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. Astrologers[1] claim that the positions of the planets can influence events on Earth. In this problem, you'll calculate whether this is plausible or not.

   (a) Which planet's gravity do you think would have the greatest effect on Earth? Venus' orbit is closest, but Jupiter is largest.

   (b) Look up astronomical parameters for Earth and your chosen planet. What is the closest they ever are to each other? You may approximate their orbits as circles, and can find all the information you need on Wikipedia. Show how you estimate their distance of closest approach.

   (c) What acceleration does your chosen planet impart to objects on Earth? Is this acceleration relevant to anything?

3. In this exercise, you will think carefully about the meaning of our constant g.

   Recall that scales measure the normal force they exert, and the "apparent weight" of an object is the normal force exerted on it by the surface below it.

   For this exercise, use the "standard average value" of $g - 9.8067\ rmm/\mathrm{s}^2$. Later we will see why this is not quite a standard – nor an average.

   In this problem, treat the Earth as a sphere with radius 6378 km. This is not quite right (the radius near the equator is a little larger), but it is close enough.

   (a) Suppose that Tux the Penguin, with a mass of one kilogram, stands on a scale at the Sorth Pole. What value will the scale read?

   (b) Suppose Tux then travels to the Equator and stands on a scale there. What is its *acceleration?* (Remember that the Earth is rotating around its axis at an angular velocity of one rotation per day. You will need to convert this to radians per second.)

   (c) What is Tux's apparent weight at the Equator?

[1] *Astronomy* is the scientific study of the stars. *Astrology* is the practice of fortune-telling and divination based on the apparent motion of stars and planets. They are not the same thing. :)

(d) This difference suggests that there are two different ways we could define g:

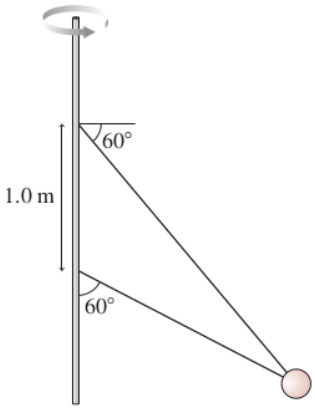
i. ... based on the *force of gravity* that an object experiences

ii. ... or based on the *apparent weight* that an object experiences

Which definition do you think is most useful to engineers, and why?

4. Satellites in *geostationary orbit* revolve around the Earth at the same rate as the Earth rotates, so that they complete one orbit every 24 hours. What is the altitude of geostationary orbit? You may measure this altitude from the Earth's surface or its center, but tell me which one you are using. *(Hint: This question may be approached in the same manner as our others: 1) draw force diagram, 2) write down $F = ma$, 3) put in what you know and solve for what you don't. Don't overcomplicate things!)*

5. Two wires are tied to the sphere of mass 3 kg shown here. The sphere revolves around the pole in a horizontal circle at constant speed. *(Hint: Usually high school geometry isn't that helpful, but here it is. You will need to be a bit clever to find the radius of the circle that the ball travels in. As a first step, try finding the interior angles of the triangle formed by the two wires and the pole.)*



(a) For what speed is the tension the same in both wires?

(b) What is that tension?

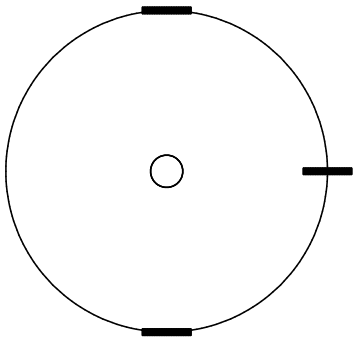
6. A ball is attached to the end of a string hanging from the roof of a subway car. The train goes around a curve, turning to the left. You know that the car is traveling at 60 km/hr.

(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?

7. 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?