Name: ____________________ Date: ____________________ Period: ____________________

AP PHYSICS 1: SHM UNIT REVIEW

KEY EQUATIONS REFERENCE

ESSENTIAL SHM FORMULAS

Spring Period: $T = 2\pi\sqrt{\frac{m}{k}}$

Pendulum Period: $T = 2\pi\sqrt{\frac{L}{g}}$

Max Velocity: $v_{max} = A\omega = \frac{2\pi A}{T}$

Max Acceleration: $a_{max} = A\omega^2 = \frac{4\pi^2 A}{T^2}$

Total Energy: $E = \frac{1}{2}kA^2$

Linearization: $T^2 = \frac{4\pi^2}{k}m$

QUICK CALCULATIONS

1 Spring Period

A 0.40 kg mass attached to a spring undergoes SHM with a period of 0.80 s. What is the spring constant?

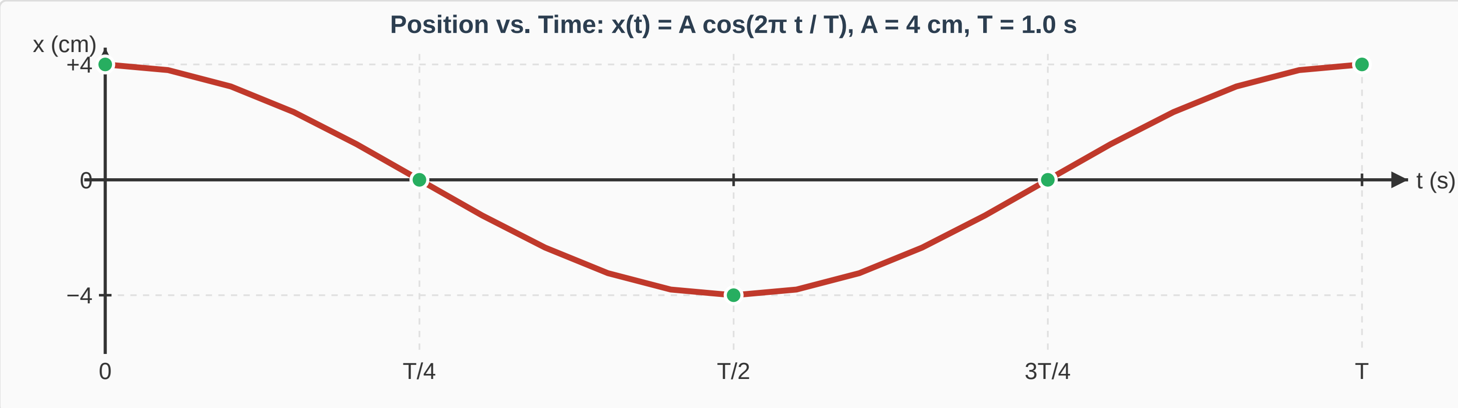
2 Pendulum Period

A simple pendulum with length 0.60 m is placed where $g = 9.8\ \mathrm{m/s^2}$. What is its period? If the length is doubled, what is the new period?

GRAPHS & VELOCITY FROM POSITION

POSITION GRAPH GIVEN — SKETCH VELOCITY & IDENTIFY TIMES

Below is $x(t)$ for an oscillator with $A = 4\ \mathrm{cm}$ and $T = 1.0\ \mathrm{s}$, shown over exactly one period.



YOUR TASK:

3 Sketch and Analyze

A) On the grid below, sketch $v(t)$. Remember: $v = 0$ when $x = \pm A$ (at the turning points) and $|v| = v_{\max} = A\omega = \frac{2\pi A}{T}$ when $x = 0$ (at equilibrium).

B) At what time(s) is velocity maximum? At what time(s) is position maximum?

ENERGY PROBLEM

4 Velocity at a Displaced Position

A $0.25\ \mathrm{kg}$ mass on a spring with $k = 100\ \mathrm{N/m}$ oscillates with amplitude $A = 0.10\ \mathrm{m}$. Find the speed of the mass when $x = A/2 = 0.05\ \mathrm{m}$. (Hint: use energy conservation.)

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INTEGRATED PROBLEMS

PROBLEM 5: COMPARING SPRING AND PENDULUM

5 Same Period, Different Systems

A mass-spring system has period $T_s = 1.5\ \mathrm{s}$ with $m = 0.60\ \mathrm{kg}$. A simple pendulum also has period $T_p = 1.5\ \mathrm{s}$. Find: **(A)** the spring constant k, and **(B)** the length of the pendulum.

PROBLEM 6: ENERGY CONSERVATION & BAR DIAGRAMS

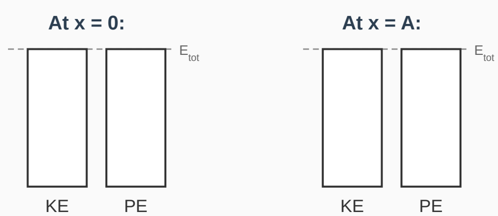
6 Energy as Position Changes

A 0.50 kg mass oscillates horizontally on a frictionless surface with spring constant $k = 80\ \mathrm{N/m}$ and amplitude $A = 0.20\ \mathrm{m}$.

A) Find the total mechanical energy.

B) When the mass is at $x = 0.10\ \mathrm{m}$, find the kinetic energy and elastic potential energy. Do they sum to equal the total?

C) Complete the energy bar diagram below for $x = 0$ (equilibrium) and $x = A$ (maximum displacement):



Shade each bar to show the KE and PE magnitudes — dashed line indicates total energy (all values in joules)

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AP PHYSICS 1 FREE-RESPONSE OVERVIEW

Section II of the exam is **50% of your score**: four free-response questions in 100 minutes, 10 points each. Each FRQ targets a distinct kind of reasoning — know the pattern, match the format, and earn the points the rubric is looking for.

THE FOUR FRQ TYPES

TYPE 1 · MR

Mathematical Routines. Apply equations and physics principles to solve multi-step quantitative problems. Often asks you to derive a symbolic expression *before* substituting numbers.

Strategy: work in symbols, substitute at the end, check units.

TYPE 2 · TBR

Translation Between Representations. Convert among graphs, equations, diagrams, tables, and words. A classic move: "given $x(t)$, sketch $v(t)$ and $a(t)$."

Strategy: label axes, mark key points (intercepts, extrema, zeros), and keep the sign of each quantity consistent with the physics.

TYPE 3 · EDA

Experimental Design & Analysis. Design a procedure, pick measurements and equipment, propose a graph that *linearizes* the relationship, extract a physical quantity from a slope, and identify error sources.

This is the "Lab Investigation" — modeled on pp. 5–6 of this review.

TYPE 4 · QQT

Qualitative/Quantitative Translation. Construct a paragraph-length argument that weaves physics reasoning together with equations. Claim → evidence → equation → explanation.

Strategy: state the principle, cite the equation, reason about magnitudes and signs *in prose*.

ANATOMY OF A LAB INVESTIGATION (EDA) FRQ

WHAT THE FOUR PARTS USUALLY LOOK LIKE

- **(a) Procedure — ~4 pts:** list the measurements, the equipment used for each, and how varying one quantity yields the unknown. *Be operational: "time 10 oscillations on the stopwatch, then divide by 10."*
- **(b) Graphical Plan — ~3 pts:** state what goes on each axis so the slope (or intercept) gives the unknown. *Linearize first — rewrite the equation as $y = mx + b$.*
- **(c) Data Analysis — ~3 pts:** use a slope or a provided data table to compute the target quantity; interpret what the intercept physically represents.
- **(d) Uncertainty / Justification — ~2 pts:** identify specific error sources (*systematic* = bias vs. *random* = scatter) and state the direction of the effect on your result.

Scoring hint: graders reward *specific, operational* language. "Measure the period" is a weak claim. "Pull the mass 5 cm from equilibrium, release, and time 10 complete oscillations with the stopwatch; divide by 10 to get T" earns the point.

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LAB INVESTIGATION FRQ (10 PTS)

Problem 7 — Determining the Spring Constant of an Unknown Spring

A student is asked to experimentally determine the spring constant k of an unknown spring. The spring may be treated as massless. The student is provided with:

- One unknown spring
- A set of five labeled masses: 0.100 kg, 0.200 kg, 0.300 kg, 0.400 kg, 0.500 kg
- A digital stopwatch (resolution ±0.01 s)
- A meter stick (resolution ±1 mm)
- A ring stand with a horizontal clamp from which the spring hangs vertically

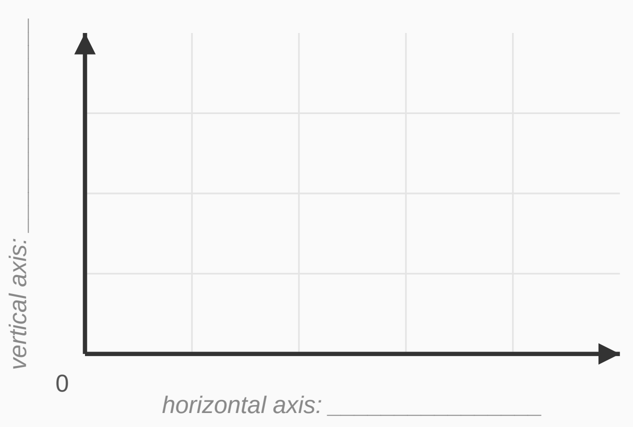
PART A Experimental Procedure (4 pts)

Describe an experimental procedure the student could use to collect enough data to determine k. Your description should explicitly include:

- **(i)** The quantities that should be measured and the equipment used for each one.
- **(ii)** How the student should *vary* one parameter across trials so that the data isolate k.
- **(iii)** One specific step the student should take to reduce *random* error in the measurements.

PART B Graphical Analysis Plan (3 pts)

On the axes below, indicate the quantities that should be plotted so that the **slope** of a best-fit straight line can be used to determine k. Label each axis (including units). Then, in the space to the right, *linearize* the period equation to justify your choice and express k in terms of the slope.



Linearization & expression for k:

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LAB INVESTIGATION FRQ (CONTINUED)

PART C Data Analysis (3 pts)

The student's data are shown below. They plot T^2 (s²) on the vertical axis vs. m (kg) on the horizontal axis and obtain a best-fit line with **slope = 0.50 s²/kg** and **y-intercept = 0.02 s²**.

m **(kg)**	0.100	0.200	0.300	0.400	0.500
T **(s)**	0.27	0.34	0.41	0.46	0.51
T^2 **(s²)**	0.073	0.116	0.168	0.212	0.260

(i) Using the slope, calculate the spring constant k. Include units.

(ii) Suggest one *physical* reason the y-intercept of the T^2 vs. m graph is not exactly zero.

PART D Uncertainty & Justification (2 pts)

Identify **two** sources of experimental uncertainty in this investigation. For each source, (i) state whether it is *systematic* or *random*, and (ii) explain whether the calculated value of k would come out too high, too low, or not systematically biased — and why.

PRE-TEST STUDY CHECKLIST

Before the Test, Make Sure You Can:

- Identify whether a system is a mass-spring or simple pendulum, and apply the correct period formula.
- Sketch $x(t)$, $v(t)$, and $a(t)$ and explain where each is zero, maximum, or minimum in terms of the motion.
- Apply energy conservation: $E_{\text{tot}} = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$.
- Linearize a non-linear equation and read physical constants from the *slope* or *intercept*.
- Explain qualitatively why a pendulum's period depends on g but a horizontal spring's does not.
- Structure an EDA response: **procedure** → **graphical plan** → **calculation** → **uncertainty**.

Key Insight: The Lab Investigation FRQ rewards *specificity*. Name the equipment, write the formula, linearize explicitly, and tie each error source to a *direction* (high / low / no bias). Don't just describe — design.