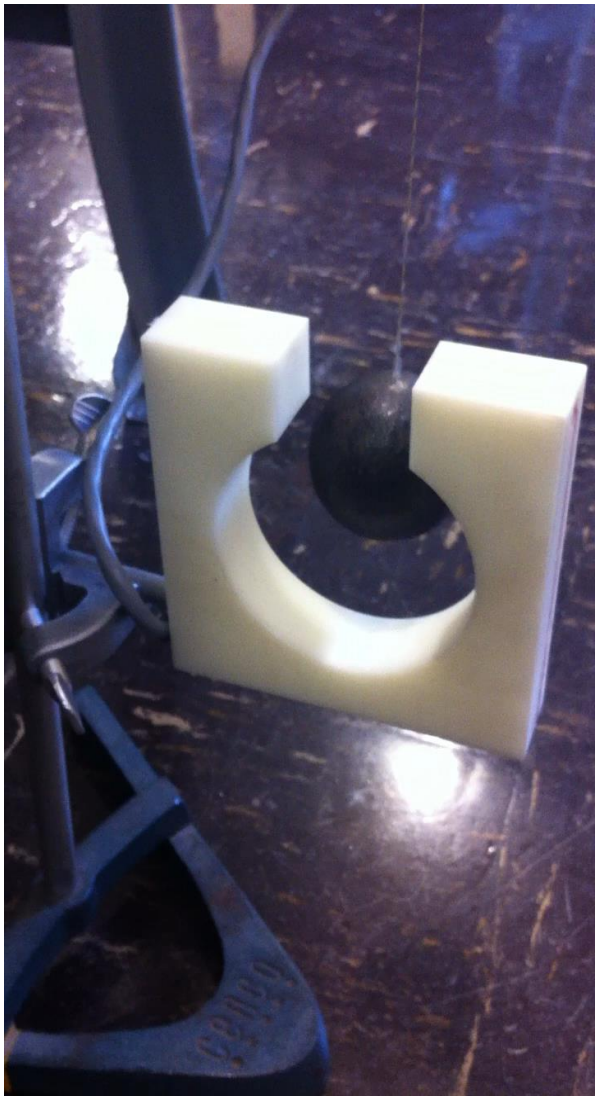
PHYS 275 – Experiment 12
Designing an experiment to measure *g* to 0.1%

Experiment Summary

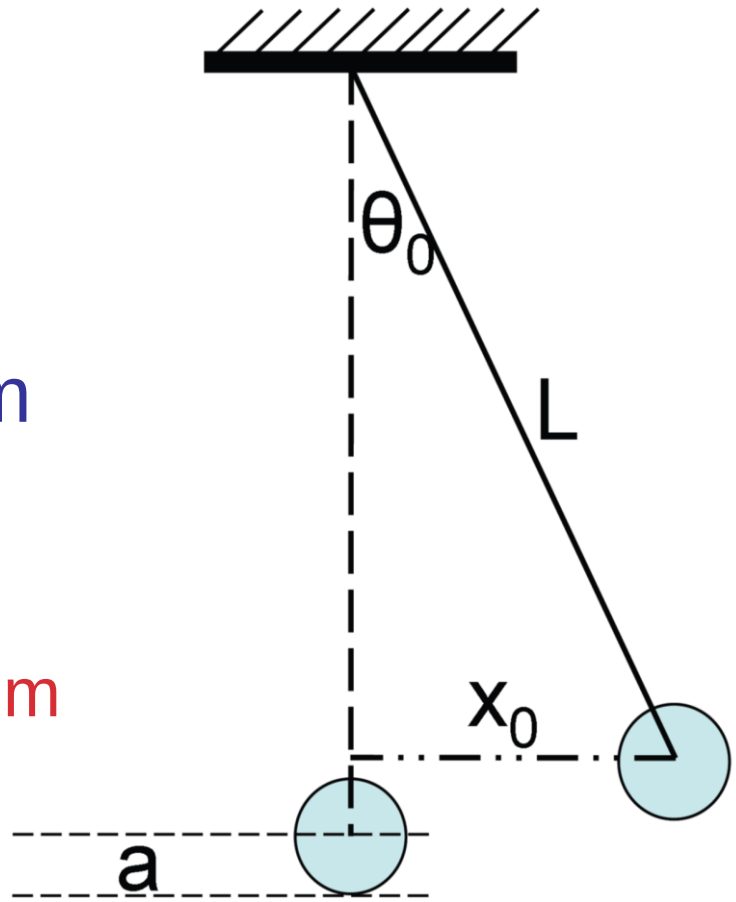
- Today you will design an experiment to measure *g* with a relative precision better than 0.1%
  - Learn how to keep systematic and random errors under control



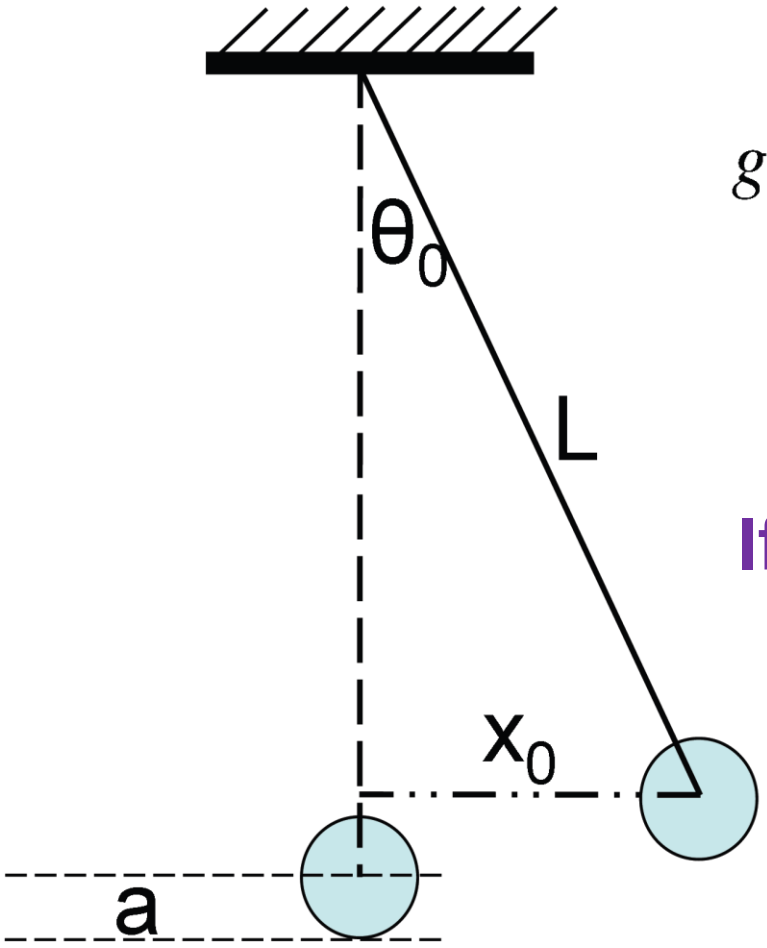
(Indeed we will use a pendulum…)

Theory (1)

- We will study the motion of a simple pendulum
  - A bob of mass *m* and radius *r*, attached to a string of length *l*
- The time it takes the pendulum to complete one oscillation is called its *period* (T)
  - Which properties of the pendulum determine its period?
    - Length, bob mass, bob size, bob material, initial amplitude?



Theory (2)



$$g = \frac{4\pi^2 L}{T^2}\left\{\left(1+\frac{2}{5}\left(\frac{a}{L}\right)^2\right)\left[1+\frac{\sin^2\left(\frac{\theta_0}{2}\right)}{4}\right]^2\right\}$$

If $\frac{a}{L} \ll 1$ and $\theta_0 \approx \frac{x_0}{L} \ll 1$, then:

$$g = \frac{4\pi^2 L}{T^2}$$

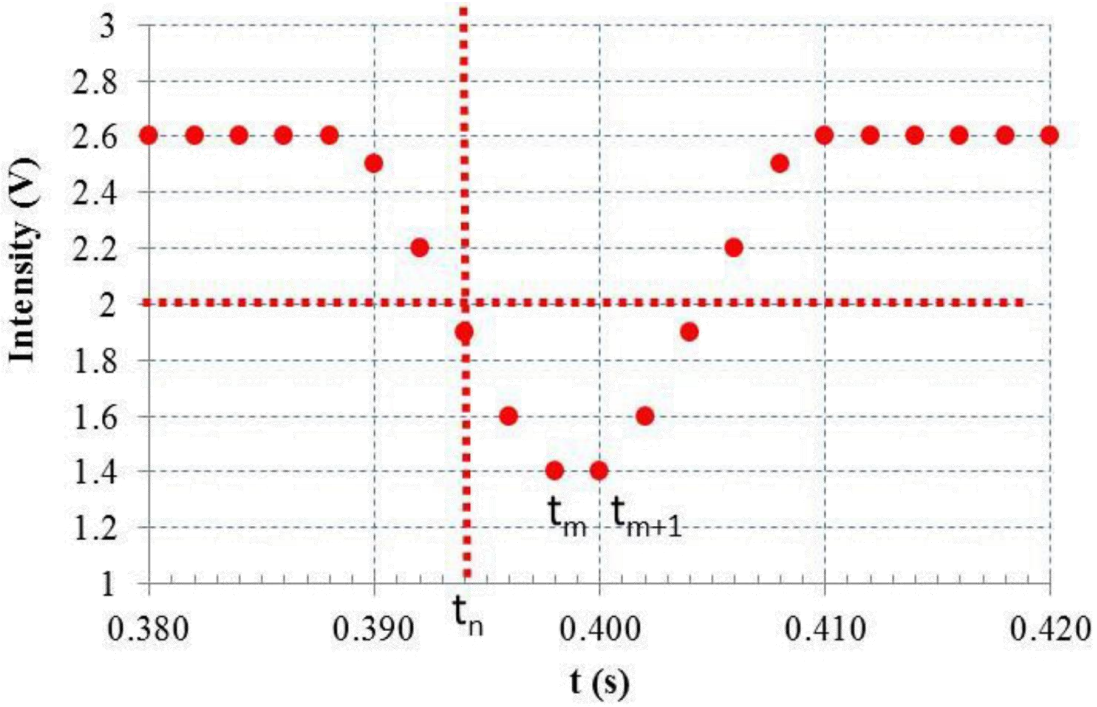
Important Questions

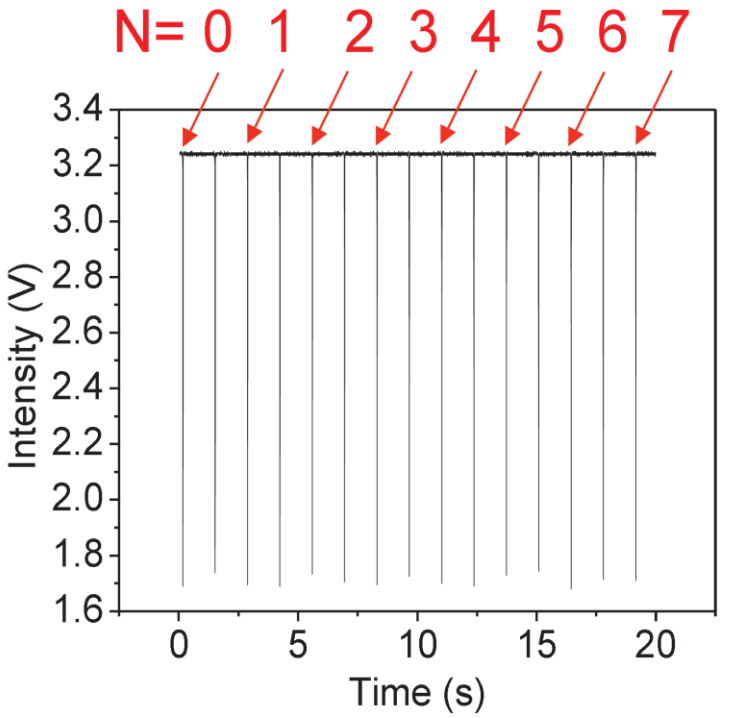
- In order to make the approximation $g = \frac{4\pi L}{T^2}$ valid, how should you choose a, L, and θ_0?
- Let us assume we will use the approximation $g = \frac{4\pi L}{T^2}$. In order to achieve the required precision ($\frac{\sigma_g}{g} < 10^{-3}$), what precision is required on the L and T measurements?
  - Length: calibrate your ruler!
  - Time: choose right sample rate and number of periods

Suggestions and Notes

- Write your final results in Excel spreadsheet, but show your procedure to us before you move to the next step
- Measure *a*, estimate the minimal *L* you need, then estimate the maximal x_0 you can afford
  - However, this does not mean that you have to set *L* to be equal to the minimal affordable value…
    - Note that the larger *L* you use, the larger range of x_0 you will have available
- Page 96, Part B: measure *a* for five times and take average
- *L* = (length from the attachment point to the bottom of the pendulum bob) – (radius of bob)
- Do not forget to calibrate your 2-meter ruler, and record your ruler number
- Page 98: when you measure *L*, ask other students around you to double-check your result
  - Do not proceed with the experiment until yours and another student's measurements of your pendulum's length are in agreement within the required uncertainty

More Suggestions





- $T_{av} = (t_N - t_0)/N$; need σ_{t_N} and σ_{t_0} to calculate $\sigma_{T_{av}}$
  - We will assume $\sigma_{t_N} = \sigma_{t_0}$
- How can we estimate σ_t?
  - It is related to LoggerPro sampling frequency *f*: $\sigma_t \sim \Delta t = 1/f$
    - You shall choose *f* that achieves your precision goal on σ_g

Notes and Reminders

- Submit your Excel spreadsheet on ELMS and turn in your check sheet before leaving the lab
- Complete the final version of your report by 1pm next week
- Finish the homework set in Expert-TA by 2pm next week
- Turn off your equipment and clean up your bench area before leaving the classroom
- Save your data on the local disk frequently!