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.

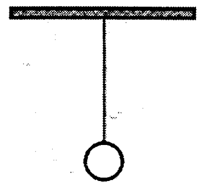
3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth 1 point and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still awarded. 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 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 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



2. (15 points)

The simple pendulum above consists of a bob hanging from a light string. You wish to experimentally determine the frequency of the swinging pendulum.

(a) By checking the line next to each appropriate item on the list below, select the equipment that you would need to do the experiment.

____ Meterstick	____ Protractor	____ Additional string
_✓_ Stopwatch	____ Photogate	____ Additional masses

(b) Describe the experimental procedure that you would use. In your description, state the measurements you would make, how you would use the equipment to make them, and how you would determine the frequency from those measurements.

I would use the stopwatch to time the period of the bob. I would pull the bob up to some point and start the stopwatch at the moment I released the bob, then stop the timer once the bob swung over and back to the same spot where I had released it. I would plug that time (in seconds) into the equation $\frac{1}{T} = f$ (hz) to find the frequency; simply taking the reciprocal of the period.

(c) You next wish to discover which parameters of a pendulum affect its frequency. State one parameter that could be varied, describe how you would conduct the experiment, and indicate how you would analyze the data to show whether there is a dependence.

I would vary the mass at the end of the same string by using the additional masses and the stopwatch. I would do a few trials with each mass, using the same procedure to find frequency; timing how long the mass takes to come back to the point where I release it. I would analyze the data by seeing if the average frequencies ($\frac{1}{T}$) are equal or not. If the frequencies are equal to each other, the pendulum's frequency does not depend on the mass attached to the end of the string.

(d) After swinging for a long time, the pendulum eventually comes to rest. Assume that the room is perfectly thermally insulated. How will the temperature of the room change while the pendulum comes to rest?

__✓__ It would slightly increase. _____ It would slightly decrease.

_____ No effect. It would remain the same.

Justify your answer.

The pendulum transfers heat to the environment because not all its energy is conserved, the PE at its maximum height, and the KE at its lowest point, the energy lost is released as heat to its environment.

(e) Another pendulum using a thin, light, metal rod instead of a string is used in a clock to keep time. If the temperature of the room was to increase significantly, what effect, if any, would this have on the period of the pendulum?

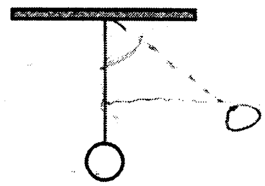
__✓__ It would increase. _____ It would decrease. _____ No effect. It would remain the same.

Justify your answer.

$T = 2\pi\sqrt{\frac{l}{g}}$

$\Delta l = \alpha l_0 \Delta T$

If the temperature increases, then the metal rod expands, causing the period of the pendulum to increase by a factor of $\sqrt{\Delta l}$



2. (15 points)

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(a) By checking the line next to each appropriate item on the list below, select the equipment that you would need to do the experiment.

____ Meterstick	✓ Protractor	____ Additional string
✓ Stopwatch	____ Photogate	____ Additional masses

(b) Describe the experimental procedure that you would use. In your description, state the measurements you would make, how you would use the equipment to make them, and how you would determine the frequency from those measurements.

When the pendulum is swingingingin, I would put up a protractor to the top of the string without interfering with the motion. I would then use the stopwatch to record the time it takes the pendulum to complete one cycle from swinging from the max θ from vertical and return. This is the period $\frac{1}{T}$ = frequency, so the inverse of that time is the frequency.

(c) You next wish to discover which parameters of a pendulum affect its frequency. State one parameter that could be varied, describe how you would conduct the experiment, and indicate how you would analyze the data to show whether there is a dependence.

Changing the mass of the bob would affect frequency. If I used the same technique above, measuring the period of the swing from the maximum angle in relation to the vertical, I could take the inverse of that time and compare it to the frequency found in a).

(d) After swinging for a long time, the pendulum eventually comes to rest. Assume that the room is perfectly thermally insulated. How will the temperature of the room change while the pendulum comes to rest?

X It would slightly increase. ____ It would slightly decrease.

____ No effect. It would remain the same.

Justify your answer.

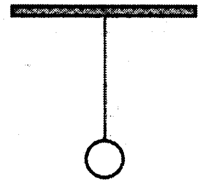
The temperature is related to total energy. When the total mechanical energy of the pendulum is dissipated into the room, the total energy of the room increases, as does the temperature.

(e) Another pendulum using a thin, light, metal rod instead of a string is used in a clock to keep time. If the temperature of the room was to increase significantly, what effect, if any, would this have on the period of the pendulum?

✓ It would increase. ____ It would decrease. ____ No effect. It would remain the same.

Justify your answer.

If the temperature of the room significantly increased, the length of the thin rod would increase as a result of thermal expansion. Increasing the length of the rod also increases the period of the pendulum.



2. (15 points)

The simple pendulum above consists of a bob hanging from a light string. You wish to experimentally determine the frequency of the swinging pendulum.

(a) By checking the line next to each appropriate item on the list below, select the equipment that you would need to do the experiment.

_√_ Meterstick	____ Protractor	____ Additional string
____ Stopwatch	____ Photogate	____ Additional masses

(b) Describe the experimental procedure that you would use. In your description, state the measurements you would make, how you would use the equipment to make them, and how you would determine the frequency from those measurements.

$T = 2\pi\sqrt{\frac{l}{g}}$

$f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$

Measure the length of the string with the meterstick. Since the value of g is already given, use equation $f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$ to determine the frequency of the swinging pendulum.

(c) You next wish to discover which parameters of a pendulum affect its frequency. State one parameter that could be varied, describe how you would conduct the experiment, and indicate how you would analyze the data to show whether there is a dependence.

One parameter can be the length of the string. Conduct experiment with 1m, 2m, 3m, 4m, 5m, 6m, 7m, 8m length of strings, making, swinging a pendulum with each string. Then, measure the period with the stopwatch. Pair the string length and measure period of each pendulum. Find out whether the value of the period increase or decrease in respect to the ~~string~~ value of the string length. If it does, ~~it~~ there is a dependence between two variables.

In addition, in this ~~experiment~~, independent variable is the length of the string and assumed dependent variable is the period of the swinging pendulum.

GO ON TO THE NEXT PAGE.

(d) After swinging for a long time, the pendulum eventually comes to rest. Assume that the room is perfectly thermally insulated. How will the temperature of the room change while the pendulum comes to rest?

__✓__ It would slightly increase. ____ It would slightly decrease.

____ No effect. It would remain the same.

Justify your answer.

~~The law of~~ It is because of the law of the conservation of the energy. The ~~pendulum~~ bob, moving, had certain amount of dynamic energy. The energy is not eliminated as the pendulum stops, but is transferred to [Commensurate amount of] heat by friction with surrounding air.

(e) Another pendulum using a thin, light, metal rod instead of a string is used in a clock to keep time. If the temperature of the room was to increase significantly, what effect, if any, would this have on the period of the pendulum?

____ It would increase. ____ It would decrease. __✓__ No effect. It would remain the same.

Justify your answer.

$T = 2\pi\sqrt{\frac{l}{g}}$ since there is no change in the length of the string and there is no change in the rate of gravitational acceleration ~~period~~ during the motion, the period remains the same. ~~However, increased temperature means~~

Question 2

Sample: B-2A
Score: 14

One point was deducted in part (b) for failure to discuss error reduction (e.g., measuring the time for multiple cycles). Responses in all other parts are correct, with thorough explanations throughout.

Sample: B-2B
Score: 12

Part (a) earned all 3 points for selecting the stopwatch and for including a plausible use of the protractor in part (b). In part (b) only 2 points were earned because the response does not discuss error reduction. In part (c) 1 point was earned for identifying mass as a parameter to investigate, and a second point was earned for an explanation of the experimental procedure, even though it is weak. Part (d) received full credit. The mathematical relationship between length and period is missing in part (e), so only 2 points were earned.

Sample: B-2C
Score: 5

Parts (a) and (b) received no credit because the method is not a direct experimental determination of the pendulum frequency. Part (c) features a good procedural description involving the length of the pendulum but is weak on data analysis (e.g., the relationship between period and frequency is not discussed) and thus lost 1 point. Part (d) earned full credit. Part (e) does not include the key effect of thermal expansion and thus earned no credit.