Name: ____________ Date: ____________ Period: ____________

AP PHYSICS C: MECHANICS — OSCILLATIONS 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

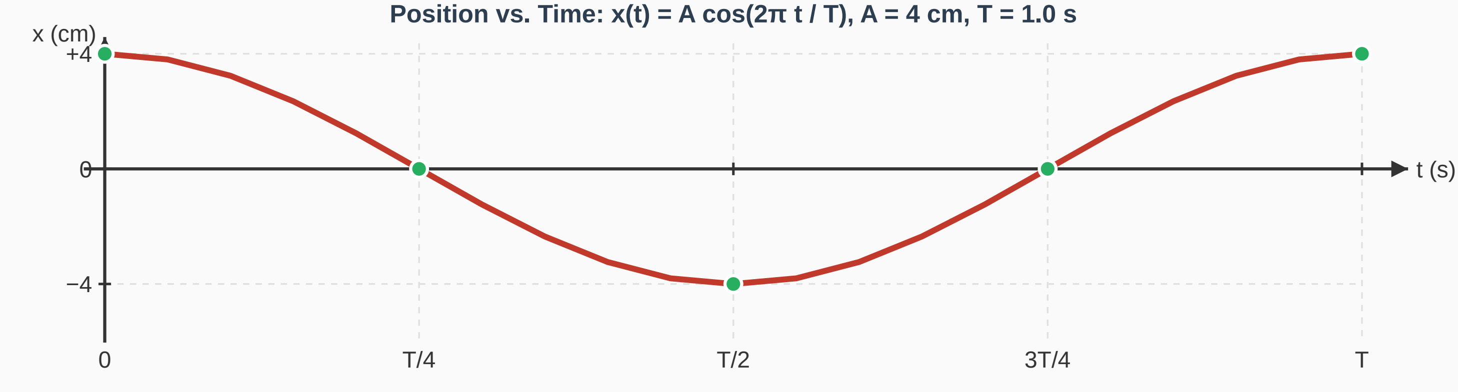
A simple pendulum with length 0.60 m is placed where $g = 9.8\ \mathrm{m/s^2}$. What is its period? If the length is doubled, what is the new period?

Name: ______________________ Date: ______________________ 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.)

Name: ____________ Date: ____________ Period: ____________

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

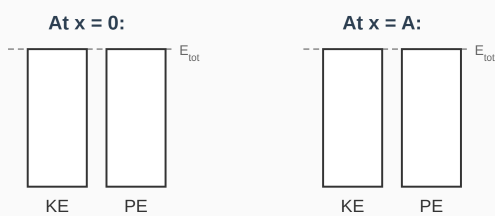
6 Energy as Position Changes

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)

Name: ____________ Date: ____________ Period: ____________

AP PHYSICS C: MECHANICS FREE-RESPONSE OVERVIEW

Section II of the exam is **50% of your score**: four free-response questions in 100 minutes. The revised AP Physics exams all share the same four FRQ types below — on the C exam, expect the calculus you built this year (derivatives, work and impulse integrals, differential equations) to appear inside them. 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.

Name: ____________ Date: ____________ Period: ____________

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

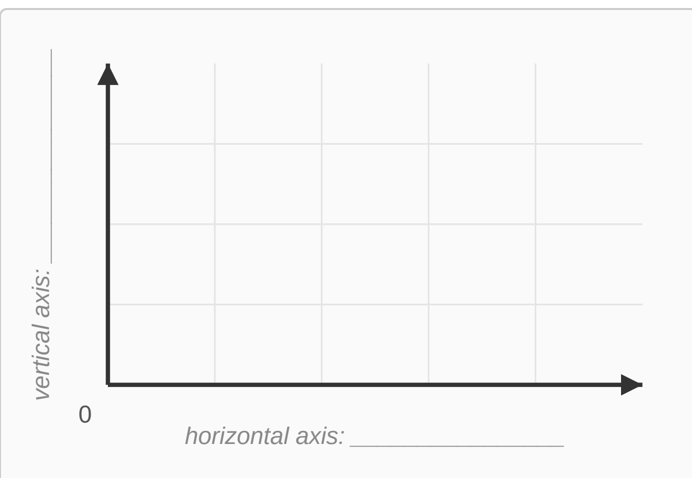
PART A Experimental Procedure (4 pts)

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:

Name: ______________ Date: ______________ Period: ______________

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.