F=ma Problem Set: Medium

TJPT Officers

December 2015

This problem set will be the second part of a series of problem sets that will focus on preparing you for the F=ma exam. This set in particular will be focused on giving problems that are reminiscent of problems that would appear on #16-25 of the F=ma exam. These problems will largely be derived from past F=ma exam problems, but other problems may appear. As usual, do them to the best of your ability and if you can solve all of these problems you are well on your way to qualify for the semifinalist exam! If you have any questions, please email us at **tjhsstphysicsteam@gmail.com**.

1. (F=ma 2009) A uniform rectangular wood block of mass M, with length b and height a, rests on an incline as shown. The incline and the wood block have a coefficient of static friction, μ_s. The incline is moved upwards from an angle of zero through an angle θ. At some critical angle the block will either tip over or slip down the plane. Determine the relationship between a, b, and μ_s such that the block will tip over (and not slip) at the critical angle. The box is rectangular, and $a \neq b$.

2. (F=ma 2010) The gravitational self potential energy of a solid ball of mass density ρ and radius R is E. What is the gravitational self potential energy of a ball of mass density ρ and radius $2R$?

3. (F=ma 2011) A particle is launched from the surface of a uniform, stationary spherical planet at an angle to the vertical. The particle travels in the absence of air resistance and eventually falls back onto the planet. Spaceman Fred describes the path of the particle as a parabola using the laws of projectile motion. Spacewoman Kate recalls from Kepler's laws that every bound orbit around a point mass is an ellipse (or circle), and that the gravitation due to a uniform sphere is identical to that of a point mass. Which of the following best explains the discrepancy?

   (A) Because the experiment takes place very close to the surface of the sphere, it is no longer valid to replace the sphere with a point mass.

   (B) Because the particle strikes the ground, it is not in orbit of the planet and therefore can follow a nonelliptical path.

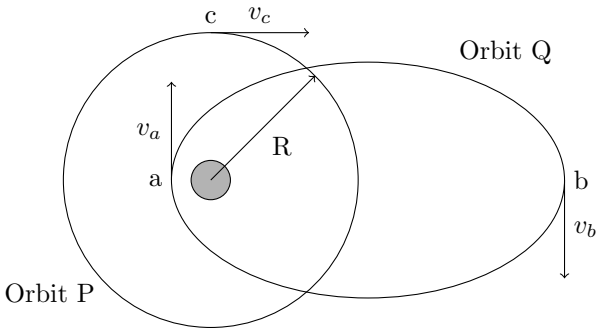
   (C) Kate disregarded the fact that motions around a point mass may also be parabolas or hyperbolas.

   (D) Kepler's laws only hold in the limit of large orbits.

   (E) The path is an ellipse, but is very close to a parabola due to the short length of the flight relative to the distance from the center of the planet.

4. (F=ma 2007) Find the period of small oscillations of a water pogo, which is a stick of mass m in the shape of a box (a rectangular parallelepiped.) The stick has a length L, a width w and a height h and is bobbing up and down in water of density ρ. Assume that the water pogo is oriented such that the length L and width w are horizontal at all times. Hint: the buoyant force on an object is given by $F_{\text{buoy}} = \rho V g$, where V is the volume of the medium displaced by the object and ρ is the density of the medium. Assume that at equilibrium, the pogo is floating.

5. (F=ma 2012) Consider the two orbits around the sun shown below. Orbit P is circular with radius R, orbit Q is elliptical such that the farthest point b is between $2R$ and $3R$, and the nearest point a is between $R/3$ and $R/2$. Consider the magnitudes of the velocity of the circular orbit v_c, the velocity of the comet in the elliptical orbit at the farthest point v_b, and the velocity of the comet in the elliptical orbit at the nearest point v_a. Which of the following rankings is correct?



(A) $v_b > v_c > 2v_a$

(B) $2v_c > v_b > v_a$

(C) $10v_b > v_a > v_c$

(D) $v_c > v_a > 4v_b$

(E) $2v_a > \sqrt{2}v_b > v_c$

6. (F=ma 2008) A bullet of mass m_1 strikes a pendulum of mass m_2 suspended from a pivot by a string of length L with a horizontal velocity v_0. The collision is perfectly inelastic and the bullet sticks to the bob. Find the minimum velocity v_0 such that the bob (with the bullet inside) completes a circular vertical loop.

7. (F=ma 2012) A hollow cylinder with a very thin wall (like a toilet paper tube) and a block are placed at rest at the top of a plane with inclination θ above the horizontal. The cylinder rolls down the plane without slipping and the block slides down the plane; it is found that both objects reach the bottom of the plane simultaneously. What is the coefficient of kinetic friction between the block and the plane?

8. (F=ma 2010) Four masses m are arranged at the vertices of a tetrahedron of side length a. What is the gravitational potential energy of this arrangement?