Pretend I put a joke here

PHY151

Practical

5

Outline for Today

- First 50 minutes: Practice problems
  - Prof. Wilson has written 4 problems similar to those on tests. Please work ***together*** on these ***(not for marks)!***
- Final 2 hours: working on the Practical Activities of the week.
  - Write-ups in the TERM booklets **for marks**
  - Freefall with Python, Activities A & B (questions 1-8, and 9 if you have time). You can do activities C & D after if you like, but there are no bonus marks for these so make sure A & B are completely done before you try them.
  - Print out your code and plots (not tables of data though). Make sure your code is explained.

Last week's practical

If you get an **analytic result** t = 2.0203… s, this is an exact result. An exact result has **infinite significant figures**.

So if you then get a numerical result t_f = 2.015 ± 0.005 s, that means that t is not consistent with the uncertainty on your measurement of t_f.

When you get a measurement that is not consistent with theory, you should try to explain why this might be. In this case it's because you're using a numerical algorithm to approximate a quadratic that will always undershoot, no matter how small you make the time increment (it wasn't a great numerical algorithm for this problem, in other words).

Today’s Tutorial Problems

1. Centripetal force vs gravity
2. Remember: for modelling questions, you’re trying to get a good physically motivated estimate of the result. There isn’t one “right” way of doing it, think about what you know about air resistance and make approximations to come up with a good guess.
3. Remember that in these sorts of questions, what you’re expected to do on a test is not as statistically rigorous as what you do in labs. Think about the error bars and try to come up with a reasonable estimate of what functions would fit these data.
4. A pretty counter-intuitive thing about uniform circular motion is often figuring out what force it is that provides the centripetal force. In this case, what force are we looking at?

Today's Tutorial Problems

1. Tension must be $T = 2mg$ so that the hanging ball does not move. Note that m is the mass of the lighter ball.

   For the rotating ball, the string will make an angle θ from the horizontal. We get vertically:

   $T\sin\theta - mg = 0$ which means $2mg\sin\theta = mg$ and thus $\theta = 30°$.

   And horizontally we get:

   $T\cos\theta = m\omega^2 R = 2mg\cos(30)$ or $\omega^2 = \frac{g}{R}\cos(30)$ or $\omega = 2.9$ rad/s which is about 0.46 rotations per second.

2. Terminal speed of a tennis ball comes from

$mg = \frac{1}{2} C_D \rho_{air} A v^2$

Assume $C_D = 0.5$ (for a sphere), $\rho_{air} = 1.2$, A is a circle of radius 4 cm. We get a terminal speed of around 20 m/s.

If we assume that a normal person can throw a tennis ball around 20 m/s, we get the situation that the initial velocity is the terminal speed, but not pointed down. It would be reasonable to guess that such a thrown ball would maintain a constant speed, just change direction, so it's travelling in uniform circular motion if the ball is thrown horizontally. Given the height of the building, a horizontal throw is probably close to the optimal angle anyway.

If that's true, we know that at the inital throw we have a radial acceleration of $g = v^2/R$, so the radius would be about 40 m.

Once the ball is going straight down, it would continue to go down, so 40 m is how far it would get.

Check: throwing it horizontally at 20 m/s and ignoring air, it would go about 60 m (takes about 3 seconds to fall 50 m). My answer is close to this, but a bit shorter, which seems reasonable since this simple answer ignores air.

Alternatively: if you throw it 20 m/s horizontally, the drag force is initially the same as gravity. If the x-component of the drag force is a constant (a very rough assumption), then the ball would stop travelling horizontally after two seconds, for a horizontal distance of 20 m. This is clearly a lower limit for the horizontal distance. If the time-averaged horizontal force is half the initial force you'd get double the time and thus 40 m. The ball probably won't hit the ground in 4 seconds since it takes 3 seconds to hit without a terminal speed.

Today’s Tutorial Problems

3. At the bottom of the hill, the normal force (measured by the scale) points up, gravity points down, and the net force needs to be mv^2/R upward, where R is the radius we’re looking for. Newton’s second law gives:

   $\frac{mv^2}{R} = n - mg$ or $n(v^2) = mg + \frac{m}{R}v^2$.

   We have plotted n as a function of v^2 which should be a straight line, and the slope should be $\frac{m}{R}$. We know $m = \frac{100\,\mathrm{N}}{g} = 10.2\,\mathrm{kg}$, so we have $R = \frac{10.2\,\mathrm{kg}}{X}$ where X is the slope of the data.

The slope looks to be somewhere between $\frac{210-100}{245-5} = 0.458$ and $\frac{208-102}{250-0} = 0.424$. That gives a radius between 24.06 m and 22.25 m. Call it 23 ± 1 m.

Today's Tutorial Problems

4. Look at a "particle" of water on the surface. It has a force mg down and a ficticious centrifugal force $m\omega^2 r$ horizontally where r is the distance from the centre of the bucket (axis of rotation). The third force that balances the forces (in our accelerating reference frame) is the "normal" force which is perpendicular to the water.

   The non-normal forces are perpendicular to each other, and the normal force is the hypotenuse. That means normal force points at an angle from the vertical given by

   $\tan\theta = \frac{m\omega^2 r}{mg}$.

   But $\tan\theta$ is also the slope of the function of the surface of the water. If $y(r)$ is the height of the surface, the slope is

   $\frac{dy}{dr} = \frac{\omega^2}{g} r$

   and so an easy integral gives us

   $y = y_0 + \frac{\omega^2}{2g} r^2$

   where y_0 is the height of the water at the center of the bucket. This shape is a parabola.

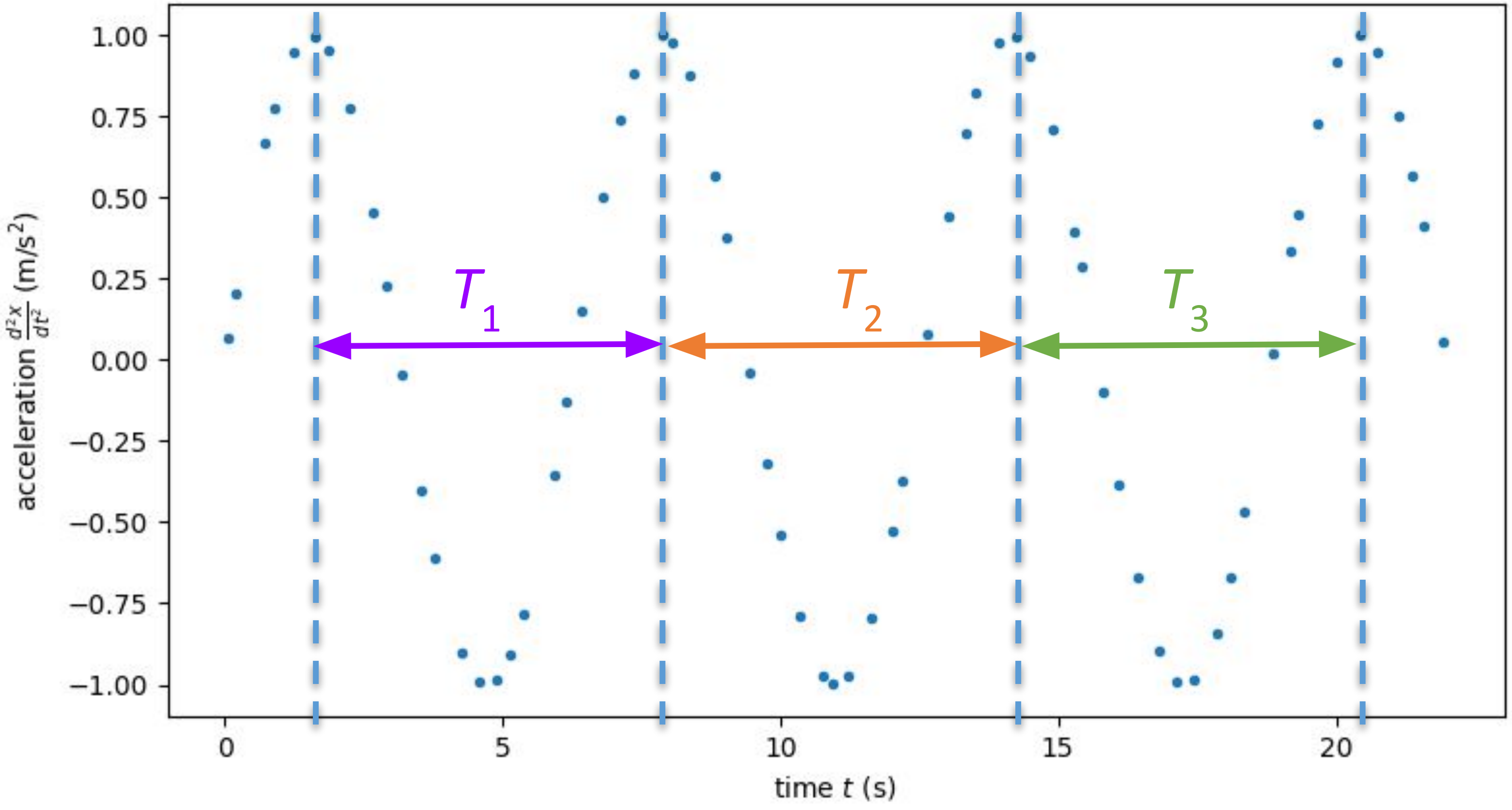
Today's Practical

- Write-ups in the TERM booklets **for marks**
- Today: **Mechanics Module 5**, **Activities 5-8** (and 9 if you have time)
- The first 3 problems are theory only, you should be able to finish them in the first hour. Problem 8 will use the theory you develop in 5-7.
- Note: this spring DOES NOT have an unstretched equilibrium, to determine the spring constant *k*, you'll need to consider two other configurations.

- **Cite lab manual** or write out complete procedure.
- **Save yourself time**: no need to print raw data or write out the questions. You can also submit scrap pieces of paper so you can all be working rather than person B sitting and waiting for person A to finish writing their bit before person B can add theirs
- **REFLECT ON RESULTS!!!**

Today's Practical

- Remember: standard deviation is the uncertainty in one measurement, standard error is the uncertainty in the mean of N measurements of the same quantity.



$\langle T \rangle = (T_1 + T_1 + T_1) / 3$

$\sigma^2 = \Sigma_i \, (T_i - \langle T \rangle)^2 / 3$

$SE = N^{-½} \sigma$

So you would say a given measurement is $T_i \pm \sigma$ and the number you report is $T = \langle T \rangle \pm SE$