Midterm for General Physics A I
Date: Nov 9, 2010

(1) Please do not flip the sheet until instructed.
(2) Please try to be as neat as possible so that I can understand your answers without ambiguity.
(3) While it is certainly your rights to make wild guesses or memorize irrelevant details, I would truly appreciate if you try to make your answers logical.
(4) Good luck for all hard-working students!

Lecturer: Hsiu-Hau Lin

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1. Time dilation (20%) (A) From the constancy of speed of light, the method to build a "light clock" was explained in class. In the view of a stationary observer O, the clock is moving at a constant velocity v, while the clock is at rest for another observer O' moving with it. Derive the formula for time dilation for a moving clock. (B) Choose two appropriate point events and use Lorentz transform,

$$x' = \gamma(x - vt), \quad y' = y, \quad z' = z, \quad t' = \gamma(t - vx/c^2),$$

where $\gamma = 1/\sqrt{1-(v/c)^2}$, to derive the same formula for time dilation.

2. Degrees of freedom in a dynamical system (20%) Two blocks are connected together by a light string of fixed length L as shown in Fig. 1. The blocks start to move from rest and the hanging block m_2 stops without bouncing when hitting ground. (A) Explain in details what the active degrees of freedom for the dynamical system are. (B) What is the shortest L so that it does not go taut while m_1 is in flight?

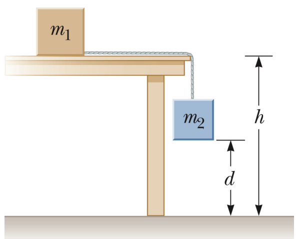

FIG. 1: Connected blocks.

3. Falling sand on the moving belt (20%) Sand from a moving hopper falls onto a moving belt as shown in Fig. 2. Supposed the mass of each sand grain is m and the falling rate for the sand grains is γ. (A) Find the external force F_{ext} so that the belt can move at constant velocity. (B) Compute the percentage of the work done by the external force transferred to the sand grains and explain why internal forces can cause energy loss.

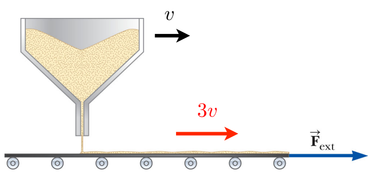

FIG. 2: Connected blocks.

4. Collision involving rotation (20%) In Fig. 3, a disk strikes the end point of a stick on the frictionless surface. The impact forces are along the horizontal direction and no energy loss occurs during the collision. (A) List and explain all conserved quantities. (B) The kinetic energy of the stick after collision contains $K_{\text{c.m.}}$ from the linear motion of the center-of-mass and K_r from rotation around it. Given the moment of inertia $I = (1/12)Mr^2$ for the stick, find the ratio between $K_{\text{c.m.}}$ and K_r.

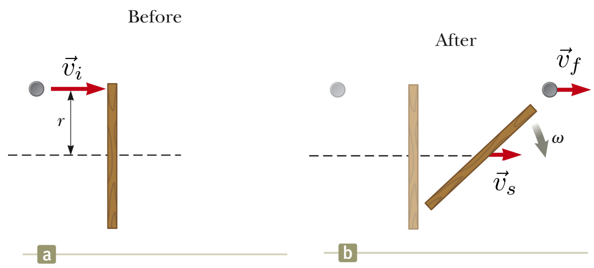

FIG. 3: Hit and rotate.

5. Energy of many-particle system (20%) (A) For a many-particle system, derive the following relation between different energies from Netwon's second law,

$$W_{\text{nc}} = \Delta\left(\frac{1}{2}Mv_{\text{c.m.}}^2 + U + E_{\text{in}}\right),$$

where W_{nc} is the work done by non-conservative force, U is the potential energy of the system and E_{in} is the internal energy. (B) In a baseball game, when the pitcher throws a curved ball to the catcher, describe all energy terms you can find during the pitch-catch process.

6. Tension on a rotating rod (Bonus 20%) For a falling rod (shown in Fig. 4), find out the tension $T(x)$ on the rod at different positions and explain why the acceleration at the end $a = 3g/2$ is larger than free fall.

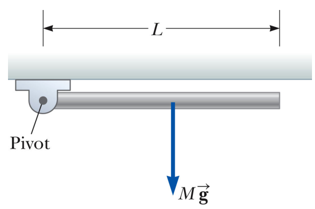

FIG. 4: A rotating rod.