8 Friction

Name____________________________________

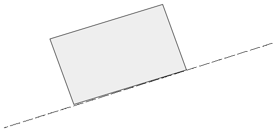
Worksheet on Friction and Air Drag

Inquiry Physics

1. A car is parked and at rest on a level driveway. Draw a free-body diagram of the car.

2. Why did you omit frictional force from the free-body diagram? Explain completely, using complete sentences.

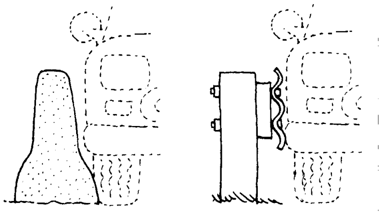
3. Now a car is parked on a sloping driveway, and thus still at rest. Draw a free-body diagram of the car, showing the weight (F_g), normal force (N), and frictional force (F_f). Remember, the normal force must be *normal* (perpendicular) to the surface.



4. Looking at your free body diagram in question 3, why was there a frictional force when the driveway was sloped, but not when it was level? Explain completely, using complete sentences.

5. The rear of some sports cars feature curved surfaces called spoilers. Spoilers are designed so that air flowing past them exerts a downward force. Use your understanding of friction to explain why this improves the handling of the sports car.

6. Concrete road dividers and barriers are replacing steel rails on our nation's highways and bridges. The figure at right shows how a side-swiping car would interact with each type of barrier. Use your knowledge of **friction** to speculate as to why concrete barriers are preferred over steel barriers.



Concrete vs. Steel Rail Barrier

A Related Topic: Air Drag

We found out earlier in the course that all objects fall downward at the same acceleration (9.8 m/s^2) in the absence of air resistance. ***Drag***, friction from the air, can have a significant effect on falling bodies. As a body falls with increasing speed, drag builds up. This will reduce the net force on the falling body, making it accelerate at less than 9.8 m/s^2.

It is possible for a body to fall fast enough that the upward push of drag balances the body's weight. If this happens, the net force on the falling body will be zero, and it will no longer accelerate. The body has reached its ***terminal velocity***. Feathers are everyday objects that reach a terminal velocity very quickly when dropped. Coins, however, are objects which do not show much effect from air resistance. A coin would have to drop for a few minutes before its speed would be great enough for the air resistance to increase to its weight. Its terminal velocity might be as high as 200 km/h downward.

The terminal velocity for a human skydiver varies from about 150 to 200 km/h downward (93 to 124 mph), depending on weight and body position. A heavier person will have a higher terminal speed than a lighter one because the larger weight is better at "plowing through" the air. A heavy and light skydiver can remain in close proximity if the heavy person spreads out his or her limbs (like a flying squirrel) while the light person falls head or feet first. A parachute's greater surface area greatly increases air resistance and lowers the terminal speed down to 15 to 25 km/h (9 to 16 mph). With a parachute, the "terminal" speed isn't deadly!

7. A basketball is dropped high above the ground. While the ball is falling, its speed is increasing due to the pull of its weight. What then must be happening to the amount of air drag it experiences as it continues to fall?

8. Still thinking about our basketball, draw a free-body diagram of the ball while it was falling through the air. In your diagram, draw the weight and drag vectors to appropriate lengths to indicate their relative sizes. Remember, the ball is still speeding up as it falls.

9. Let's suppose for ball falls for several seconds. Circle the best answers.

During the first part of its fall...

its speed is	LOW	HIGH
so the distance it travels each second is	LOW	HIGH
but its acceleration is (think about how much unbalanced force there is)	LOW	HIGH
so the amount of speed it gains each second is	LOW	HIGH

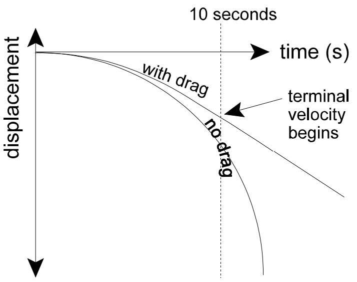
During the final part of its fall...

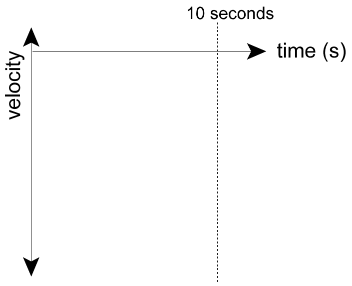
its speed is	LOW	HIGH
so the distance it travels each second is	LOW	HIGH
but its acceleration is (think about how much unbalanced force there is)	LOW	HIGH
so the amount of speed it gains each second is	LOW	HIGH

10. Now suppose the basketball was dropped from such a great height that it reaches terminal velocity (which is about 20 m/s or about 45 mph for a basketball). When it is falling at a constant speed, how does the size of its weight compare to the size of the drag force? Explain your answer.

11. After she jumps, a certain skydiver reaches terminal speed after ten seconds. The d vs. t graph at right shows her displacement with and without air drag.

    On the blank axes, sketch her velocity vs. time **with and without** drag from 0 seconds out to more than 10 s. Clearly label your **two** lines.





12. Look at your v vs. t graph. Does the skydiver **gain more speed** during the first second of fall or the ninth second of fall?

13. Look at the d vs. t graph. Does the skydiver fall a greater **distance** in the first second of fall or the ninth second?

Finally, let’s consider a basketball thrown up in the air and then caught at its original height.

14. If we ignore air resistance, we know the ball returns at its original speed. But if there IS air resistance, how is its upward motion different than when you ignore air drag?

15. Now consider when the ball begins falling back down. If there IS air resistance, how is its downward motion different than when you ignore air drag?

16. So, when there IS air drag, is the ball’s speed when it returns smaller, unchanged, or larger than it would have been with no air resistance? That is, does the ball return to its original speed, or is its final speed larger or smaller than the initial speed?