

(d) 3 points

For indicating that the pressure would decrease 1 point
For correctly indicating an intermediate effect: the height of the water will decrease or the total force at the bottom of the water is less. 1 point
For a correct relationship between the intermediate effect and the pressure: $P \propto \rho g h$ or $P = F/A$ 1 point

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Question 7

10 points total **Distribution of points**

(a) 2 points

$K_{max} = hf - \phi$

The work function can be determined when $K_{max} = 0$.

For a correct relationship for determining the work function 1 point

$\phi = hf_0$

For correctly substituting f_0, determined from the graph 1 point

$\phi = \left(4.14 \times 10^{-15} \text{ eV•s}\right)\left(4.5 \times 10^{14} \text{ Hz}\right)$

$\phi = 1.9 \text{ eV}$

One earned point was deducted if the answer was not expressed in eVs.

(b) 3 points

For using the correct equation 1 point

$K_{max} = hf - \phi$

For correctly substituting the value of ϕ from part (a) 1 point

For correctly substituting the value of f from the graph 1 point

$K_{max} = \left(4.14 \times 10^{-15} \text{ eV•s}\right)\left(8 \times 10^{14} \text{ Hz}\right) - 1.9 \text{ eV}$

$K_{max} = 1.4 \text{ eV}$

One earned point was deducted if the answer was not expressed in eVs.

Alternate solution: *Alternate points*

For indicating a direct connection between the 1.5 V needed to stop the highest-energy electrons (as read from the graph) and the 1.5 eV maximum initial kinetic energy *1 point*

For justifying that connection *2 points*

(c) 2 points

For a correct relationship to calculate the wavelength of light 1 point

$\lambda = c/f$

$\lambda = \left(3.00 \times 10^8 \text{ m/s}\right)/\left(8 \times 10^{14} \text{ Hz}\right)$

For the correct answer 1 point

$\lambda = 3.75 \times 10^{-7} \text{ m}$

Alternatively, the equation $\lambda = hc/E$ can be used with E equal to the sum of the answers to parts (a) and (b).

(d) 3 points

For correctly indicating that the required wavelength would be longer 1 point

For indicating that a lower K_{max} means the light must have a lower frequency 1 point

For indicating that a lower frequency corresponds to a longer wavelength 1 point