Physics 7A, Fall 2018, Sections 2 and 3, Instructor: Professor Adrian Lee
Midterm Examination 2, Tuesday, April 3, 2018

Please do work in your blue/greenbooks. Show your reasoning carefully so that we can be sure that you derived the answer rather than guessing it or relying on memory; in addition, this enables us to give partial credit. You may use one double-sided 3.5 x 5 index card of notes. Test duration is 110 minutes. Simple calculators allowed.

1 Qualitative Questions [15 pts. total].

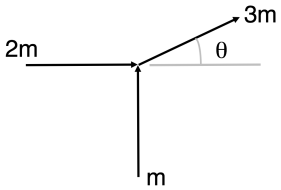
Answers should be a short paragraph only, perhaps with a drawing, and very little, if any, math.

a) A Physics Professor entertains his students by sitting in a wheeled chair and discharging a fire extinguisher to the rear to propel himself forward. Can you explain what causes this propulsion? [5 pts.]

b) If you jump off of a wall onto the ground, staying on your feet (not rolling), what can you do to reduce the force on your legs? Please explain in terms of physics concepts. [5 pts.]

c) Usually friction is considered a "non-conservative" force and gravity is considered a "conservative force," but some would argue that all forces are fundamentally conservative. Please explain both points of view. [5 pts.]

2 Skaters Collide [30 pts. total]

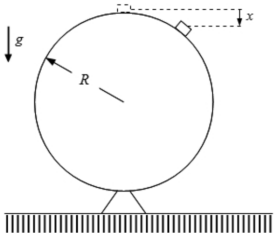


A small and a big ice skater of masses m and $2m$ travelling at 90 degree angle to each other collide and hug.

a) What angle do they end up going relative to the original velocity of the small skater? [15 pts.]

b) Is energy conserved? If yes, why? If no, how much energy is lost or gained? [15 pts.]

3 Falling off the world [20 pts. total]



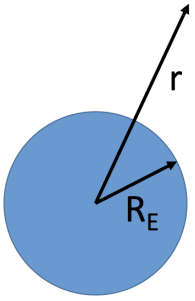
A small block slides from rest from the top of a frictionless sphere of radius R (see figure). The distance from top to current position is given by x. For what value of x does the mass first lose contact with the sphere? [20 pts.]

4 Earthly Problems [30 pts. total]

The force of gravity for two masses M and m can be written:

$$F = -\frac{GMm}{r^2}\hat{r}$$

where r = 0 is the location of M and $\hat{r}$ points in the direction of m (that is, gravity is an attractive force).



a) Derive the potential energy of an object with mass m as a function of r and make a sketch of this function. Explain any choices you made in defining the potential energy. [10 pts.]

b) Derive an expression for the "escape velocity" needed to fully escape the earth's gravity starting from the surface of the earth at $r = R_E$. [10 pts.]

c) Now consider a satellite in circular orbit around the earth. The "virial theorem" says that the average kinetic energy is equal to 1/2 the absolute value of the potential energy for many systems. Is it true for the orbiting satellite? [10 pts.]

5 Rocket Explosion [20 pts. total]

A Space-X rocket accidentally explodes at the top of its trajectory. The horizontal distance between the launch point and the point of explosion is L. The rocket breaks into two pieces which fly apart horizontally. The large piece has three times the mass of the smaller piece. To the surprise of Elon Musk, the smaller piece returns to earth at the launching station. How far away does the larger piece land? Neglect air resistance and effects due to the earth's curvature. [20 pts.].