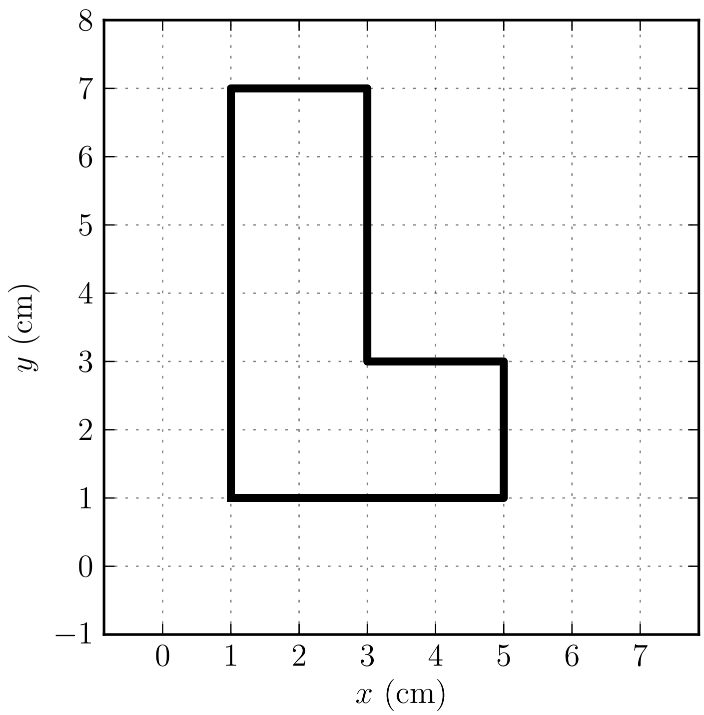
NYU General Physics 1—Problem set 7

Problem 1: The diagram shows a flat object cut out of a thick sheet of aluminum of constant thickness, so it has the same mass per unit area everywhere.



Find the position of the center of mass of this object, in the given coordinate system; that is, give the coordinates $(x_{\mathrm{cm}}, y_{\mathrm{cm}})$ of the center of mass. If you want practice, think up four qualitatively different ways of doing the center-of-mass calculation.

Problem 2: A New York City Bus moving down Broadway at $15\,\mathrm{m\,s^{-1}}$ hits a small elastic rubber ball, which has happens to be very close to at rest just before the collision. The bus has a mass of $2 \times 10^4\,\mathrm{kg}$ and the ball has a mass of $0.02\,\mathrm{kg}$.

(a) Draw a diagram showing the bus and the ball and their velocities, immediately *prior* to the collision. Compute the kinetic energies and the momenta of the bus and the ball. For the momenta, you will have to choose

a direction for your coordinate system.

(b) Draw the same diagram, but now from the point of view of the driver of the truck next to the bus, who is driving at the exact same speed. That is, draw the diagram in the "reference frame" in which the bus is at rest before the collision. In this frame, the bus is stationary and the ball is moving. Again, compute the kinetic energies and momenta. Why are they different from what you got in part *(a)*? Aren't energy and momentum conserved?

(c) Staying in this new reference frame, imagine now how the ball bounces off the bus. The collision will be elastic, but you don't really have to calculate anything: What happens when a tiny ball bounces elastically off a huge bus? Draw a diagram showing the bus and the ball and their velocities, in the frame of the bus, immediately *after* the collision. Compute the kinetic energies and momenta.

(d) If you made a certain vere useful approximation, then you probably didn't conserve momentum in part *(c)*. Why not? In detail, the velocity of the bus is affected by the collision. By how much does the velocity of the bus change, approximately, in the collision? If you *did* conserve momentum in part *(c)*, then just report here the change in velocity of the bus.

(e) Now take what you had in part *(c)* and re-draw it back in the original reference frame, which is that of the stores on Broadway. Compute the kinetic energies and momenta. How fast is the rubber ball moving after the collision? Don't try the experiment.

(f) After the collision, the ball is moving fast, but its mass is much smaller than that of the bus. At the end of the problem, what fraction of the total system momentum and kinetic energy are in the ball?

Problem 3: A student of mass $m_{\text{student}} = 80\,\text{kg}$ stands at rest next to a block of ice of mass $m_{\text{ice}} = 320\,\text{kg}$, also at rest, on a frictionless frozen lake. The student pushes on the block until the block is moving away from the student at $1.5\,\text{m}\,\text{s}^{-1}$ (that is, until $|\vec{v}_{\text{ice}} - \vec{v}_{\text{student}}| = 1.5\,\text{m}\,\text{s}^{-1}$). How much work did the student do? Give your answer in J. Don't forget to conserve momentum! *Hint:* All that work went into kinetic energy. *Another hint:* One of the hard things about this problem is that I am giving you the *relative* velocity and not the absolute velocity. How are you going to deal with that? Spend some time visualizing the problem before writing equations.