Homework 5

Due at the end of the day of Monday, 29 March

1. A heavy ball with mass 10 kg is suspended by a rope of length 4.5 m. It is pulled to one side and released, swinging like a pendulum; at its lowest point, it reaches a speed of 6 m/s.

   (a) What is the tension in the rope at that point?

   (b) Explain in words (without using mathematics) why the tension in the rope here is greater than the weight of the ball.

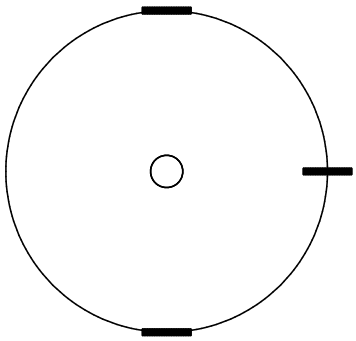
2. A ball is attached to the end of a string hanging from the roof of a subway car. The train goes around a curve, turning to the left. You know that the car is traveling at 60 km/hr.

   (a) Which way will the ball appear to swing?

   (b) What force pushes the ball in that direction? If there is no such force, explain why the ball swings to the side even though there is no force pushing on it.

   (c) If the ball swings at an angle of 15°, what is the radius of curvature of the curve in the tracks?

3. A carnival ride consists of a vertical wheel of radius r rotating at angular velocity ω around a horizontal axis. There is a horizontal platform attached to it; a person stands on the platform. (This platform stays horizontal, and does not rotate; the person remains upright during the whole ride.) This person has mass m, and stands on a scale. The coefficient of static friction between their feet and the scale is $\mu_s = 0.5$.



   (a) Draw force diagrams for the person at the top of the circle, the bottom of the circle, and the position at the same height as the middle of the circle. (You will need to think carefully about the third one of these.)

   (b) How does the scale reading relate to the forces that act on the person standing on the platform?

(c) In terms of m, g, r, μ_s, and ω, what is the scale reading at the top? (Your answer may not depend on all of these.)

(d) In terms of m, g, r, μ_s, and ω, what is the scale reading at the bottom? (Your answer may not depend on all of these.)

(e) What coefficient of static friction is required for the person not to slide at the position at the same height as the middle, in terms of m, g, r, and ω?

4. The film *Apollo 13* tells the story of three astronauts trying to survive aboard a crippled spacecraft in space between the Earth and the Moon. It involves scenes where the actors appear to be "weightless", mimicking the experience of the astronauts. Since going to space was prohibitively expensive, the producers shot those scenes in a set inside an aircraft. The aircraft flew in parabolas with an acceleration of precisely g downward; during this time, the astronauts appeared to float inside the set, as the aircraft climbed and then dove toward the ground.

   (a) The astronauts were able to experience "weightlessness" for about 25 seconds at a time. How far did the aircraft have to climb and then dive in order to do this?

   (b) Consider three forms of "weightlessness":

   - The experience of the actors and crew of the film *Apollo 13* in this aircraft
   - The experience of astronauts in the Space Station, in orbit around Earth at a low altitude
   - The experience of the astronauts in a real deep space mission like *Apollo 13*, in which the astronauts flew 400,000 km from Earth (which has a radius of around 6000 km).

   What are the similarities between the dynamics of "weightlessness" in these situations? What are the differences?