Modeling Tasks

1) Devise a practical question about a Frisbee which you can answer treating the Frisbee as a point particle. Include a labeled diagram with your question.

2) List all of the assumptions that must be met in order for the projectile range equation to give an exactly correct answer for the range of a thrown object.

3) You and your friend are playing with the loop-the-loop apparatus at the local science museum. The track is rather smooth. Two small balls of the same size are available to roll down the track: a lighter plastic one and a heavier metal one. You and your friend decide to predict the minimum height from which the balls should be released in order for them to make it through the loop without falling off. You suggest modeling the balls as point particles to make the prediction, while your friend thinks that the heavy metal ball has a considerable moment of inertia that cannot be neglected. You use a ruler to determine the diameter of the loop (D=18 cm); a scale to determine the mass of the balls ($m_{plastic}$= 10 g; m_{metal}= 55 g); and a caliper to measure their diameters (d= 2.5 cm). What are the predictions for the minimum height of release for each model of the ball (in terms of the radius of the loop)? What other modeling assumptions do you need to make a prediction?

4) You have been hired as a forensic scientist at the local police lab. Recently, a person was injured while crossing a street. The driver claims he was driving at the speed limit of 35mph when the woman "appeared out of nowhere" and was hit. Your job is to figure out how fast the driver was actually going, because prosecutors want to decide whether they should press charges against the driver. The crime scene investigation unit gives you the following data:

> The car left skid marks which are nearly straight, and 20m long
> The coefficient of kinetic friction for the car's tires on the road is 0.8 (when dry)
> The road is approximately level
> The woman was hit before the skid marks were made

a. Given this data, how fast was the driver going when he hit the brakes and started skidding? Should prosecutors press charges against the driver?

b. List all the assumptions you need to make about the car, the road, and the interactions between the car and road, in order for your calculation to be accurate. This is important, because attorneys for both the prosecution and defense want to know how reliable your calculations are.

5) A cart on an air-track is attached by a string that passes over a pulley down to a hanging object. You push it abruptly in the left direction. The cart moves to the left, slows down, stops, and starts moving to the right with increasing speed. The graph for acceleration versus time of the cart is shown in figure 3b. When you repeat the same experiment with a cart on a regular track, the acceleration-versus-time graph looks different. Identify models of objects, interactions, systems, and processes that can help you to explain each graph and discrepancies between them.

6) A helium-filled balloon is attached to a light string and placed inside a box made of transparent plastic. The box has wheels on the bottom that allow it to roll. Explain why the balloon and string are vertical. What models of objects and interactions did you use? Predict what will happen to the thread and the balloon if you abruptly push the box to the left. To make the prediction, explain what models of objects and interactions you will include in your system, and how you will model any processes that occur. Then observe the experiment. If your prediction does not match the result, revise your model in order to get a new prediction that does match the result.

7) You have been hired as an engineer for a candy company. Your job is to design a spray nozzle which will apply a coating of chocolate on a new type of candy bar. The candy bars roll by on a conveyor belt, and the system you design must spray each bar with chocolate. You have been given the following information:

i) The chocolate is stored in an open, vertical vat. The vat is 3m tall, and the density of the chocolate is 1.1×10^3 kg/m^3.

ii) The vat has a single, horizontal outlet hole along the bottom rim. The hole has a radius of 5cm, and is at a height of 1m above the conveyor belt.

iii) Your spraying system must have an output of 10 cm^3/s in order to sufficiently coat the candy bars.

a. Based on this information, what radius must the spray nozzle have?

b. You have to present your calculations for the spray nozzle to your supervisor. In order to prepare for your meeting with her, you decide to think about all the potential problems which may make your calculation inaccurate. List all the assumptions about this system (the vat, the chocolate, the atmosphere, and the flow of the chocolate) which must be met for your calculation to be accurate.

8) You have been hired as a consultant for NASA when the following task is given to you: You are in charge of a group whose job is to design a computer program which can quickly calculate the energy of the rocket-Earth system. The rocket will travel from Earth to an orbit high above the Earth. You know that the gravitational potential energy of a system of two objects of masses *M* and *m* outside the massive object is $U = -GMm/r$. To make your computer program as fast as possible, though, you want to know when it is ok to treat the gravitational potential energy of the system as $U = mgh$.

a) Where do we set $U = 0$ when we use $U = mgh$? Where do we set $U = 0$ when we use $U = -GMm/r$?

b) Using your answer to part (a), show that we can use $U = -GMm/r$ to derive $U = mgh$. (hint: $(R+h)^{-1} \approx R^{-1} - (h/R^2)$ if $h \ll R$).

c) Based on the approximation used in part (b), when do you think it is reasonable to use $U = mgh$?

9) A solid object is rotating about some axis of rotation, under the influence of a net torque. What assumptions must we make about the solid object, its motion, and the forces acting on the object, in order for our model of rotational motion to be accurate?