PHYS 1901 Physics Advanced
Tutorial 2: Mechanics

A. Qualitative Questions:

1. Roller Coaster

A group of engineering students are designing a roller coaster. They want to make it go faster along a straight, frictionless length of track. Brent suggests filling the bottom half of the carriage with water and adding a plug, which can be removed. His theory is that when the plug is removed the carriage will speed up. Rebecca tells him that he's a silly duffer, and that the carriage will instead slow down. Julia doesn't think it will make any difference, but lets them go ahead and try it, just to prove her point. Who is right and why?

2. Gravitational Potential Energy

Gravitational potential energy is usually defined as $U = mgh$ where m is the mass of the object, g is the acceleration due to gravity and h is the height.

a. Where is h measured from?

b. Is it possible to have a negative gravitational potential energy? If so, how?

Kinetic energy is defined as $K = 1/2\ mv^2$, where m is the mass of the object, and v is its speed.

c. Is it possible to have a negative kinetic energy?

d. Is it possible to define an absolute value for gravitational potential energy and kinetic energy anyway?

B. Demonstration Questions:

1. *Loop-the-loop*

Roll the balls from different heights.

What happens if you roll a rubber ball instead of a steel ball down the apparatus?

Explain the difference, if any, in the behaviour of the balls.

2. *Tennis racquet*

The strings on a tennis racquet are designed so that the energy absorbed by the strings are minimal. Explain the following observations:

a. A tennis ball has a greater final speed when rebounding off a racquet with looser strings (but not too loose) than one with very tight strings.

b. The tennis ball bounces higher from a racquet that is held firmly on the ground with your feet than from a racquet that is clasped firmly with your hands.

3. *Bouncing balls*

a. Can a ball dropped from rest return to its original height?

b. How can you get a ball to return to a greater height?

c. What determines the final height of a dropped ball? Compare dropping a steel ball on lead and a lighter ball on lead.

C. Quantitative Questions:

1. *Child on a banister*

A 45 kg child slides from rest down the banister of a flight of stairs. The 3.0 m long banister is at an angle of 30° to the horizontal. The coefficient of kinetic friction between the child's trousers and the banister is $\mu_k = 0.50$.

a. Draw a free-body diagram showing the forces acting on the child as she slides down the banister.

b. Which of these forces does work on the child?

c. Describe the energy transfers (noting the forces causing them) that take place as the child slides down the banister.

d. Write down an equation relating the total energy at the top of the banister and the total energy at the bottom of the banister. Be sure to include all the types of energy mentioned in **c**.

e. Estimate the speed of the child as she reaches the bottom of the banister.

f. What is the average rate at which energy is dissipated as the child slides down the banister?

2. *Very fast train*

A project to operate a very fast train, VFT, between Melbourne, Canberra and Sydney has been proposed. The VFT will travel at up to 300 km.h^{-1}! It is argued that the track should be built as straight as possible, going directly over hills, because the effect of a hill on the speed of a train decreases with increasing speed, but the acceleration going around a curve increases with speed. Assume that the power supplied by the engine is just enough to overcome drag and keep the train at a steady speed.

a. If the train has speed v at the bottom of a hill of height h, what will be its speed at the top of the hill?

b. A VFT is approaching the edge of the Great Dividing Range on the way from Sydney to Canberra. If it is travelling at 300 km.h^{-1} as it approaches, what will be its speed when it reaches a height of 300 m?

c. The operators of the train have decided that the maximum sideways acceleration that a passenger should experience so that they don't spill their drinks is one tenth that due to gravity. What is the minimum acceptable radius of curvature, r, of the track if the train is to maintain 300 km.h^{-1}?