Christmas Examination Physics 100

December 6, 2012

Instructions: 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. Point values are shown with the questions. Complete the questions in any order. Total exam is worth 90 points. The 9 questions are not worth equal amounts (11, 12, 6, 7, 8, 4, 14, 14, and 14 points respectively).

For multiple choice questions clearly indicate the correct answer. There is mark breakdown shown for the multiple choice answer and the work associated with the question/answer.

For multiple-part questions I have sometimes included "dummy" answers to be used in that part or the next part. 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.

If I ask for an "expression" I usually mean a formula where you have substituted in some variables and 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) How do forces affect the motion of objects? (3)
   (b) A 23 kg child goes down a straight slide inclined 38^o above the horizontal. The child is acted on by his weight, the normal force from the slide and kinetic friction.
      i. Draw a free body-diagram of the child. (4)
      ii. How large is the normal force of the slide on the child? Explain your reasoning. (4)

2. As a roller coaster car crosses the top of a 40 m diameter loop-the-loop, the normal force of the track on the car is directed downward and, for this particular speed, is equal in magnitude to mg. (Note: this is the same as saying its apparent weight is equal to the true weight, which is what you saw in tutorial problem 6.25.)
   (a) What is the car's speed at the top? Drawing a free-body diagram is not required but it is a really good idea. (for part value calculate the speed if you know the mass of the car and rider is 320 kg and the magnitude of centripetal force is 6400 N). (6)
   (b) Without referring to centrifugal force explain why the roller coaster doesn't fall off the track (same as the explanation for a bucket of water). (4)
   (c) Now explain why the roller coaster stays on the track if you can use centrifugal force. (2)

3. Kepler's 3rd Law Problem: The asteroid belt circles the sun between the orbits of Mars and Jupiter. One asteroid has a period of 5 earth-years (1.6×10^8 s). What are the asteroid's orbital radius and speed? You may find the following constants useful $G = 6.67 \times 10^{-11}$ Nm^2/kg^2, $M_{\text{sun}} = 2.0 \times 10^{30}$ kg, r(Earth to Sun) $= 1.50 \times 10^{11}$ m. (for part value assume that r(asteroid to sun) $= 4.1 \times 10^{11}$ m to calculate speed).

   Keep in mind that Kepler's 3rd law means T^2 is proportional to r^3 so that

$$\frac{T^2_{\text{Earth}}}{r^3_{\text{Earth}}} = \frac{T^2_{\text{aster}}}{r^3_{\text{aster}}} \tag{1}$$

   (6 points)

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? (7)

5. A boy reaches out of a window and tosses a ball straight up with a speed of 10 m/s. The ball is 20 m above the ground as he releases it. Use conservation of energy to find

   (a) The ball's maximum height above the ground. (3)

   (b) The ball's speed as it passes the window on the way down. (2)

   (c) The speed of impact on the ground. (Use a dummy answer of max height equal to 35 m if you wish.) (3)

6. A 10% efficient engine accelerates a 1500 kg car from rest to 15 m/s. How much energy is transferred to the engine by burning gasoline? (i.e the energy you pay for) (4)

7. 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.

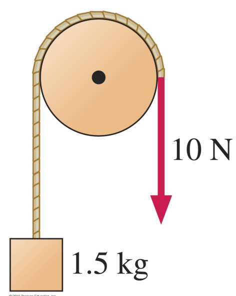

Figure 1: Figure for question 7

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

   (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. (3)

   (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.

$$-\frac{1}{2}a_y = \frac{T - 10}{M} \qquad (2)$$

   $M = 2.5$ kg is the mass of the pulley. This equation and the one you have from part 7b form a system of equations. Solve the equations to show that $a_y = -1.7$ m/s^2. (6)

   (d) The constraint equation is $\alpha = -a_y/R$. Assuming the pulley is orginally at rest calculate how long it takes the pulley to rotate one quarter turn counterclockwise (you need to convert to radians and use kinematics). (3)

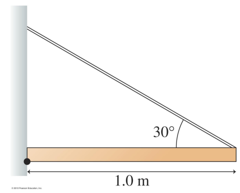

Figure 2: Figure for question 8

8. This is a problem in static equilibrium. The beam is uniform with a length of 1.0 m and a mass of 10 kg. The beam is free to pivot where it connects to the wall. The angle between the cable and beam is 30°.

   (a) Write the equations that define static equilibrium. (2)

   (b) The tension in the cable is (A) 130 N, (B) 49 N, (C) 98 N, (D) 57 N (E) 200 N. (4 points for work, 2 points for the right answer.) Use any value except (E) as a dummy answer)

   (c) A fairly large cat (weight 40 N) walks gingerly out on the beam. How far can he go if the maximum tension in the cable before breaking is 150 N? (Hint: write the $\tau_{\text{net}} = 0$ expression leaving r_{cat} as a variable and set $T = 150$ N.) (6 points)

9. My kids and I are fooling around with a windsurfer board (no sail in place, treat it like Laura's canoe from the assignment). It is a calm day and the drag force of the water on the board is negligible. The board has a mass of 15 kg and my son Matthew has mass of 20 kg. Matthew is a fast runner and he is moving 2.0 m/s relative to the windsurfer board when he jumps off. I am observing all of this from the water and initially neither the board nor Matthew are moving. All of this is in 1-dimension so I am not writing the x subscripts.

   (a) Is linear momentum always conserved? Is this a situation when it is conserved? (2)

   (b) Write the expression for the momentum of the system after Matthew jumps in terms of v_{MC} and v_{BC} (the "C" means relative to me, "B" is for the windsurfer board). (2)

   (c) Write the expression that relates the v_{MB} to the other velocity variables. Remember that $v_{BC} = -v_{CB}$. (3)

   (d) Now solve for the recoil velocity of the board v_{BC} in m/s. (If you are stuck you can use the dummy value $v_{MC} = 0.86$ m/s.)
   (A) -0.86 (B) -2.7 (C) -1.14 (D) 1.14 (E) 0. (5 points for work and 2 points for the right answer)