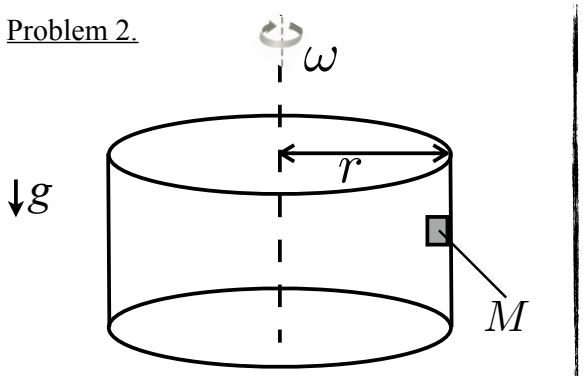
1. [13 pts.] Use dimensional analysis to **determine the exponents** b**,** c**, and** d in this formula for the force of light scattering off of an atom:

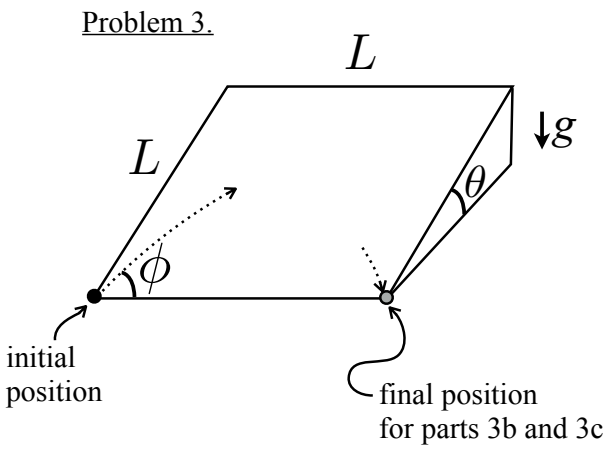
$$F = h^b A^c L^d$$

where F is the force, h is Planck's constant (units kg m^2/s), A is the photon scattering rate (units 1/s) and L is the wavelength (units of length). Show your work.

---

2. [12 pts.] Consider a cylinder turning at constant rate, with inner radius $r = 2.9\,\text{m}$. If spinning fast enough, friction can pin objects to the inside of the cylinder, overcoming gravity. What is the **maximum period** T **of revolution** for which which a block of mass M turns with the cylinder, and does not slide downwards? Assume that $\mu_S = 0.40$ between the block and the cylinder, that the block starts at rest with respect to the cylinder, and that the size and shape of the block are unimportant.





3. [27 pts.] Consider the trajectory of a particle sliding (without friction) on a tilted square board, whose size is L times L. The lower edge of the board is on level ground, but the rest of the board is tilted at angle θ with respect to the ground. (SEE FIGURE ABOVE.) The particle starts at the lower left corner, with speed v_0 and angle ϕ with respect to the lower edge. Use $L = 4.0\,\text{m}$ and $\theta = 30^\circ = \pi/6.0$.

   (a) [15 pts.] What is the **longest time** that the particle can stay on the board? **Explain** your logic.

   (b) [12 pts.] **What speed** v_0 gives a trajectory that has its final position at the lower right corner of the board? Give an expression for v_0 **as a function of** ϕ.

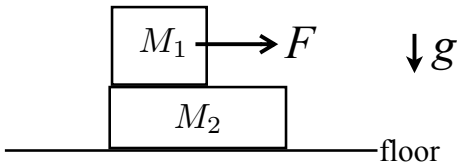
4. [21 pts.] Two stacked blocks, have mass M_1 and M_2. There is friction (with coefficients μ_S and μ_K) between the blocks, but no friction with the floor below. The two blocks are accelerated from rest by a force F on the upper block. Answer each of the following questions with a simplified expression in terms of F, g, M_1, M_2, μ_K, and μ_S, as needed.

   (a) [6 pts.] For small enough F, the two blocks have the same acceleration. **What is their acceleration**?

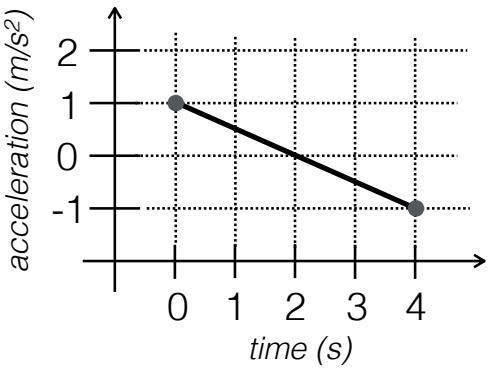
   (b) [10 pts.] What is the **maximum** F for the two blocks to move **together**?

   (c) [5 pts.] Now consider a stronger F, so that the blocks do not accelerate at the same rate. What is the **acceleration of the upper block** ?

Problem 4.



Problem 5.



5. [27 pts.] The acceleration of a particle in 1D motion changes linearly between $t = 0.0\,\text{s}$ to $t = 4.0\,\text{s}$, as shown in the figure above. Assume that the particle started at rest.

   (a) [4 pts.] What was the **average acceleration** between 0.0 s and 4.0 s ?

   (b) [5 pts.] What is the **maximum velocity**, and **when** does it occur?

   (c) [5 pts.] **Plot the velocity versus time**, in a style similar to the figure above: label axes, give numerical values for minimum and maximum velocity. Pay attention the slope of the line you draw.

   (d) [7 pts.] Give an equation for **displacement versus time** t. (Assume t is within the range of 0.0 s to 4.0 s)

   (e) [6 pts.] What was the **average velocity** between 0.0 s and 4.0 s ?

---

6. [Bonus 4 pts.] In question 3, show that the trajectory that combines conditions (a) and (b) has a ϕ that does **not** depend on the values of L, θ, g, or v_0, and explain why.

END OF EXAM.