Alternate Christmas Examination Physics 100

January 14, 2013

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 10 questions are not worth equal amounts (11, 12, 6, 5, 13, 6, 5, 4, 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° 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. (a) 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.) (3)
   (b) You hold a bucket in one hand, and in the bucket is a 0.500 kg rock. You swing the bucket so the rock moves in a vertical circle 2.2 m in diameter. What is the minimum speed the rock must have at the top of the circle if it is to always stay in contact with the bottom of the bucket? (3)
   (c) Without referring to centrifugal force explain why the rock stays in the bucket (same as the explanation for a bucket of water). (4)
   (d) Now explain why the rock stays in the bucket 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, $r(\text{Earth to Sun}) = 1.50 \times 10^{11}$ m. (for part value assume that $r(\text{asteroid to sun}) = 4.1 \times 10^{11}$ 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. The carbon isotope ^{14}C is used for carbon dating of archeological artifacts. ^{14}C (mass of 2.34×10^{-26} kg) decays by the process known as *beta decay* in which the nucleus emits an electron (the beta particle) and a subatomic particle called a neutrino. In one such decay, the electron and the neutrino are emitted at right angles to each other. The electron (mass 9.11×10^{-31} kg) has a speed of 5.00×10^{7} m/s and the neutrino has a momentum of 8.00×10^{-24} kg·m/s. What is the recoil speed of the nucleus? (5)

5. A 0.050 kg marble moving at 2.0 m/s strikes a 0.020 kg marble at rest.

   (a) Assume the collision is perfectly elastic and the marbles collide head-on. What is the speed of each marble immediately after the collision? (Hint: consult the formula sheet) (4)

   (b) Explicitly show that energy is conserved by calculating E_{initial} and E_{final}. (4)

   (c) What is the relative velocity of the marbles? (2)

   (d) Suppose instead the marbles stick together after the collision (i.e. an inelastic collision) but you can still use conservation of momentum. Calculate the speed of the two "stuck" marbles immediately after the collision. (3)

6. A hockey puck is given an inital speed of 5.0 m/s. If the coefficient of kinetic friction between the puck and the ice is 0.05, how far does the puck slide before coming to rest? Solve this problem using conservation of energy. (6)

7. A star the size of our sun rotates in 30 days. Explain why it rotates so much faster if it "collapses" to a neutron star that is only 10 km across. You don't need to use numbers but if it helps the formula for moment of intertia of solid (non-hollow) sphere is $I = \frac{2}{5}MR^2$, $M_{\text{sun}} = 2.0 \times 10^{30}$ kg, $R_{\text{sun}} = 7.0 \times 10^{8}$ m. (5)

8. 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)

9. 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.

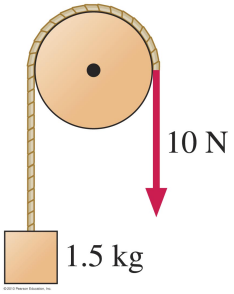

Figure 1: Figure for question 9

   (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.

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

$M = 2.5$ kg is the mass of the pulley. This equation and the one you have from part 9b 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 half turn counterclockwise (you need to convert to radians and use kinematics). (3)

10. 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°.

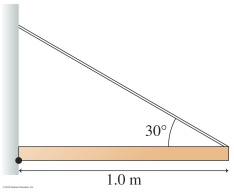

Figure 2: Figure for question 10

(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)