Practice Exam 2 for Physics 205/210 — Light and Matter, ch. 0–6

1 Jill runs off a cliff at 4 m/s and dives into the ocean. At 300 ms after she leaves the cliff, her friend takes a picture of her in the air. Find Jill's speed (the magnitude of her velocity) at this time.

2 One of Sam's coping mechanisms is to leave a $20 bill inside his dictionary, on the page with the word "emergency." That way if he ever realizes there's no booze in the house, he has enough money to go buy a bottle of vodka. The dictionary is upright on the shelf. Analyze the forces in which the $20 bill participates.

Copy the following table header onto your paper.

force acting on $20 bill			equal and opposite force involved in Newton's 3rd law		
type of force	object exerting the force	direction	type of force	object exerting the force	direction

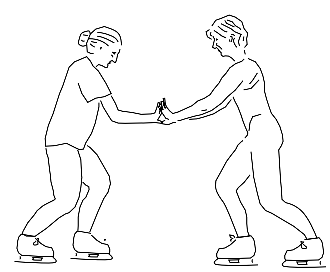
3 (a) A baseball player is sliding in to home plate. For the sake of visualization, let's imagine the view from the point of view of the first-base player, so that the runner is sliding to the left. Analyze the forces acting on the player who is sliding.

Copy the following table header onto your paper.

force acting on player			equal and opposite force involved in Newton's 3rd law		
type of force	object exerting the force	direction	type of force	object exerting the force	direction

(b) If the player starts to slide with a certain velocity, they will slide a certain distance. Show that this distance does not depend on the player's mass.

4 The figure shows skaters with masses m_1 and m_2. They push off from each other with a constant force F, which lasts until they lose contact. The distance between their centers of mass is ℓ_0 initially and ℓ_f when they lose contact. (a) Find the amount of time T for which they remain in contact. (b) Show that your answer in part a has units that make sense. (c) Show that your answer has the right dependence on F. (d) Interpret the case where one of the masses is very small.



Question 4

Answer to problem 1

The horizontal and vertical motions are independent. Let positive x be to the right and positive y down. There are no forces in the horizontal direction, so her horizontal velocity is constant, $v_x = 4$ m/s. In the vertical direction, she has a constant acceleration g, which we can approximate as 10 m/s^2 since this is a one-sig-fig problem. We have $g = \Delta v_y/\Delta t$, so at the given time, $v_y = 3$ m/s. Her speed is $|\mathbf{v}| = \sqrt{v_x^2 + v_y^2} = 5$ m/s.

Answer to problem 2

force acting on \$20 bill			*equal and opposite force involved in Newton's 3rd law*		
type of force	*direction*	*object exerting the force*	*type*	*direction*	*object exerting it*
gravity	down	earth	gravity	up	\$20 bill
normal	left	page n of dictionary	normal	right	\$20 bill
normal	right	page $n+1$ of dictionary	normal	left	\$20 bill
static friction	up	page n of dictionary	static friction	down	\$20 bill
static friction	up	page $n+1$ of dictionary	static friction	down	\$20 bill

Answer to problem 3

(a)

force acting on player			*equal and opposite force involved in Newton's 3rd law*		
type of force	*direction*	*object exerting the force*	*type*	*direction*	*object exerting it*
gravity	down	earth	gravity	up	player
normal	up	dirt	normal	down	player
kinetic friction	right	dirt	kinetic friction	left	player

(b) Let positive x be to the right and positive y up. The player is not sinking into the dirt or flying up in the air. Their center of mass may be dropping a little during the motion, but that's too complicated to describe in our model, so let's just say that $a_y = 0$. Then by Newton's second law, the two vertical forces in the table above must cancel out: $-mg + F_N = 0$. Therefore $F_N = mg$. The kinetic friction force is then $F_k = \mu_k F_N = \mu_k mg$. Applying Newton's second law in the horizontal direction, we find that the player's horizontal deceleration is $a = F_k/m = \mu_k g$, which is independent of m. Therefore the player's motion is independent of their mass, as claimed.

Answer to problem 4

(a) By Newton's third law, the forces are F and $-F$. Pick a coordinate system in which skater 1 moves in the negative x direction due to a force $-F$. Since the forces are constant, the accelerations are also constant, and the distances moved by their centers of mass are $\Delta x_1 = (1/2)a_1 T^2$ and $\Delta x_2 = (1/2)a_2 T^2$. The accelerations are $a_1 = -F/m_1$ and $a_2 = F/m_2$. We then have

$$\begin{aligned} \ell_f - \ell_0 &= \Delta x_2 - \Delta x_1 \\ &= \frac{1}{2} F \left(\frac{1}{m_1} + \frac{1}{m_2} \right) T^2, \end{aligned}$$

resulting in

$$T = \sqrt{\frac{2(\ell_f - \ell_0)}{F\left(\frac{1}{m_1} + \frac{1}{m_2}\right)}}$$

(b)

$$\sqrt{\frac{\mathrm{m}}{\mathrm{N/kg}}} = \sqrt{\frac{\mathrm{m}}{\mathrm{kg \cdot ms^{-2} kg^{-1}}}} = \mathrm{s}$$

(c) If the force is bigger, we expect physically that they will reach arm's length more quickly. Mathematically, a bigger F on the bottom results in a smaller T.
(d) If one of the masses is very small, then $1/m_1 + 1/m_2$ gets very big, and T gets very small. This makes sense physically. If you flick a flea off of yourself, contact is broken very quickly.