Alternate Christmas Examination Physics 100

January 6, 2012

Instructions: Complete all work in your exam booklet. Formulas at the back. 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 98 points. The 6 questions are not worth equal amounts (26, 16, 21, 14, 13, and 10 points respectively).

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.

Everything is 2 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 are giving the appropriate units.

1. 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 tutorial and the assignment.

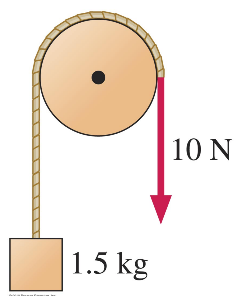

Figure 1: Figure for question 1

   (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. (2)

   (c) Give a numerical value for T if the 1.5 kg block is motionless ($a_y = 0$). (2)

   (d) What is the numerical value for the torque applied to the pulley from the 10 N force? Use the correct sign convention. (2)

   (e) If the 10 N force was the *only* one providing torque to the pulley how long would it take for the pulley to reach $\omega_f = -20$ rads/s if $\omega_i = 0$? (Hint: find α then use kinematics.) (2)

   (f) Write the "angular" Newton's 2nd law expression for the pulley now including *both* the 10 N force and the tension in the string. (It will be a formula for α.) (2)

(g) The constraint equation is $\alpha = -a_y/R$. Use this to eliminate α from the expression in part 1f. You can either keep the value of I calculated above or cancel the factors of R to leave an expression in terms of M. (Dummy answer: "(-2 kg) $a_y = T - 10$ N") (2 points)

(h) Now by solving a system of equations find the value of a_y. (6)

(i) Suppose the mass is released from rest and $\Delta t = 1.0$ s. Calculate Δy and v_{yf}. (Use $a_y = -1.7$ m/s^2 for a dummy answer if you wish.) (Hint: kinematic equations) (6)

2. 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^o.

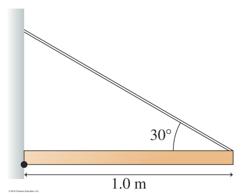

Figure 2: Figure for question 2

(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 120 N as a dummy answer for the next part if you wish.)

(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)

(d) I say he walks "gingerly" why would "stomping" or "leaping" make a difference? (2)

3. In class, I poured 3.0 kg of water (and other unspecified liquids) into a 1.0 kg bucket and then swung the bucket and liquid in a vertical circle. At one point the bucket was right over my head but I remained dry. The radius of the circular path was 0.88 m.

(a) Before getting into the concepts try these numerical questions: If the speed of bucket and water is $v = 3.3$ m/s calculate ω, the period T, and the centripetal acceleration. (4)

(b) How much energy did I need to add to the system to go from a bucket at rest at the low part of its path to the upper part when moving at 3.3 m/s? (4) (K will contain either $\frac{1}{2}mv^2$ or $\frac{1}{2}I\omega^2$ with $I = mr^2$.)

(c) Without referring to centrifugal force explain why I stay dry. The centripetal acceleration is slightly greater in magnitude than g (6).

(d) Now explain why I stay dry if you can use centrifugal force. (2)

(e) I chicken out and let go of the bucket when it is over my head. Which of the following takes place (3 points, no reasoning required and no part marks for this part)

i. There is no more force on the bucket from me so I get wet when the bucket stops.

ii. There is no more force on the bucket from me so gravity makes it and the water follow a projectile path.

iii. There is no more force on the bucket from me so the centrifugal force just lifts it straight up momentarily and then I get wet.

iv. Some parts of the above statements are true but the descriptions of the motion are false.

4. 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)

   (e)

5. A rocket cruiser with a mass of 2200 kg and weighing 5000 N is flying horizontally over the surface of a distant planet. At its present speed, a 3000 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. (6)

   (b) What is the cruiser's acceleration in the y-direction? (dummy answer for next part $a_y = 2.3$ m/s^2) (2)

   (c) Use Newton's 2nd Law for the y-components of the force to give a value for $|\vec{F}_{\text{thrust}}| \sin\theta$. (dummy answer for next part $|\vec{F}_{\text{thrust}}| = 14\ 000$ N). (2)

   (d) Solve for the cruiser's acceleration in the x-direction. (Use $\theta = 25^{\circ}$as a dummy answer if you like.) (3)

6. A bullet weighs 0.0025 kg and is shot horizontally into a dense block of wood of mass 3.0 kg. The block is resting on a frictionless surface and is originally at rest. The bullet ends up being lodged in the block. The final velocity of the block is 0.45 m/s. All of this is in 1-dimension so I am not writing the x subscript.

   (a) What is the final x-momentum of the bullet-block system? (2) (dummy answer 1.5 kg m/s)

   (b) What was the initial speed of the bullet? (dummy answer 720 m/s) (4)

   (c) Give the initial and final kinetic energies. Is the collision elastic? (4)