Christmas Examination Physics 100

December 6, 2013

Instructions: Duration of exam is 2.5 hours. Complete all work in your exam booklet. Formulas at the back of exam. Rip those sheets off if you want to. Questions are on both sides of the exam sheet. Calculator permitted. Keep it in degree mode! Point values are shown with the questions. Complete the questions in any order. Total exam is worth 72 points. The 10 questions are not worth equal amounts (13, 4, 9, 6, 6, 14, 3, 3, 9 and 5 points respectively).

I have sometimes included "dummy" answers to be used in that part or the next part of a question. They may or may not be the actual answer but you can use them, the correct answers, or reasonable "wrong" answers to continue with later parts of the problem with no penalty.

Quote your answers to 3 significant figures. Include correct units.

If I ask for an "expression" I usually mean a formula where you have substituted in some variables and/or values. Usually it is an intermediate step on the way to the final answer.

If I ask for a "numerical" value I mean that you have put numbers in and calculated a value giving the appropriate units.

1. A rocket cruiser with a mass of 1200 kg and weighing 4500 N is flying horizontally over the surface of a distant planet. At its present speed, a 2500 N drag force acts on the cruiser. The cruiser's engines can be tilted so as to provide a thrust angled up or down. The pilot turns the thrust up to 14 000 N while pivoting the engines to continue flying horizontally.
   (a) Draw a free-body diagram. Let θ be the angle that $\vec{F}_{\text{thrust}}$ makes with the x-axis. (4)
   (b) Eventhough the thrust is at an angle to the x-direction, the cruiser's acceleration in the y-direction is zero. Use Newton's 2nd Law for the y-components of the force to give a value for $|\vec{F}_{\text{thrust}}| \sin\theta$. (3)
   (c) Solve for the cruiser's acceleration in the x-direction. (Use $\theta = 25^{\circ}$ as a dummy answer if you like.) (3)
   (d) Notice in this problem that "g" is not equal to 9.8 m/s^2; it is 3.75 m/s^2. Show that this is consistent with what you would expect at the surface of Mars. $G = 6.67 \times 10^{-11}$ N m^2/kg^2, mass of Mars is 6.42×10^{23} kg, mass of the Sun is 1.99×10^{30} kg, radius of Mars is 3.37×10^{6} m, radius of the Sun is 6.96×10^{8} m, average distance between the Sun and Mars is 2.28×10^{11} m. (3)

2. A ball on a string moves in a vertical circle at a constant speed. When the ball is at its lowest point, is the tension in the string greater than, less than, or equal to the ball's weight? Explain. (You may want to include a free-body diagram as part of your explanation.) (4)

3. (a) Suppose that a bicycle wheel has a moment of inertia of 0.40 kg·m^2 and makes one full rotation in the counterclockwise direction in 0.80 s. What is the angular momentum? (3)
   (b) In the classroom I used the spinning bicycle wheel to do a demonstration of conservation of angular momentum. Explain what happened and include either a description or diagram of "initial" and "final". You don't need to give a quantitative description but if it helps you can say that my moment of inertia is 9.0 kg·m^2. (4)
   (c) Linear momentum is conserved if there are no external forces. Why do you think I stood on the freely-rotating, low-friction pedestal to do demonstrations of conservation of angular momentum? (2)

4. Conservation of momentum in 2D: A 0.020 kg ball of clay traveling east (i.e. the positive x-direction) at 2.0 m/s collides with a 0.030 kg ball of clay traveling 30° south of west (i.e. $v_x = -v\cos 30^o$ and $v_y = -v\sin 30^o$) at 1.0 m/s. They end up forming one blob of clay. What are the speed and direction of the resulting 0.050 kg blob? (6)

5. Use conservation of energy to solve these problems. You don't need to elaborate on your choice of "system" or what energy terms are zero but you do need to show your mathematical steps.

   (a) A car is parked at the top of a 50 m high hill. It slips out of gear and rolls down the hill. How fast will it be going at the bottom? (3) (Ignore friction.)

   (b) As a 15 000 kg jet lands on an aircraft carrier, its tail hook snags a cable to slow it down. The cable is attached to a spring with a spring constant of 60 000 N/m. If the spring stretches 30 m to stop the plane, what was the plane's landing speed? (Again, ignore friction.) (3)

6. A $m = 1.5$ kg mass is suspended from a massless string. The string runs over a solid pulley with a mass of $M = 2.5$ kg and a radius of $R = 0.25$ m. A force of 10 N is applied downward to the "free" end of the string. The shaft of the pulley is frictionless but the string does not slip on the pulley. The general plan of this problem follows what was covered in the assignment.

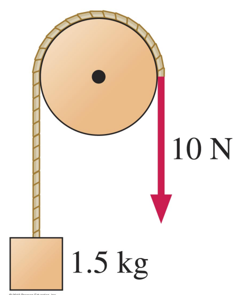

Figure 1: Figure for question 6

   (a) Calculate the moment of inertia of the pulley using $I = \frac{1}{2}MR^2$. (2)

   (b) Give the Newton's 2nd law expression for the y componenent of the acceleration of 1.5 kg mass in term of the tension T in the string, m, and g. (2)

   (c) If you use Newton's 2nd law for rotational motion and the constraint equation you find a second equation that relates a_y and T.

$$-\frac{1}{2}Ma_y = T - 10 \tag{1}$$

   $M = 2.5$ kg is the mass of the pulley. This equation and the one you have from part 6b form a system of equations. Solve the equations to show that $a_y = -1.7$ m/s^2. (4)

   (d) How long does it take the hanging mass to fall 0.50 m? (3)

   (e) How much work does the 10 N force do as the hanging mass falls? Comment on the sign of your answer. (3)

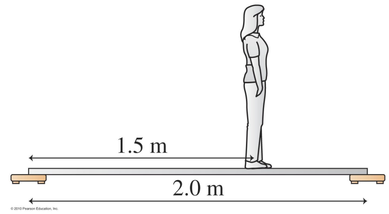

Figure 2: Figure for question 7

7. This is a problem in static equilibrium. A 64 kg woman stands on a very light, rigid board that rests on a bathroom scale at each end, as shown in Fig. 2. What is the reading on the right hand scale in Newtons? (3)

8. How much torque must the pin exert to keep the rod in Fig. 3 from rotating? Use the pin location as the pivot point and leave τ_{pin} as a variable in the τ_{net} expression prior to solving for it. (i.e. don't try to put in an "r" or "F" for the pin.) (3)

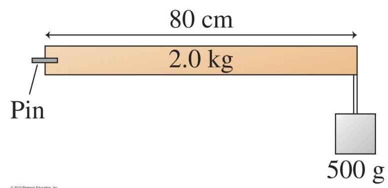

Figure 3: Figure for question 8

9. Laura, whose mass is 35 kg, jumps horizontally off a 55 kg canoe at 1.5 m/s relative to the canoe. There are no external forces in the x-direction. All of this is in 1-dimension so you don't need to write the x subscripts.

   (a) What is the canoe's speed just after Laura jumps? (Use $v_L = 1.0$ m/s relative to the water as a dummy answer for part credit.) (5)

   (b) What impulse did Laura deliver to the canoe? (2)

   (c) Prior to Laura jumping there was no kinetic energy but afterwards both objects are moving. Where does the extra energy come from or is energy not conserved in this case? (Remember there are no external forces in the direction of motion.) (2)

10. A 0.050 kg marble moving at 2.0 m/s strikes a 0.020 kg marble at rest. What is the speed of each marble immediately after the collision? Assume the collision is perfectly elastic and the marbles collide head-on. (Just use the formulas to solve, don't start from momentum and energy conservation.) (5)