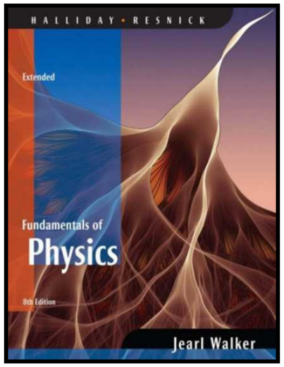
Workshop Physics

1017 - 312

University Physics II

Week 5 : Day 2

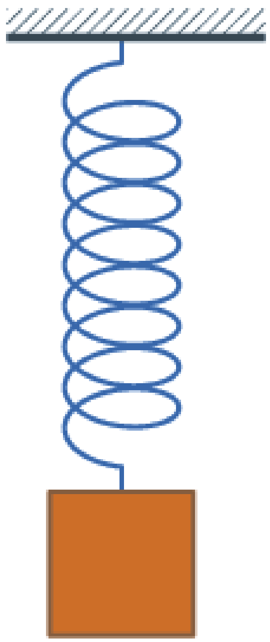


Outline

- **The Simple Harmonic Oscillator System**
  - Equations of motion
    - *Hooke's Law*
  - Frequency and period
- **Activity – Simple Harmonic Motion Lab**
  - Use static and dynamic methods to find k
  - Compare values attained and get % error

The SHO System

- Begin with Newton's law
  - $F = ma$
- Use Hooke's law for the force
  - $F = -kx$
- Construct the differential equation
  - $m\, d^2x/dt^2 + k\, x = 0$
- Substitute the solution $x(t) = x_m \cos(\omega t + \varphi)$
  - $-\omega^2 x(t) + (k/m)\, x(t) = 0$
- Solve for frequency
  - $\omega^2 = k/m$
- Express period of motion
  - $T = 2\pi\sqrt{m/k}$



Activity – Simple Harmonic Motion Lab

- Verify period of spring-mass system by comparing k-values attained via two methods:
  - **Static method:** Utilize Hooke's Law to determine the spring constant, k.

$$F = k\Delta x$$

  -
    - *Hang spring from the small end.*
    - *Measure the extension for several different hanging masses.*
    - *Graph* $\mathbf{mg}$ *versus* $\mathbf{\Delta x}$ *and determine k graphically.*
    - *Report value attained as* k_1 *using standard units*

  - **Dynamical method**: Utilize period relationship to attain a value for the spring constant, k

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

    - *Hang spring from the small end.*
    - *Use a stopwatch to determine the period of oscillation for several different hanging masses.*
    - *Graph* $\mathbf{T^2}$ *versus* $\mathbf{m}$ *and determine k graphically.*
    - *Report the value attained as* k_2 *using standard units.*

Your Name (**Print**): ______________________ Date: ________
Group Members: ______________________
______________________ Group: ________

Simple Harmonic Motion Lab

Verifying the relation between period, *T*, spring constant, *k*, and mass, *m*, for a system of a mass on a spring.

Your text and workshop notes claim that for a mass *m* attached to a light spring executing simple harmonic motion, the period is:

$$T = 2\pi\sqrt{\frac{m}{k}}\ .$$

Your task is to investigate this using good experimental technique. Note that the book looks at the situation for a mass on a horizontal frictionless surface, while we use a mass hung vertically. You have seen in a previous activity that the two systems are mathematically equivalent.

1) **Static method:** In a previous activity, you found that the spring obeys Hooke's Law; $F = - k\,x$. Accurately measure *k* for your spring, the way you did in the previous activity with the spring not moving. (We have to redo this because all the springs are slightly different). Measure the extension from a reference point such as the bottom of the mass holder and not the spring itself as the spring might rotate as it extends. You want to be as accurate as possible here.

2) **Dynamical method**: Your second task is to check the validity of the above equation. Use a **graphical** approach. What variables will you use? How can you measure period accurately and precisely? Think about what you will plot on the axes. You have the use of the computers, and you should try out the motion detectors to see how accurately things can be measured with it. You might want to also use a stopwatch to make sure the computer is doing things right. Terrible accidents have occurred (not in this lab but in designing aircraft and cars, etc.) because engineers have blindly trusted computer readouts without checking them.

Equipment: a spring and place to hang it from, some masses and a mass hanger, a meter stick, a computer with a motion detector, anything else you want to use in the boxes, and anything you don't see - just ask.

Very precise results are possible in this experiment. The instructors got results that agree within errors less than 1%. You should be able to get this close also! Note that this handout is deliberately sparse to encourage you to think about and discuss how measurements are to be made. Sometimes students even come up with ideas the professors hadn't thought of.

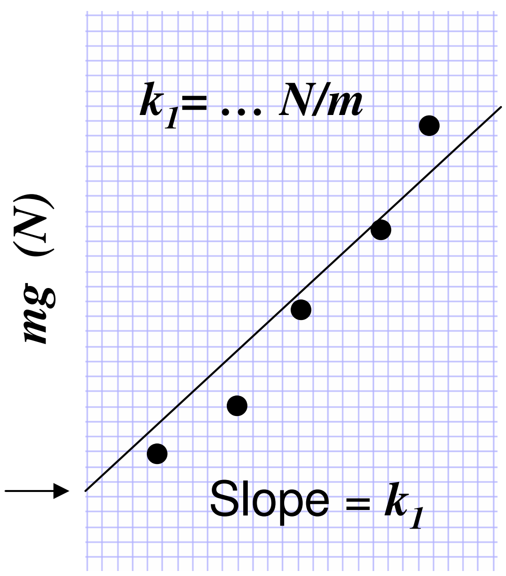
Graphs and Units

$$F = -kx \Rightarrow mg = k\underbrace{\Delta x}_{x_i - x} \pm m_{eff}\, g$$

$$T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow T^2 = \left(\frac{4\pi^2}{k}\right)m + const.$$

❑ Static Method

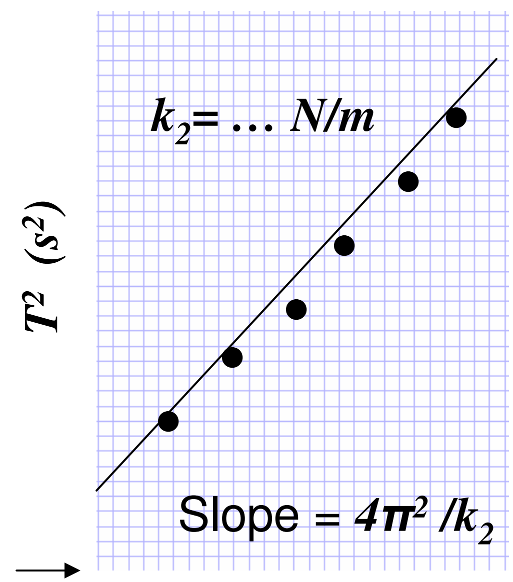
- Determine k_1



Use y-intercept to get effective mass of spring

❑ Dynamic Method

- Determine k_2



Should not include origin when making best-fit line

RIT

Group Laboratory Write-Ups

- **Follow guidelines available on site**
  - **Abstract**
    - *Include goal, values attained and the % Error achieved*
    - *% Error =* $\dfrac{|k_1 - k_2|}{k_1 + k_2} \times 100$
  - **Theory**
    - *Include all equations and derivations*
    - *Show steps from Hooke's Law to period*
  - **Data and Analysis**
    - *Tables (with units)*
      - Include uncertainty and error propagation
    - *Graphs (static and dynamic methods)*
      - Must do graphs by hand
      - Include error bars and indicate slope on graph
  - **Conclusion**
    - *Summarize results and state error*