

Two kittens on a sloped roof. Which one slides off first?
The one with the lowest mew.



Announcements

- Major confusion about Ch 6 reading questions moved deadline to next Tues, Sept 30th
- Ch 6&7 homework will open next Monday, due the Friday, Oct 10th
- Sign up sheet for Paul?

Reading Questions

Is fluid friction just for things in the water, or can it also be for things in the air (air friction)?

Large/fast, and slow/small fluid friction equations-how are they derived, how do you know which to use.

I would like to address when it is appropriate to use the different fluid frictions. How do we know when something is relatively big, fast moving, etc.?

Foothold ideas: Drag force



- The drag (“Newtonian drag”) is a resistive force felt by an object moving through a fluid. It arises because the object is pushing fluid in front of it, bringing it up to the same speed it’s going.
- Occurs for objects that are “relatively large” and moving “relatively fast”
- The result is a force proportional to the density of the fluid, the area of the object, and the square of the object’s velocity.

$$F_{fluid \rightarrow object}^{big, fast} = \frac{1}{2} C_{fluid} \rho_{fluid} A v^2$$

A tennis ball is released from rest and falls, being accelerated by the force of gravity acting upon it. As its downward speed increases, the upward frictional force resisting its motion also increases. As time goes on, what happens?

- A. The ball's downward acceleration remains g
- B. The ball's downward acceleration is reduced to a non-zero value
- C. The ball's downward acceleration is reduced to zero
- D. The ball's downward speed is reduced to zero
- E. None of the above



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As the drag force increases, it resists the force from gravity until the point where the net force is 0, meaning the acceleration is also 0.



- A. The ball's downward acceleration is a non-zero value
- B. The ball's downward acceleration is a non-zero value
- C. The ball's downward acceleration is reduced to zero
- D. The ball's downward speed is reduced to zero
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Foothold ideas:

Viscosity



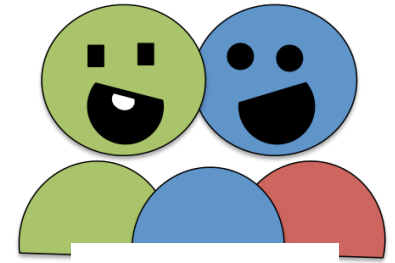
- Viscosity is a resistive force that an object feels when it moves through a fluid as a result of the fluid sticking to the object's surface. This layer of fluid tries to slide over the next layer of fluid and the friction between the speeds that layer up and so on.
- Occurs when objects are “relatively small” moving “relatively slowly”
- The result is a force proportional to the velocity of the object.

$$\vec{F}_{fluid \rightarrow object}^{small, slow} = -6\pi\eta R_{object} \vec{v}$$

A Helpful Idea: Reynold's Number

- How do you know whether an object is “relatively small” moving “relatively slowly”?
- Generally, for an object moving in a fluid both drag and viscosity are present. However, often, one is much more important.
 - The ration of the two forces produces a constant you can look up called the “Reynolds' Number”

$$\mathfrak{R} = \frac{F^{drag}}{F^{viscous}}$$



Discuss It!

What does the Reynolds' number depend upon? (Assume your object is a sphere.)

$$\mathfrak{R} = \frac{F^{drag}}{F^{viscous}}$$

$$\mathfrak{R} = NC\rho \frac{R_{obj}v}{\eta}$$

A paramecium swimming through a fluid is moving at approximately a **constant velocity** as a result of wiggling its cilia. What can you say about the **net force** that is being exerted on it while it is doing this?

- A. It is significantly greater than zero
- B. It is a little bit greater than zero
- C. It is equal to zero
- D. It cannot be determined from the information given.

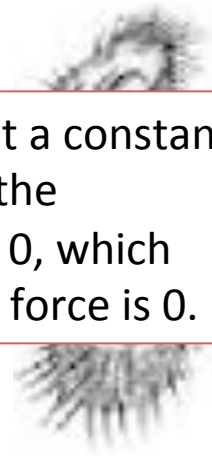


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If it's moving at a constant velocity, then the acceleration is 0, which means the net force is 0.



A paramecium swimming through a fluid is moving at approximately a **constant velocity** as a result of wiggling its cilia. What can you say about the magnitude of the force that the paramecium's cilia exert on the water compared to the magnitude of the force the water exerts back on the cilia?

- A. $F_{c \rightarrow w}$ is greater than $F_{w \rightarrow c}$
- B. $F_{c \rightarrow w} = F_{w \rightarrow c}$
- C. $F_{c \rightarrow w}$ is less than $F_{w \rightarrow c}$
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Newton's 3rd law tells us these forces must be equal in magnitude (and opposite in direction)



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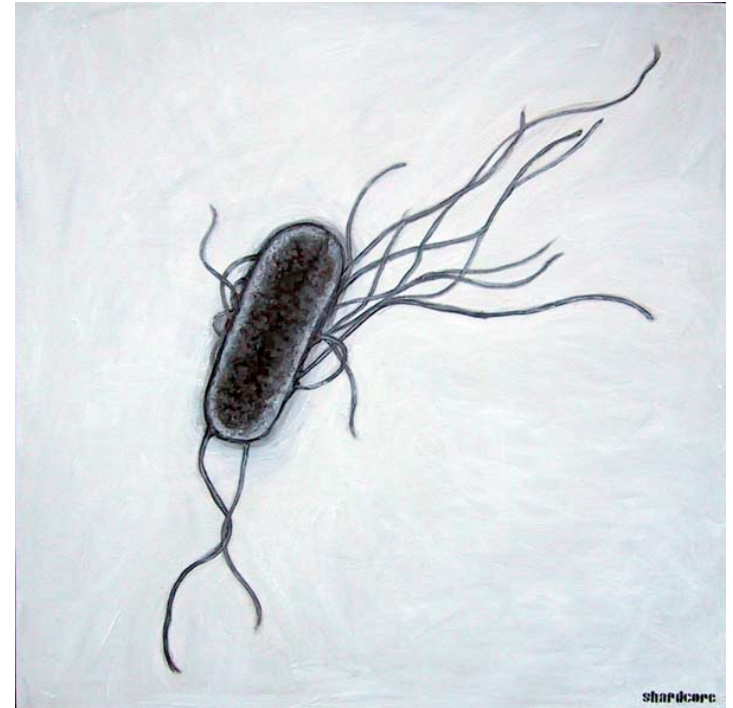
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An *e coli* bacterium is roughly 2 μm long and 0.5 μm in diameter. *e coli* bacteria can use their flagella to propel themselves at speeds of up to 0.05 mm/s (around 0.0001 miles per hour) in water, which has a viscosity of $\approx 0.8 \times 10^{-3} \text{ N}\cdot\text{s}/\text{m}^2$ at room temperature. What can you say about the resistive force on the bacterium as the bacterium speeds up?



- A. The resistive force remains constant because the fluid doesn't change.
- B. The resistive force increases as the speed increases.
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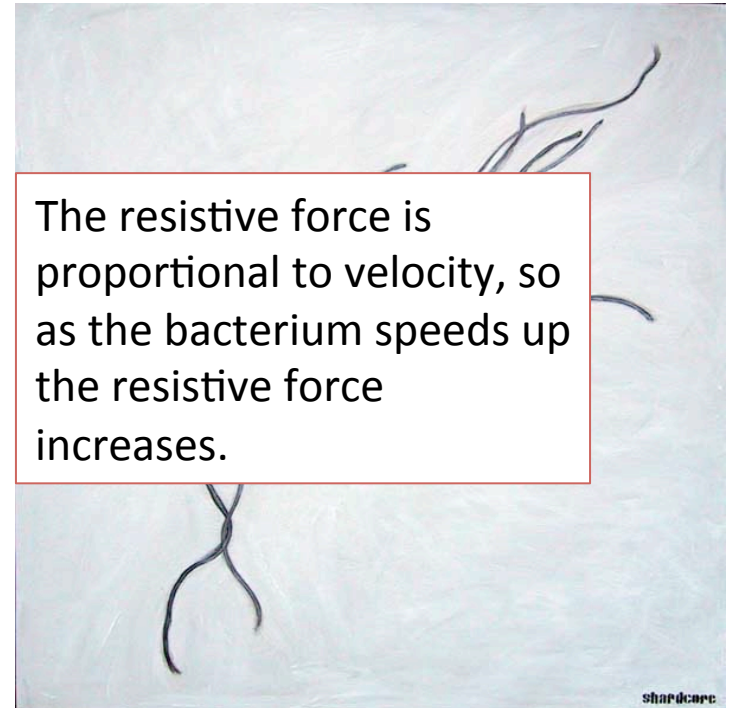


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The resistive force is proportional to velocity, so as the bacterium speeds up the resistive force increases.



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- A. The net force is in the direction of motion of the bacterium because it's moving fast.
- B. The net force is in the opposite direction of motion because the viscous force increases as it speeds up.
- C. The net force is 0 because as the flagella push harder so does the viscous force.
- D. None of the above



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As the flagella push harder on the fluid, the bacterium speeds up. As the bacterium speeds up the viscous force increases. So to speed up a little more the bacterium has to push harder. So at its maximum speed the forces must sum up to be 0.