

**Physics 100: Homework 2 Solutions:** Chapters 4 and 5, due Sep 18

- 1) Consider if, Galileo dropped two balls from the top of the Leaning Tower of Pisa, air resistance was not really negligible. Assuming both balls were the same size, one made of wood and one of metal, which ball struck the ground first?

The metal ball. This is because the heavier ball accelerates for longer, reaching its terminal speed later, than the lighter ball. Why? Because air resistance depends on both the size of the object (same for the wooden and metal balls) as well as their speed. The balls begin to fall together, experiencing in the first few instants, the same upward air resistance force  $R$ . The net force on each ball is  $mg - R$ , where  $m$  is the mass of the ball, and points downward. Because of the increasing speed, the  $R$  increases, to the point at which  $R = mg$ , when there is no longer a net downward force on the ball, at which point onward, the ball goes at constant speed (terminal velocity). Since  $m$  is larger for the metal ball than the wooden one,  $R=mg$  happens later for the metal ball than the wooden ball, hence the metal ball accelerates for longer, ends up with a faster terminal speed, and strikes the ground first.

- 2) A firefighter of mass 80kg slides down a vertical pole with an acceleration of  $4 \text{ m/s}^2$ . What is the friction force that acts on the firefighter?

Newton's second law says  $a = F_{\text{net}}/m$ . In this case there are two forces acting on the firefighter: the downward gravitational force of  $mg = 80\text{kg} \times 10\text{N/kg} = 800 \text{ N}$ , and the upward-directed friction force that we have to find. So:

$$a = F_{\text{net}}/m \rightarrow 4 \text{ m/s}^2 = (mg - f)/m = 10 - f/80 \rightarrow f = (10-4)*80 = 480 \text{ N}$$

- 3) You push a heavy car by hand. The car, in turn, pushes back with an opposite but equal force. Doesn't this mean the forces cancel one another, making acceleration impossible? Why or why not?

When you push a car, you exert a force on the car. The car simultaneously pushes back on you with an equal force, but this force acts on you, not on the car. You cannot cancel a force on the car with a force on you. For cancellation, the forces have to equal and opposite on the same object. In this case, the car accelerates forward, and you accelerate backward – the degree to which, depends on the masses, and also on other forces (e.g. friction) acting on you and the car.

- 4) Suppose two carts, one twice as massive as the other, are held together and joined by a compressed spring. They will fly apart when the compressed spring that joins them is released. How fast does the heavier cart roll compared to the lighter cart?

The force on each cart will be the same, but since their masses are different, their accelerations will be different. The twice-as-massive cart will undergo only half the acceleration of the less massive cart (since  $a = F_{\text{net}}/m$ ), and will gain only half the speed.

- 5) Your clicker question!