Final Exam —Phy171—Spring 2001
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- Use a new page of your exam booklet for each problem.
- Write **NEATLY** and **MAKE YOUR REASONING CLEAR** to make the most of partial credit!
- **Advice**: *Work out formulae* **before** *putting in numbers. Check dimensions and limits to smoke out errors!*
- Do all eight problems. Each is worth 10 points.

1. A block of mass M sits on top of another block of mass 3M, which sits on a frictionless surface. The coefficient of static friction between the two blocks is 0.7. What is the minimum horizontal force F, applied to the bottom block, for which the top block will slip relative to the bottom block? (*Hint*: First find the acceleration of the blocks in terms of F, then find the force on the top block.)

2. An electron makes a spiraling motion along the direction of a magnetic field line in the z direction. The z-component of the position has constant acceleration 3 m/s^2 and the x-y motion is uniform circular motion with speed 4 m/s and radius 4 m.

(a) What is the magnitude of the acceleration vector? (Include the units!)

(b) What angle does the acceleration vector make with the $+z$ axis?

3. A ball is tossed up at an angle θ from the horizontal and on the way down passes the initial height 4 s later and 12 m away in the horizontal direction. What is θ? (Neglect air resistance.) (*Suggestion*: First find the horizontal and vertical components of the intial velocity.)

4. A space expedition takes off from the earth and travels at constant speed $v = 0.9c$ along a straight path to a star 2 lightyears away. When they arrive they realize they forgot their toothbrushes so they send a radio signal (which travels at the speed of light) back to earth, saying that they are on their way back. They then return immediately along a straight path at speed $v = 0.5c$. Treat this as a one dimensional problem.

(a) Draw a spacetime diagram of this process showing the worldlines of the earth and spaceship and of the radio signal. (Use x/c for the horizontal axis so light rays go at 45 degree angles.)

(b) How much time passes on earth during the round trip?

(c) How much time passes on the spaceship during the round trip?

5. A 5 kg mass bounces up and down hanging from a spring with force constant $k = 4$ N/cm. The distance between the top and the bottom of one bounce is 30 cm.

(a) How much total work is done on the mass between the top and the bottom of one bounce?

(b) How much work is done by gravity between the top and the bottom of one bounce?

(c) How much work is done by the spring between the top and the bottom of one bounce?

(d) What is the kinetic energy of the mass at the midpoint halfway between the top and bottom of a bounce?

(*Hint for (d)*: The gravitational and spring forces add to zero at the equilibrium point, and the gravitational force is constant, so the net force is just like that of a spring with that equilibrium point and force constant k.)

6. A particle of mass 3 kg moves along the x axis through a region in which the potential energy is given by $U(x) = x^2 - 3x$, where x is in meters and $U(x)$ is in joules. At $t = 0$ the particle is at $x = 1$ m and its velocity is -2 m/s.

(a) Sketch a graph of $U(x)$ showing clearly where its zeros, maxima, and minima are.

(b) What is the force on the particle at $x = 1$ m?

(c) Describe the motion for $t > 0$. How far does the particle go in the negative x direction? How far in the positive x direction?

(d) How much work is done by the force as the particle goes from $x = 1$ m to $x = -0.5$ m?

(e) Is the force conservative?

7. In the laboratory a particle of mass 3 kg moving at 15 m/s to the left collides head-on with a particle of mass 2 kg moving at 12 m/s to the right.

(a) Find the velocity of the center of mass of the system of two particles after the collision.

(b) If the collision is elastic, what is the velocity of the 3 kg mass after the collision in (i) the center of mass frame, and (ii) the laboratory frame?

(*Hint for (b)*: You could do this with the general formula if you have it. Alternatively, in the c.m. frame the velocity just reverses sign.)

8. A 100 gm yo-yo is shaped like a disc of radius 3 cm and has an inner axle of radius 5 mm, around which is coiled a thin string. The yo-yo is resleased from rest and spins as it falls vertically.

(a) What is the rotational inertia of the yo-yo? (Neglect the mass of the axle.)

(b) How long does it take the yo-yo to fall through 70 cm?

(*Hint for (b)*: First find the acceleration.)