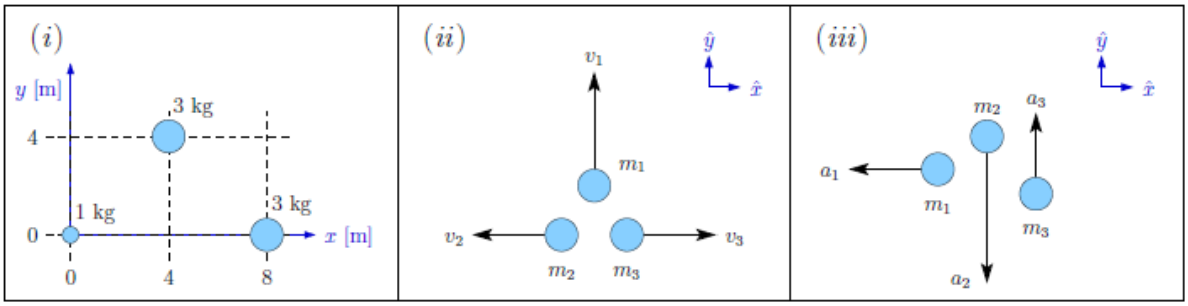
CENTER OF MASS, (CONSERVATION OF) MOMENTUM, & COLLISIONS

1. **Vectors:** For the systems shown, compute the x and y components of the center-of-mass (i) position, (ii) velocity, and (iii) acceleration.



2. **Steel Ball:** A steel ball with mass m is dropped from a height of H onto a horizontal steel slab. The ball rebounds to a height of h.
   (a) Calculate the impulse delivered to the ball during impact.
   (b) If the ball is in contact with the slab for δt, find the average force on the ball during impact.

3. **Railroad Handcar**: A railroad handcar is moving along straight, frictionless tracks with negligible air resistance. In the following cases, the car initially has a total mass (car and contents) M and is traveling east with a velocity of magnitude v. Find the final velocity of the car in each case, assuming that the handcar does not leave the tracks.
   (a) A $m = M/8$ mass is thrown sideways out of the car with a velocity of magnitude $0.4v$ relative to the car's initial velocity.
   (b) A m mass is thrown backward out of the car with a velocity of v relative to the initial motion of the car.
   (c) A m mass is thrown into the car with a velocity of $1.2\ v$ relative to the ground and opposite in direction to the initial velocity of the car.

4. **Space Walk**: In one scene, an astronaut's safety line is cut while on a space walk. The astronaut, who is 200 meters from the shuttle and not moving with respect to it, finds that the suit's thruster pack has also been damaged and no longer works and that only 4 minutes of air remains. To get back to the shuttle, the astronaut unstraps a 10 kg tool kit and throws it away with a speed of 8 m/s. In the script, the astronaut, who has a mass of 80 kg without the toolkit, survives, but is this correct?

5. **Vine Swing**: George attempts to save his friend, an ape named Ape, from a stampeding herd of wildebeests. Ape is at the base of a tall tree which has a vine attached to its top. George is in another tree holding the other end of the vine. George plans to swing down from the tree, grab Ape at the bottom of the swing, and continue up to safety on a ledge which is half of George's initial height in the tree. Assuming that Ape weighs the same as George, will they successfully make it to the top of the ledge?

6. **Blocks and Spring**: Two blocks, one with mass m and the other with mass $3m$, are forced together, compressing a spring between them; then the system is released from rest on a level, frictionless surface. The spring, which has negligible mass, is not fastened to either block and drops to the surface after it has expanded. The spring has a force constant of k and initially compressed Δx from its original length. For each block, what is
   (a) the acceleration just after the blocks are released;
   (b) the final speed after the blocks leave the spring?

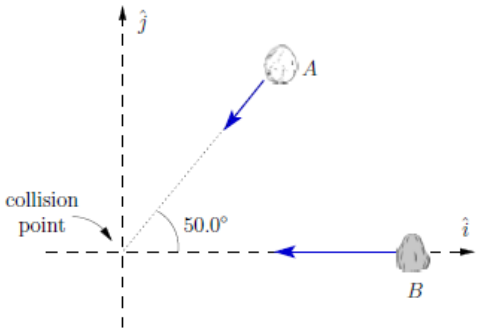
7. **Accident Analysis**: A m_1 sedan goes through a wide intersection traveling from north to south when it is hit by a m_2 SUV traveling from east to west. The two cars become enmeshed due to the impact and slide as one thereafter. On-the-scene measurements show that the coefficient of kinetic friction between the tires of these cars and the pavement is 0.75, and the cars slide to a halt at a point l_1 west and l_2 south of the impact point. How fast was each car traveling just before the collision?

8. **Frozen Lake**: You are standing on a concrete slab that in turn is resting on a frozen lake. Assume there is no friction between the slab and the ice. The slab has a weight five times your weight. If you begin walking forward at v relative to the ice, with what speed, relative to the ice, does the slab move?

9. **Exploding Shell**: A 7.0 kg shell at rest explodes into two fragments, one with a mass of 2.0 kg and the other with a mass of 5.0 kg. If the heavier fragment gains 100 J of kinetic energy from the explosion, how much kinetic energy does the lighter one gain?

10. **Fragments**: A shell of mass M is launched at an angle of 55.0° above the horizontal with an initial speed of v. At its highest point, the shell explodes into two fragments, one three times heavier than the other. The two fragments reach the ground at the same time. Ignore air resistance. If the heavier fragment lands back at the point from which the shell was launched, where will the lighter fragment land, and how much energy was released in the explosion?

11. **Two rocks:** Two flat rocks are sliding across the surface of a frozen lake and approach one another as shown in the figure. They move in such a way as to collide at the origin of the coordinate system shown. After the collision, rock A moves off along the $-\hat{\boldsymbol{\imath}}$ direction and rock B moves off along the $-\hat{\boldsymbol{\jmath}}$ direction. The rocks A and B have masses $4m$ and m respectively and initial kinetic energies K_A and $K_B = 9\,K_A$



   (a) What are the initial velocities (magnitude and direction, or $\hat{\boldsymbol{\imath}}$ and $\hat{\boldsymbol{\jmath}}$ components) of the two objects?
   (b) What is the initial momentum of the system of the two rocks?
   (c) Find the speeds of the two rocks after the collision.
   (d) Quantitatively determine whether this collision is elastic or inelastic.