- worksheet: `positron.hep.upenn.edu/p8/files/ws08.pdf`
- 2 short calculations, 5 short conceptual force Q's
- Before Monday's class meeting, either finish skimming Mazur ch08 or watch my ch08 (part two of two) video.
- Today: Newton's 3rd and 2nd laws:

$$\vec{F}_{\mathrm{by\,1\,on\,2}} = -\vec{F}_{\mathrm{by\,2\,on\,1}}$$

$$\vec{a}_{\mathrm{object\,B}} = \frac{1}{m_B} \sum \vec{F}_{\mathrm{on\,B}}$$

Free-body diagram **for object B** is a helpful way to keep track of the forces acting **on object B**, as a check that you are correctly writing Newton's 2nd law for **object B**.

Two administrative questions to ponder!

- **Do we want occasional quizzes?**
- Three reasons you might say yes are: (a) if you are especially concerned about the "free rider" problem, or (b) if you want a stronger incentive to be sure you understand what you are writing down on your worksheets, or perhaps more cynically (c) if you feel that quizzes give you an advantage, or (d) to give me feedback on where I should spend my time in class.
- **Do we want a traditional final exam?**
- Two reasons you might say yes are: (a) it is simpler to schedule than the alternative, which is small-group chalkboard presentations of problem solving, and (b) if you plan to ace the exam and you want me to be able to quantify in a letter of recommendation how much you distinguished yourself on the final exam.
- Ponder, discuss among yourselves, and we'll vote.
- `pollev.com/billashmanskas261` (QR code next slide.)

Does pollev.com/billashmanskas261 work for you?

For the following few slides:

- ALPHA = yes
- BETA = maybe / difficult to say
- CHARLIE = no
- DELTA = ChatGPT?!

Did this person watch the train segment of my video?

When the driver of the engine decides to make the train go forward, the frictional force of the track on the engine causes the CoM of the train as a whole to accelerate forward.

Did this person watch the train segment of my video?

In order to accelerate a system, we need a force external to the system. The frictional force forward exerted by the track on the engine is what allows the engine-car system to move forward.

Did this person watch the train segment of my video?

The forces on the engine are the contact force of the wagons on the engine, which pull the engine back and the force from the friction on the engine that allows the engine to accelerate forward. For the wagons, they experience the contact force of friction from the tracks on the wagons and contact force from the engine on the wagons, which is stronger and accelerates forward. Because internal forces do not accelerate the center of mass of the system, they cancel out in a free-body diagram for the system. This means that the system as a whole is only affected by the friction on the wagon going backward and the friction on the engine pulling the train forward and allowing it to accelerate.

Did this person watch the train segment of my video?

The locomotive's force on the cars is as strong as the force of the cars on the locomotive, but the frictional force by the track on the locomotive is forward and large, while the backward frictional force by the track on the cars is small.

Did this person watch the train segment of my video?

Friction (between the locomotive's wheels and the track, mutually exerting force on one another) allows for the CoM of the system (locomotive + cars) to accelerate forward. Without friction, as demonstrated by Bill on a skateboard, the CoM remains the same while the locomotive and car move towards one another.

Did this person watch the train segment of my video?

The locomotive-car system of force is equivalent, so it is unable to move forward (interaction pair and internal forces of the system). But the external force of the track's friction allows them to accelerate forwards. This is because the locomotive has good friction (is in drive) whereas the cars do not have good friction (in neutral). In order for a system to move forward it requires an external force.

Did this person watch the train segment of my video?

The locomotive's engine generates a force through its engines and applies this force to the first train car. This force goes through the coupling mechanism connecting the locomotive to the first car. The force propels the first car forward. This force is then transmitted through the couplings to the next cars, causing a chain reaction where each car exerts a force on the next. Each train car will exert a force to the car in front of it until it reaches the locomotive. The locomotive will actually experience a backward force because of the reaction of the first car (equal and opposite reactions $\rightarrow$ 3rd law). Because of the way the locomotive is designed, the movement of the entire locomotive train is forward, and the CoM is also forward

Did this person watch the train segment of my video?

When the driver of a locomotive (engine) decides to make the train go forward or accelerate, the force responsible for causing the center of mass (CoM) of the entire train to accelerate forward is the tractive force. This tractive force is exerted by the locomotive's wheels on the train cars through the contact between the wheels and the rails. The locomotive's engines generate the power needed to turn its wheels, creating a forward force that is transmitted through the coupling mechanism to pull all the train cars. This force causes the entire train to accelerate forward as a whole.

Did this person watch the train segment of my video?

The force of the locomotive engine pulling a series of train cars forward. In this scenario, the force of the locomotive is greater in magnitude than the force of friction acting on the train wheels (in the opposite direction), allowing the locomotive to accelerate forwards.

1. You are climbing a rope straight up toward the ceiling. (a) What are the magnitude and direction of the force you must exert on the rope in order to accelerate upward at $1.05\,\mathrm{m/s^2}$, assuming your inertia (mass) is 65.0 kg? (b) If the maximum tension the rope can support (aka its tensile strength) is 1035 N, what is the maximum inertia (mass) the rope can support at this acceleration? Assume that the inertia (mass) of the rope is so small that the gravitational force on the rope itself can be ignored. [An ideal rope has negligible mass, does not stretch at all, and exerts a force of the same magnitude on whatever is connected to each of its two ends — a rope or cable basically just transmits a force from each end to the other. The magnitude of that force is called the **tension** in the rope.]

2. A 1700 kg truck and a 950 kg car are parked with their rear bumpers nearly touching each other in a level parking lot. Both vehicles have their brakes off so that they are free to roll. A woman sitting on the rear bumper of the truck exerts a constant horizontal force on the rear bumper of the car with her feet, and the car accelerates east at $1.5\,\mathrm{m/s^2}$. (a) What are the magnitude and acceleration of the center of mass of the car+truck system? (You can consider the woman to be part of the truck that she sits on, and consider her mass to be included in the stated mass of the truck. So think of the truck directly pushing on the car, or think of the woman as a massless spring placed between car and truck.) (b) What are the forces (magnitude and direction) exerted on each vehicle by the woman? [For this part, just consider the woman to be a intermediary, of negligible mass, who transmits the force between the car and the truck.] (c) What are the magnitude and direction of the acceleration of the truck? Ignore any friction between tires and parking lot surface.

(Chapter 8 conceptual questions. These questions require no calculations. Just think about them and write your answer as either (a) a sentence, or (b) a few words and a quick drawing — whichever is more appropriate for the problem. Very short answers are fine, as long as your reasoning is clear. You will probably learn a lot by discussing these questions with other students. To make grading easier, please try to make these answers as clear and succinct as possible.)

3. A worker pushes boxes in a factory. In each case decide which force has the greater magnitude — the force exerted by the worker on the box or the force exerted by the box on the worker. (a) The box is heavy and does not move no matter how hard she pushes. (b) Some contents are removed, and now when pushed the box slides across the floor at constant speed. (c) The worker pushes harder, and the box accelerates.

4. A pitcher has thrown a fastball toward home plate. (a) When the ball is halfway to the plate [ie about 10 meters away from both the pitcher and the catcher], does the ball still feel the pitcher's push? [In other words, is the pitcher still exerting a force on the ball?] Explain your answer. (b) What forces does the ball feel, if any, when it is halfway to home plate?

5. You push on a refrigerator, but it does not move. Explain how this can be. [One thing it helps to know about friction, which we will quantify in ch10: when a box is sitting at rest on the floor, if you give the box a gentle horizontal push, friction (exerted by the floor) will push on the box in the opposite direction, to prevent the box from starting to move. But there is a maximum value to the frictional force that the floor can exert on the box (which we'll quantify in ch10). If the required frictional force to prevent the box from sliding becomes too large, then friction will "lose its grip" and the magnitude of the frictional force will take on a smaller value while the box is sliding — that is, smaller than the maximum value at which friction "loses its grip."]

6. You push on a crate, and it starts to move but you don't. Draw a free-body diagram for you and one for the crate. Then use the diagrams and Newton's third law of motion to explain why the crate moves but you don't. [It may help to imagine that you are wearing rubber-soled shoes, while the bottom of the crate is wood or cardboard.]

7. When you are standing motionless on the ground, your feet are exerting a force on Earth. Why doesn't Earth move away from you?

8. The design strength of the couplings used in connecting railroad cars is determined by the maximum tension or compression that any coupling in a given train will likely feel. [Note: compression is similar to tension, but if a rope or a cable or a spring or a bar or a rod (or etc) is in tension, then its two ends are being pulled apart. If a spring or a bar or a rod is in compression, then its two ends are being pushed together. A rope or cable cannot support compression, only tension.] Assume that friction between the track and the railcars can be neglected (but of course friction between the track and the locomotive cannot be neglected). (a) If a locomotive is pulling three cars and speeding up, in which coupling is the force greatest? (b) Is this force a tension force or a compression force? (c) If the locomotive is slowing the three-car train down, which coupler feels the greatest force? (d) Is this force a tension force or a compression force? [Assume that the railcars are in neutral and have no brakes. Only the locomotive has brakes.]

Rubric: 4 points per problem: 2 for effort, 2 for correctness.

- 4 points = correct or very nearly correct
- 3 points = minor mistake
- 2 points = major mistake
- 1 point = you haven't convinced us that you put in much effort to try to solve the problem
- 0 points = nothing or very little of substance written down
- For some problems (such as today's hands-on bridge model), it may be unreasonable for us to look for "correctness," so instead all 4 points will be for effort.
- 4 additional overall points for presenting your work clearly, with adequate reasoning. So if n is the number of problems, the total points will usually be $4n + 4$.