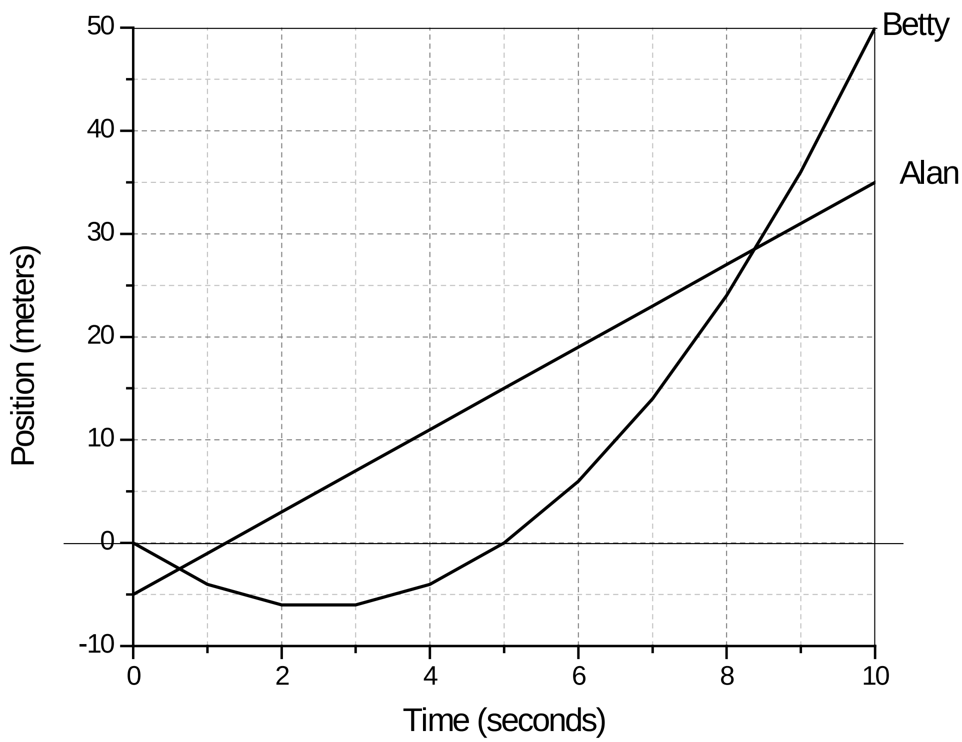
1. (*25 pts*) The plot below of position as a function of time describes the motion of two physics students, Alan and Betty, for 10 seconds from the moment a stopwatch is started at time t = 0. The plot for Alan is a straight line while the plot for Betty is parabolic. (*It's drawn as a series of straight line segments below but assume it truly is smooth and parabolic*.)

   Use this plot to <u>estimate</u>* the answers to each of the following questions. (**only very rough estimates are needed but provide enough work so that the grader understands the basis of your estimates.*)



   A. What is Betty's net displacement during this 10 second interval?

   B. What is Alan's average velocity?

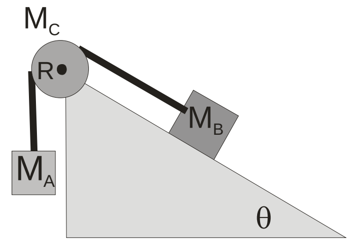
   C. Do Alan and Betty ever have the same velocity? If the answer is yes, when does this happen and how can you tell by eye without doing any calculations?

   D. Do Alan or Betty move with a negative velocity over any part of this interval? If the answer is yes, provide the time interval(s) over which this happens.

   E. Are either Alan or Betty standing still at any time? If the answer is yes provide the time(s) when this happens.

   F. What is Betty's average acceleration over the time period in this plot? *Remember that an approximate answer is fine, but show your work clearly,*

2. (*30 pts*) Two blocks, of mass M_A and M_B respectively, are positioned as shown in the figure. The rope joining them is ideal (*massless*) and runs over a pulley of radius R which has no friction but does have mass M_C; this mass is distributed uniformly over the disk-like shape of the pulley. Block B is traveling up the incline, accelerating at a magnitude *a* as it goes. The incline makes an angle θ with horizontal and the coefficient of kinetic friction between block B and the incline is μ_k.



A. Without doing any calculations, determine whether the tension on the left side of the pulley, T_L, is greater than, less than, or equal to the tension on the right side of the pulley, T_R. Explain how you know this.

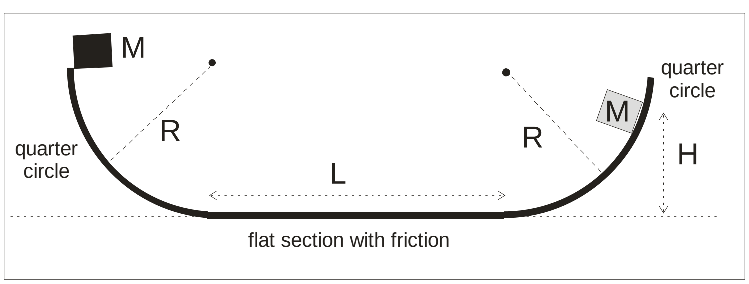
B. Draw free-body diagrams that show all the external forces acting on masses M_A, M_B and M_C.

C. Write the equations of motion (*based on $F = ma$ or $\tau = I\alpha$*) that are associated with each of the three masses. Choose the positive direction for each to correspond to the direction of motion of block B.

D. Simplify your equations as much as practical (*you should end up with 3 equations for 3 unknowns; a, T_L and T_R*) and solve for the acceleration *a* of M_A in terms of the masses and other values you are given (*the three masses, R, g, μ_k and θ*). (*NOTE: Since this test focuses on your knowledge of physics rather than your skills at algebra, the algebraic solution will not be heavily weighted when this problem is graded.*)

E. Test that your answer for part D gives reasonable results in the situations where θ approaches 90° or where M_A is much greater than the other two masses (*independent of θ*).

3. (*10 pts*) The track in the figure below consists of two frictionless, quarter-circle sections of radius R connected by a flat section of length L. This flat section has coefficients of static and kinetic friction μ_s and μ_k respectively. A block of mass M is released from rest at the top of the left side and makes it up a height H (*measured vertically from the flat surface*) on the right side before coming momentarily to rest and sliding back down again. Solve for H in terms of R, L, M, μ_s, μ_k and the acceleration of gravity g. (*You might not need all of these factors in your answer.*)



4. (*25 pts*) A solid disk of mass M and radius R is at rest at the bottom of an incline of length L (*measured along the surface of the incline*) and angle θ above horizontal. You want to give the disk a quick push, a short impulse that lets it reach the top of the hill without any additional assistance along the way, stopping just at the top of the incline.

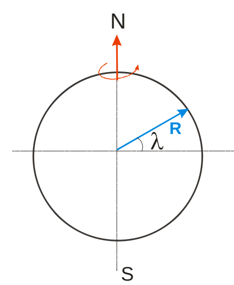
   A. If you set the disk down on one of its faces so that it can't roll and you spray that face with Teflon to eliminate friction, what initial velocity does the disk need in order to slide just to the top of the hill?

   B. What is the magnitude of the impulse J that you need to give the disk?

   C. If the Teflon coating isn't perfect and there's a coefficient of kinetic friction μ_k between the face of the disc and the hill, what initial velocity does the disk need at the bottom in order to make it just to the top of the hill?

   D. If you stand the disk up on its edge so that it can roll without slipping, what translational velocity does the disk need to have at the bottom of the hill so that it can roll all the way to the top, stopping just as it reaches the top?

5. (*15 pts*) The earth is spinning about its axis with a period T (*T = 1 day*) as you take this exam. Answer each of the following questions in terms of your latitude λ (*Cleveland's angle from the equator*), the radius of the earth R_E and T.

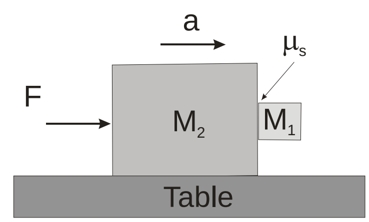


   A. What is your centripetal acceleration (*magnitude* ***and*** *direction*)?

   B. What is your angular acceleration $\alpha = d\omega/dt$?

   C. What is your tangential velocity v?

6. (*20 pts*) The block of mass M_2 in the figure on the right is supported by a frictionless table. A horizontal force F is applied to the left side of this block and, as a result, M_2 is accelerating towards the right. A smaller block of mass M_1 is held vertically stationary against the opposite face of block M_2 only by the force of static friction between the blocks. How large must F be to keep M_1 from falling? The coefficient of static friction between the blocks is μ_s. (*HINT: Work this problem systematically, starting with a FBD for the entire 2 block system. What can you learn from this? Then consider the FBD for M_1 alone. You should find that the solution to this problem is rather simple and it's not even necessary to consider M_2 alone!*)

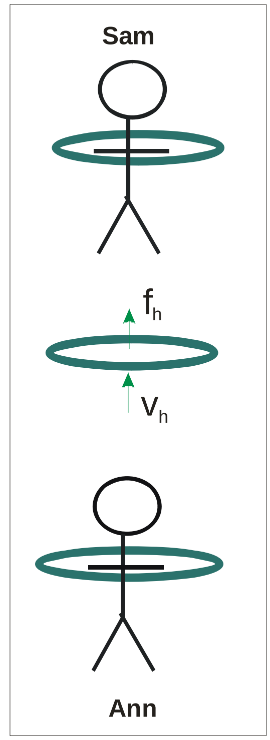


7. (*5 pts*) A particle of mass M = 10 kg sitting at rest in deep space at x = 0 suddenly explodes into two pieces, one of mass 6 kg that travels to the right at speed v = 2 m/s and the other of mass 4 kg that travels to the left.

   A. Where is the center of mass of this system t = 5 seconds later?

   B. How fast is the smaller piece traveling after the explosion?

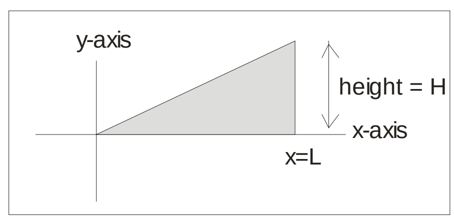
8. (*20 pts*) Ann, Sam and you are in deep space where you don't feel the effects of gravity. You are watching from a viewport of your space station when Sam and Ann go outside for a (*space*) walk, taking along a (*hula*) hoop that has a radius R and a mass M_H. You observe both Sam and Ann motionless in space a distance D apart and oriented in the same direction as each other, parallel head to toe along a line joining their centers of mass. Ann is holding the hula hoop motionless, centered on her body, but decides to throw it 'up' to Sam, giving the hula hoop a spin about its axis in the process. You observe the hula hoop moving between Ann and Sam with a translational speed v_H (*in meters/sec*) and spin of frequency f_H (*in revolutions per second*). Sam catches the hula hoop and holds it as shown. Sam has a mass M_S and a moment of inertia about his axis I_S. Ann has a mass M_A and a moment of inertia about her axis of I_A.



After Sam catches the hula hoop, you see both Sam and Anne spinning and moving away from each other. Calculate their translational velocities v_A and v_S and the frequencies f_S and f_A at which they are spinning in terms of quantities given in the paragraph above (M_A, M_S, M_H, I_A, Is, R, f_H and v_H).

9. (*10 pts*) A certain point on a guitar string executes Simple Harmonic Motion with a frequency of 440 Hz and amplitude 1.2 mm = 0.0012 m. What is the maximum speed of this point during its motion and at what phase of the motion does it occur (*does it happen at its maximum displacement, when it is at its equilibrium position or somewhere else*)?

10. (*20 pts*) A flat triangle with sides of length L and H is positioned at the origin of an *x*-y coordinate system as shown in the figure to the right. The triangle has a mass M. Calculate the x-component of its center of mass, CM. (*You are not asked to calculate the y-component of the CM.*) Following the steps suggested below should help you earn at least partial credit.



- Make a drawing in your blue book that shows how you plan to break the triangle into infinitesimal pieces of mass *dm* or area *da* for use in calculating x_{CM} .
- What is the mass *dm* of your piece in terms of *y, dy, x, dx*, L & H? (*You might not need all of these quantities to solve this problem.*)
- Write the contribution to the center of mass, dx, due to your small piece of mass.
- Write out the integral, including the limits of integration, that you need to evaluate for this particular problem in order to calculate x_{CM}.
- Evaluate the integral and check that your answer makes sense in terms of units and value. (*What are the appropriate dimensions or units for x_{CM}. If you had to guess where x_{CM} might be, what would you say and is your answer in the ballpark?*)