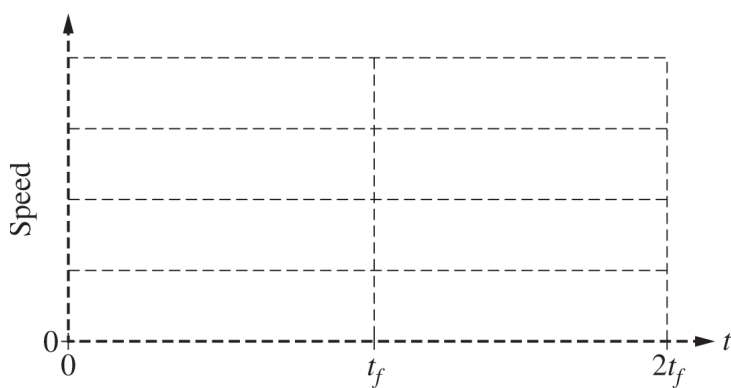


3. (12 points, suggested time 25 minutes)

(a) A student of mass M_S , standing on a smooth surface, uses a stick to push a disk of mass M_D . The student exerts a constant horizontal force of magnitude F_H over the time interval from time $t = 0$ to $t = t_f$ while pushing the disk. Assume there is negligible friction between the disk and the surface.

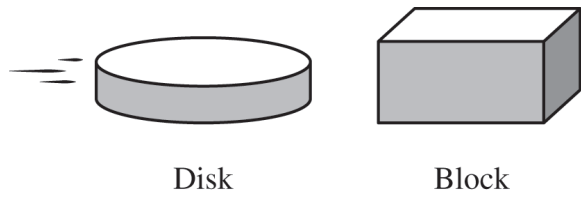
- i. Assuming the disk begins at rest, determine an expression for the final speed v_D of the disk relative to the surface. Express your answer in terms of F_H , t_f , M_S , M_D , and physical constants, as appropriate.
- ii. Assume there is negligible friction between the student's shoes and the surface. After time t_f , the student slides with speed v_S . Derive an equation for the ratio v_D / v_S . Express your answer in terms of M_S , M_D , and physical constants, as appropriate.

(b) Assume that the student's mass is greater than that of the disk ($M_S > M_D$). On the grid below, sketch graphs of the speeds of both the student and the disk as functions of time t between $t = 0$ and $t = 2t_f$. Assume that neither the disk nor the student collides with anything after $t = t_f$. On the vertical axis, label v_D and v_S . Label the graphs "S" and "D" for the student and the disk, respectively.



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(c) The disk is now moving at a constant speed v_1 on the surface toward a block of mass M_B , which is at rest on the surface, as shown above. The disk and block collide head-on and stick together, and the center of mass of the disk-block system moves with speed v_{cm} .

- i. Suppose the mass of the disk is much greater than the mass of the block. Estimate the velocity of the center of mass of the disk-block system. Explain how you arrived at your prediction without deriving it mathematically.
- ii. Suppose the mass of the disk is much less than the mass of the block. Estimate the velocity of the center of mass of the disk-block system. Explain how you arrived at your prediction without deriving it mathematically.
- iii. Now suppose that neither object's mass is much greater than the other but that they are not necessarily equal. Derive an equation for v_{cm} . Express your answer in terms of v_1 , M_D , M_B , and physical constants, as appropriate.
- iv. Consider the scenario from part (c)(i), where the mass of the disk was much greater than the mass of the block. Does your equation for v_{cm} from part (c)(iii) agree with your reasoning from part (c)(i) ?
- _____ Yes _____ No
- Explain your reasoning by addressing why, according to your equation, v_{cm} becomes (or approaches) a certain value when M_D is much greater than M_B .

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