2000 AP® PHYSICS C FREE-RESPONSE QUESTIONS

PHYSICS C
Section II, MECHANICS
Time—45 minutes
3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in the pink booklet in the spaces provided after each part, NOT in this green insert.

Mech 1.

You are conducting an experiment to measure the acceleration due to gravity g_u at an unknown location. In the measurement apparatus, a simple pendulum swings past a photogate located at the pendulum's lowest point, which records the time t_{10} for the pendulum to undergo 10 full oscillations. The pendulum consists of a sphere of mass m at the end of a string and has a length ℓ. There are four versions of this apparatus, each with a different length. All four are at the unknown location, and the data shown below are sent to you during the experiment.

ℓ (cm)	t_{10} (s)	T (s)	T^2 (s^2)
12	7.62		
18	8.89		
21	10.09		
32	12.08		

(a) For each pendulum, calculate the period T and the square of the period. Use a reasonable number of significant figures. Enter these results in the table above.

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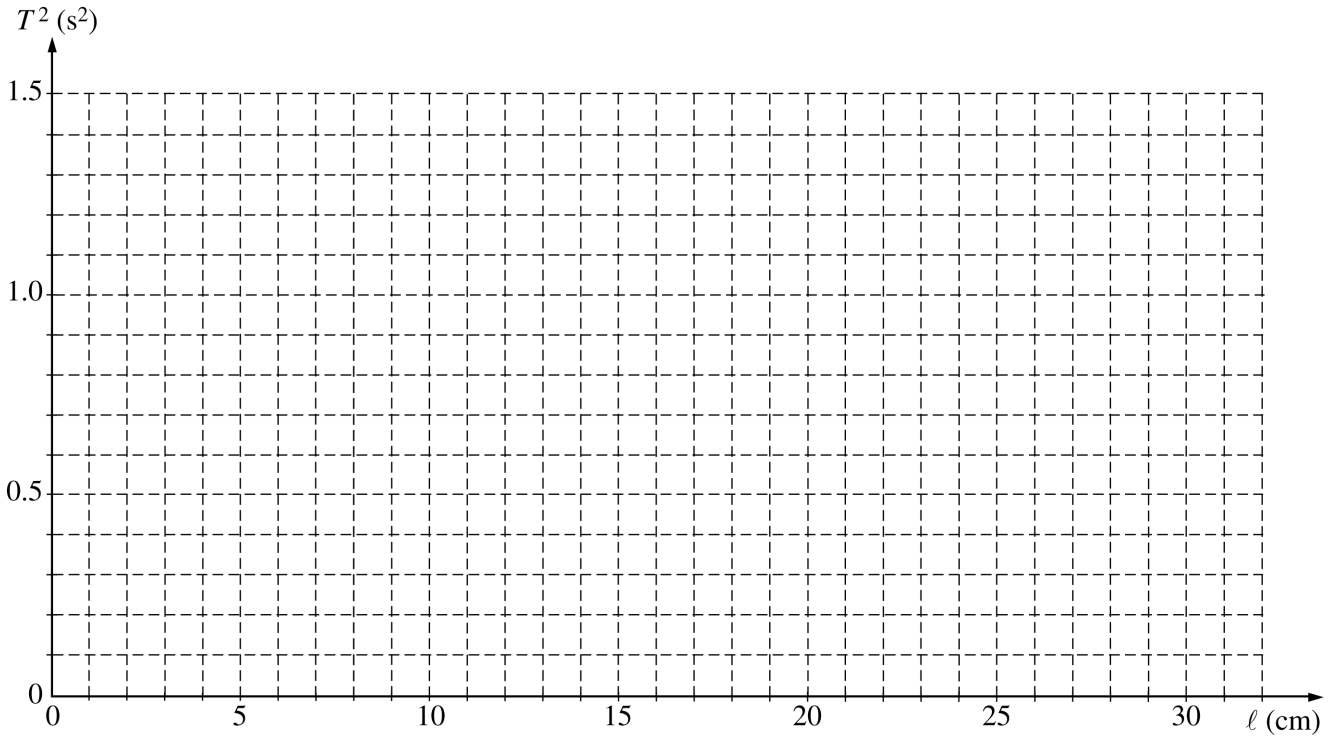
(b) On the axes below, plot the square of the period versus the length of the pendulum. Draw a best-fit straight line for this data.



(c) Assuming that each pendulum undergoes small amplitude oscillations, from your fit determine the experimental value g_{exp} of the acceleration due to gravity at this unknown location. Justify your answer.

(d) If the measurement apparatus allows a determination of g_u that is accurate to within 4%, is your experimental value in agreement with the value 9.80 m/s^2 ? Justify your answer.

(e) Someone informs you that the experimental apparatus is in fact near Earth's surface, but that the experiment has been conducted inside an elevator with a constant acceleration a. Assuming that your experimental value g_{exp} is exact, determine the magnitude and direction of the elevator's acceleration.

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2000 Physics C Solutions **Distribution of points**

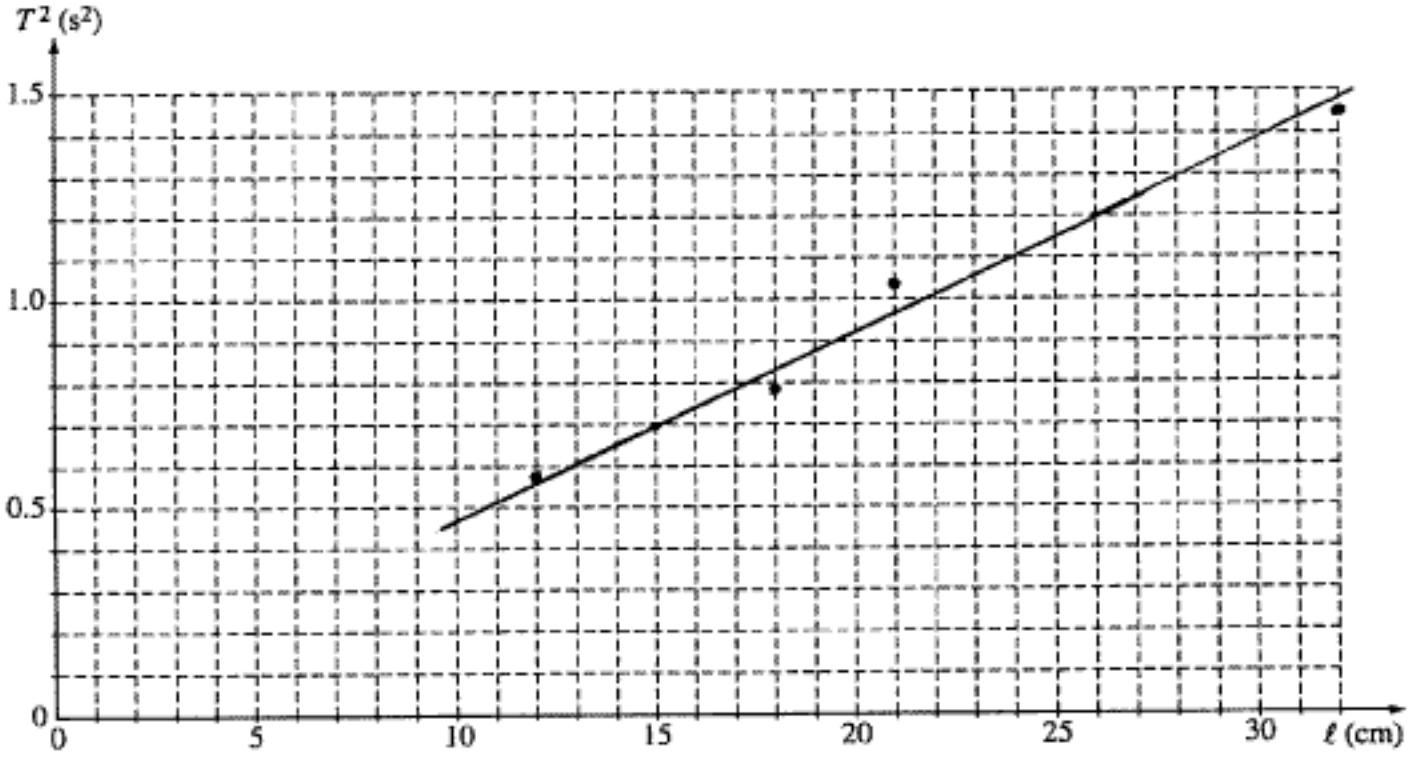
Mech. 1 (15 points)

(a) 4 points

ℓ (cm)	t_{10} (s)	T (s)	T^2 (s^2)
12	7.62	0.762	0.581
18	8.89	0.889	0.790
21	10.09	1.009	1.018
32	12.08	1.208	1.459

For correctly computing the period of each pendulum using the time for 10 oscillations — 1 point
For correctly computing the square of each period — 1 point
For expressing the periods and the squares of the periods to two or three decimal places — 1 point
For completing the data table — 1 point

(b) 3 points



For correctly plotting the square of the period as a function of the pendulum length — 1 point
For drawing a single straight line through the data points (could go through (0,0) but did not have to do so) — 1 point
For drawing this line to approximate a best fit with about an equal number of data points above and below the line — 1 point

Mech. 1 (continued)

(c) 4 points

For computing the slope of the straight line — 1 point

$$\text{slope} = \frac{\Delta T^2}{\Delta \ell}$$

Credit was awarded for a calculated value that was consistent with the line drawn. A typical correct value was 4.50 s^2/m. Most values were between 4 and 5 s^2/m.

For recognizing that the motion of each pendulum is simple harmonic or for using the equation for the period of a simple pendulum — 1 point

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

For using this relationship and the slope from the graph to determine g_{exp} — 1 point

For example, the relation between T^2 and ℓ is given by $T^2 = \frac{4\pi^2}{g}\ell$, so slope $= \frac{4\pi^2}{g_{exp}}$

$$g_{exp} = \frac{4\pi^2}{\text{slope}}$$

Credit was awarded for a calculated value that was consistent with the slope determined above. For example, for a slope = 4.50 s^2/m, $g_{exp} = 8.77$ m/s^2.

For using appropriate units for the computed acceleration — 1 point

(d) 2 points

For correctly stating whether 9.8 m/s^2 is within ±4% of the experimental value g_{exp}. — 1 point

Credit was awarded if the answer was consistent with the value obtained for g_{exp}. For example, for $g_{exp} = 8.77$ m/s^2, the experimental value is not in agreement with g.

For justification, either by displaying the range of acceptable values within ±4% of the value of g_{exp} (e.g., approximately 8.42 m/s^2 to 9.12 m/s^2, for $g_{exp} = 8.77$ m/s^2), OR by computing the percent difference between the g_{exp} and 9.80 m/s^2 (e.g., $\frac{9.80 - 8.77}{8.77} \times 100 = 11.7\%$, which is greater than 4%, for $g_{exp} = 8.77$ m/s^2) — 1 point

(e) 2 points

For correctly computing the acceleration of the elevator — 1 point

From Newton's 2nd law for objects in the elevator:

$mg - N = ma$, where $N = mg_{exp}$, so $a = g - g_{exp}$

For correctly stating whether the acceleration of the elevator is upward or downward — 1 point

Credit for magnitude and direction of acceleration given for answers consistent with g_{exp}. For example, for $g_{exp} = 8.77$ m/s^2, $a = 9.80 - 8.77 = 1.03$ m/s^2, directed downward.