Physics For Everyone

http://www.coloradocollege.edu/Dept/PC/RepresentativePhy/home.htm
Momentum Problems
August 1, 2002

Section 1. What is a System? What Counts as Isolated?

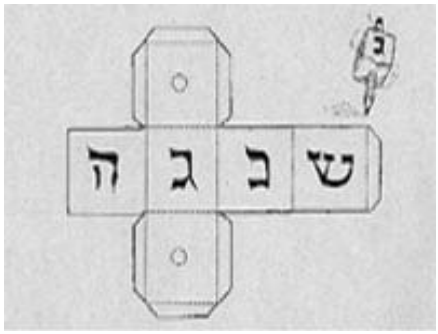
Momentum is conserved in the absence of external forces. Its usefulness as a concept depends on our ability to designate a "system" which is relatively isolated from its surroundings. In the following problems, explain what the system is, and describe its interactions with the external world. Describe the internal interactions during which momentum is (approximately) conserved. Sketch a diagram of the system before and after the interaction, labeling masses and velocities.

1.1 You and a bunch of friends circle around to play Hackey-Sack. Each of you takes care to pass and get equal time handling the hackey-sack. *

1.2

A grounds crew has put forth a good effort over the last few days, to help restore a historical landmark. Melissa picks up the last bag of ivy she has cleared, swings her arm back, and releases the bag. As it hits the deck of the flatbed truck it knocks into another bag of leaves, which jumps forward as a result of the interaction. *

1.3



It is the holiday season. Because the snow is falling outside so heavily, Rebecca and her family have decided to celebrate the first night of Chanukah with a game of Dreidel. The game is intense with competition between Rebecca and her little brother David, and when she wins his last chocolate coin he flicks it at her with a mock sigh of contempt. The coin slides straight across the table at a constant speed and collides with one of her gold coins of the same size. *

1.4 Akuvaaq steers his traditional skin covered umiak, jostling between the breaking ice of the ocean just off the coast of Point Barrow, Alaska. It is the end of June, a good time for hunting seal, and several of his Inupiat friends float alongside him in hopes of catching a meal. Suddenly, the glass surface of the water is shattered and they watch as their prey quickly surfaces the water.

Akuvaaq pulls his arm and then launches his spear at the seal. As he does so, his umiak slides backwards.**

1.5 While playing soccer in an irrigation ditch, Mia kicks the ball at a 30-degree angle against the side of the ditch that is angled at 45 degrees. **

1.6 It is November 15th, the day on which the Japanese celebrate Shichi-go-san, a holiday for the health and longevity of their young children. Mitsuko Kuwahara has dressed her three-year-old daughter Yumi in her most vibrant kimono and brought her to the Shinto shrine to receive the blessings of the Kami. First the mother rings the gong producing a long low chime. Then she sets little Yumi-chan on the ground. The child bows and then swings the rope to hit the gong, the gong recoils slightly, as it rings. **

1.7

Shaniqua and Kaesha are huddled over a small puddle. They are holding a palmful of gravel each and take turns dropping one stone at a time, marveling at the splash each stone creates. **

1.8

You and a group of friends are having a competition to see who can spit watermelon seeds the farthest. You simultaneously take a deep breath and with the seed pressed between your lips, send each out with a burst of lungpower. **

1.9 Juan and Mildred are sending their pet grasshopper down the river to explore. For its travels they have constructed a simple boat from a dried Oak leaf. They give the boat a tiny shove and watch as their tiny friend drifts down the river and then swirls in an eddy only to be caught on a twig. **

Section 2. Center of Mass

2.1 The Windmill*

Chelsea is practicing her break dancing moves for a "battle" that she will have with her next-door neighbor Arvi later in the afternoon. She has been working on the "windmill" move, in which she spins on her back and shoulders with her legs in the air, but she is having trouble keeping her turns tight about the axis of her shoulders and neck. In the language of physics, why might this be?

2.2 Native Pottery*

A Sioux Indian artist is hand crafting traditional clay pot alongside other Lakota artists at their plant in Rapid City, South Dakota. He molds the clay into a ball and drops it onto the spinning potter's wheel. The resulting shape of the clay is oblong, not round. What can we say about the distribution of mass when he dropped the clay onto the wheel?

2.3 Off to Work*

A mother who weighs 70 kg hugs her 10 kg child goodbye before she leaves for work in the morning and then hands the toddler to her husband who stays at home to watch the children and manage the house. If she is standing straight while holding the child out for her husband at what distance from her torso will their center of mass be?

2.4 Keep it in the Family*

Qinaluqana adjusts the belt around her waist that supports her 15-month-old niece who rests against her back. She wraps her light spring parka about them both and walks outside to join the rest of her Inupiat community as it helps to divide the rewards of a recent hunting expedition. Estimating heights and weights, where do you think the center of mass is located on this aunt-niece system?

2.5 Baby Shower**

A woman bends her knees and reaches across for a 15 lb sack of charcoal briquettes she is purchasing for her friend's BBQ baby shower. When she is stooped and holding the bag away from her body, where is the center of mass of the 'system'? Will she be able to balance in this position?

2.6 Baby Mobile**

Rheanna is using some of her old stuffed animals to make a mobile to hang over her baby sister’s crib. She has a teddy bear (15 g), a lamb (17 g), a puppy (21 g) and a seal (14 g). She also has 3 small dowels, each 15cm long with a mass of 4 g, and some thread of negligible mass. She wants to hang the bear and the puppy from the ends of one dowel, the seal and the lamb from the ends of the other, suspend each from the ends of the third dowel, and hang the whole thing from the ceiling. Explain where on each dowel the threads should be attached so the whole thing hangs level and looks nice.

Center of Mass Labs

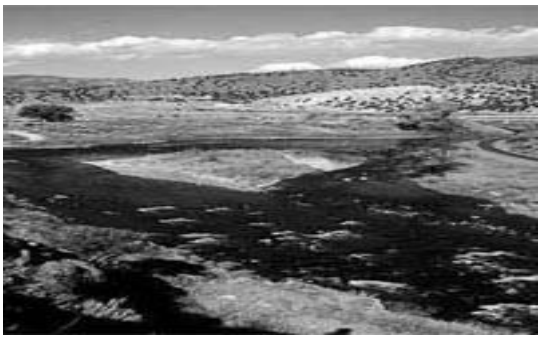
2.7 Long-boarding Lab

Imagine you and a friend are riding on a long-board with a mass of 9 kg and length of 1.3m. One of you will be standing on the back of the board pumping, while the other is sitting on the front of the board steering. Now back in the lab, measure your weights and with a board and a scale determine your centers of mass. Measure the board and label the middle with a mark. Place one end on the scale and the other on a block so it will be level. Lay flat along the board, adjusting your position until the scale reads half of your normal weight. The halfway mark on the board will be directly in line with your center of mass. Measure the displacement of the center of mass from the ground for both a standing and squatting person. Compare these displacements when added to the displacement of the longboard. Which one will make a tighter turn? Discuss.

Section 4. Momentum Transfer

4.1 Whitewater and Sunshine *

On a whitewater rafting trip down the Royal Gorge in Colorado, your boat, with a mass of 91 kg, is put into the Arkansas River where it runs relatively slowly, carrying the boat along at 0.7 m/s. Later, as the boat goes over Sunshine Rapids, it speeds up to 2.6 m/s. Compare the momentum of the boat at the beginning of the trip with the momentum of the boat at Sunshine Rapids. How much momentum does the water transfer to the boat when it goes over Sunshine Rapids? There are seven adult passengers on the boat.



4.2 Headwinds and Tailwinds *

On a still day on a straight, level road, a particular cyclist can travel at a constant speed of 25 mph. The next day she travels the same stretch of road with a headwind and travels at 19 mph. What is her momentum (in kg m/s) on the still day? How much of her momentum does she transfer to the air on the next day when there is a headwind? The bicyclist weighs 139 lbs and her bike weighs 53 lbs.

The day after that she has a tailwind and she discovers she can travel at 27 mph; how much momentum does the air transfer to her in these conditions?

4.3 Mae Jemison *

Mae Jemison is free floating in outer space to take pictures of the earth. She has become stranded while at rest 2.5 meters from her shuttle. Although she will be sorry to loose such beautiful photographs, she has determined that she must sacrifice her camera in order to return to her shuttle. Using her understanding of momentum conservation, Mae pushes the 525 gm camera away from her body and in the opposite direction of the shuttle, with a speed of 3.5 m/s. How long will it take her to reach the shuttle? (Assume Mae's mass to be 100 kg)

Section 5. Collisions (elasitic and inelastic)

5.1 Lunchtime*

Hana calls to her 25 lb. pup, Akasha, who comes racing toward the open door for her midday meal of Power Chow. She is hungry and has reached a speed of 2 m/s, but as she enters through the door she looses her footing and slides across the smooth wood floor which Hana has freshly swept. Hana watches hiding a smile as Akasha careens across the nearly frictionless surface straight toward the 1/2 lb. of dog chow at rest. The puppy collides with its lunch and continues to slide at a reduced speed of 1.94 m/s. Hana bursts into a fit of laughter as the dog chow shoots out across the floor. What is the velocity of the chow?

5.2 Cinco de Mayo*

The McCarty-Jimenez family has decided to open their pond for the season in celebration of Cinco de Mayo. Little Felicia and her twin brother Thomas are afloat atop an inner tube at rest in the middle of the pond. Their older sister is floating by at a constant speed of 0.5 ft/s. Felicia jumps from her tube to her sister's just as the two tubes touch. 1.5 seconds later, Thomas is 2.5 ft west of his initial position. Where will the girls' tube be? Assume that Selena has twice the mass of each twin, and the tubes have negligible mass.

5.3 Glacier Bay*

You and a friend are sea kayaking in the Icy Strait of Alaska. Before you row into Glacier Bay you want to have a discussion about your route around the outskirts of the bay. You, your kayak, and the gear in your kayak combined have a mass of 125 kg, and you row towards your friend at 28 mph west-northwest. Your friend is carrying slightly less gear in her kayak so her combined mass is 116 kg, and she's gliding through the water at 24 mph northwest. After you're close

enough to pull in and hold onto each other's kayaks, what is the direction of your two-kayak unit? What is your velocity?

5.4 Ski Buddies *

Jessie skis down a mountain and waits for her friend Maria at the bottom. Maria skis down the slope, spots Jessie and coasts over to her. Laughing, she mischievously aims at Jessie and an inelastic collision occurs, resulting in their combined masses moving in the same direction that Maria was traveling. If Jessie weighs 137 lbs with her skis and Maria weighs 145 lbs with hers, and they are now moving at 1.3 m/s, what was Maria's speed just before she got to Jessie?

5.5 Marbles *

You and your pal are eight years old and six years old, playing a game of marbles on the sidewalk. She shoots her lucky blue marble (30 g) at a speed of 0.5 m/s straight at a speckled yellow one (15 g). After the blue marble hits the yellow one it slows to a speed of 0.165 m/s. If the yellow marble is 0.7 m from the edge of the circle, and the concrete surface causes a marble to decelerate at 0.22 m/s per second, will the yellow marble leave the circle? *

5.6 Pups *

Two puppies, each about 4 kgs each, are running around outside, when suddenly one stops to watch a butterfly flit overhead. One puppy takes advantage of her companion's distraction to ambush him from the side at 2.1 m/s, and they roll sideways together.

What is the speed of their combined masses?

5.7 Wild Hearts Have Momentum**

In the movie *Wild Hearts Can't Be Broken,* Sonora, a determined diving girl, listens as a horse named Lightning trots up a ramp at a speed of about 17 mph. Near the top of the ramp, Sonora leaps from a standstill onto Lightning's back before he jumps off the top of the 40-ft-high ramp into the pool of water below. If Lightning weighs 1300 lbs and Sonora weighs 125 lbs, what is Lightning's momentum before Sonora leaps onto his back? If he continues at a speed of 17 mph after she jumps on, what is Sonora's change in momentum?

5.8 Trapeze *

Paolo and Maria are practicing their brother and sister trapeze act. Paolo (144 lbs) swings down off a platform. When he reaches the bottom of his swing, he is moving 15m/s. At that momentum, Maria (112ilbs), just at the top of her swing, transfers from her trapeze to his. What will be the velocity of Paolo's trapeze then?

5.9 Blading *

A 68 kg inline skater is coasting at a rate of 5 m/s along the sidewalk, when she sees a woman's handbag lying in her path. The woman is ahead of her on the sidewalk and so the skater decides to pick up the bag as she drifts by and then hand it to the woman. She bends down to scoop up the bag, but once she does, notices that the readout on her home-built roller-blade velocity-meter decreases to 4.9 m/s. What does this tell the skater about the approximate mass of the handbag? What will happen to the skater's velocity once she has handed the bag off to the woman (assuming she does so while coasting by)?

5.10 Photos*

Phoebe is printing photographs to give to her friends as graduation presents. She watches as the image of 3 smiling faces comes to life in the developer, and then moves the print to the stop bath. The paper enters the liquid with a speed of about 12 cm/s and collides with a smaller print that was initially at rest on the surface of the stop bath. The two prints stick together and skim across the top of the solution at a rate of 8 cm/s. What can be said about the size of the smaller print in relation to the larger one if we assume that the larger print weighs about 14 grams? Assume that both prints are made on resin-coated paper and so have absorbed no liquid and can travel without friction across the surfaces of the liquid baths.

5.11 Boarding*

You are out skateboarding when you approach a hill. You decide you would like to try and coast up the hill by getting all your momentum on level ground. So you place your board just before the foot of the hill, then you back up to get a running start. You acquire a sprint of 5.5 m/s just as you jump onto the board. If the board is 4.5 kg, what is the speed of you and your board just after you jump?

5.12 Cookies*

Your cousin, who appreciates cookies but doesn't particularly enjoy baking, buys frozen cookie dough that is already formed into round balls. She spills them onto the counter as she attempts to put them on the baking sheet and they spill in all directions. If one ball with mass 2m sliding 60 degrees north of east at 15 cm/s and another ball with mass m sliding 30 degrees west of south at 30 cm/s collide

and stick together, what is their joint velocity (magnitude and direction) after the collision?

5.13 USA Basketball*

Players from the National Wheelchair Basketball Association are doing their strengthening exercises with a 15 lb medicine ball. Jana Stump from the USA team is coasting with a speed of 3 m/s down the court when she catches the medicine ball, which was dropped to her from above. Jana Stump's combined mass with the ball and chair is 85 kg. Determine Jana's new velocity.

5.14 Mosaics**

Anita is in her school art studio. She wants to make a mosaic resembling a famous mosaic of the Basilica for her ceramic assignment. She stands next to the table with her outline on it, and begins to break tiles to gather the pieces to make her mosaic. She drops a tile on the floor; it breaks into three pieces of equal mass, and notices that two pieces seem to travel at the same speed in a 90-degree angle. The third piece disappears under the table. How can Anita calculate how fast and in what direction the third piece went, without looking under the table?

5.15 Falcon and Sparrow**

A peregrine falcon is soaring on the thermals along the Front Range, looking for supper. She spots a sparrow flying horizontally along below her at 10m/s, folds her wings, and dives. When she hits the sparrow, she is moving vertically at 30m/s. If the falcon's mass is 3kg and the sparrow's is 50g, what will be their velocity after the hawk strikes the sparrow?