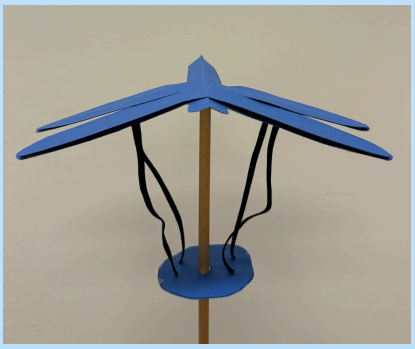
Dragonfly Muscles: Forces and Movement

SPS SOCK 2024

This demonstration asks participants to make dragonfly models with construction paper, plastic straws, tape, stirrer sticks, and elastic string. It focuses on forces, force diagrams, and the direct flight muscles of dragonflies.



PRESENTER BRIEF

The presenter should have an understanding of Newton's laws, different types of forces, and free body diagrams. If done with elementary school students, dragonflies should be pre-constructed. For older elementary students, have components pre-cut. For younger elementary students, have dragonflies prepared and have students decorate the second set of wings. Engagement strategy suggestions are anthropomorphising the dragonflies and building a storyline.

Number of Participants: 10 to 15
Audience: Elementary (with assistance) to High School
Duration: 25 minutes
Difficulty: Level 2

MATERIALS REQUIRED

- Construction paper
- Plastic straw
- Tape
- Double-sided tape
- Wooden stirrer sticks
- Elastic string
- Stapler

VOCABULARY

Force: a push or pull on an object as a result of an interaction with another object
Contact forces: forces that result from two objects in physical contact
Field forces: forces from a field that occur even when two objects are not in physical contact, such as gravitational or magnetic force
Newton's 1st Law of Motion: an object will remain at rest or at constant velocity until a force acts on it
Newton's 2nd Law of Motion: the net force an object experiences is equal to its mass times acceleration
Newton's 3rd Law of Motion: for every action there is an equal but opposite reaction
Newton: the unit of measurement for a force; 1 Newton is one kilogram per metre squared
Free body diagram: illustration used to show the relative magnitude and direction of all the forces acting on an object
Voronoi tessellation: a special pattern that divides space by distance to a set of points called 'seeds'

USEFUL EQUATIONS

Newton's 2nd Law $F = ma$
F is net force, m is mass, and a is acceleration

Newton's 3rd Law $\vec{F}_{12} = -\vec{F}_{21}$
$\vec{F}_{12}$ is the force on object 1 by object 2
$\vec{F}_{21}$ is the force on object 2 by object 1

ADDITIONAL RESOURCES

This may be a good demonstration to do with paired age groups. For example, older students may construct the dragonflies and younger students may decorate them.

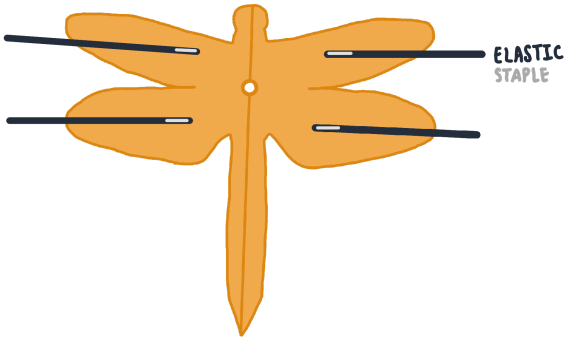
Some additional resources are:
- 'Flight' section of Dragonfly Biology
- Pattern Formation - Dragonfly Venation

Current literature for presenters:
- 'How math helps explain the delicate patterns of dragonfly wings' (ScienceNews; Conover, 2018)
- 'Students Discover the Mathematics Within Dragonfly Wings' (BNL; Mgrdichian-West, 2023)

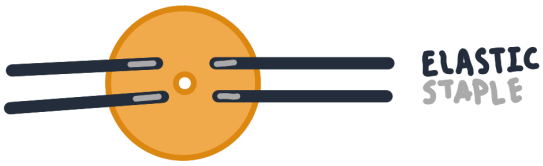
Setup:

1. Fold a piece of cardstock in half (hamburger, not hot dog). Place the dragonfly template

included in the SOCK along the fold. Trace and cut out:
   a. A dragonfly body with wings attached.
      i. Body can be decorated.
   b. A pair of dragonfly wings separately.
      i. Wings can be decorated! Voronoi tessellations are suggested.
   c. 2 circles, around 1.5 inches across. Cut a small hole in the middle of each.
2. Cut a small circle on the body of the dragonfly. The spot is marked in the template.
3. Cut four lengths of elastic string, about 5 inches long.
4. Staple the ends of the elastic spring to the spots marked on the wings.



5. (Optional) Cut coffee stirrers in half and tape onto the dragonfly wings (the set connected to the body) to strengthen them.
6. Make four evenly spaced cuts on one end of the straw, about 1/2 inch in length.
7. Poke the cut-end of the straw through the hole in the middle of the dragonfly. Flatten each section of straw against the body. Secure with tape.
8. Put the straw through the middle hole of the circle. Staple the ends of the elastic string to the circle.



9. Using double sided tape, stick both circles together, hiding all the rubber band/string ends.
10. Cover wings with double-sided tape. Stick the second pair of cardstock wings on top.
11. Gently pull the circle up and down to make the wings move.

Extensions:

- Dragonfly modifications:
  - Make dragonflies with wings of different lengths. Where do you need to place the elastic string to have them move smoothly?
  - Using elastic strings of different lengths. How does the force needed to move the wings change?
  - How can you stiffen the wings? Can you make them stiffer near the base than at

the tip? How does this change the movement of the dragonfly?

- The Dragonfly Dance
  - Have students stand up, stick their arms out to the side, and flap them up and down. What muscles are being used to do this? In what ways is this movement similar and different to how dragonflies flap their wings?

Physics and Explanation:

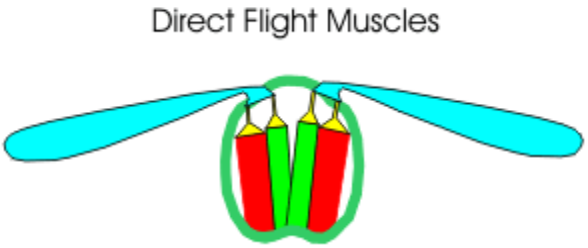
Elementary (ages 5-10):

A **force** is something that changes how an object moves, like a push or a pull. Forces are everywhere. Everything in the universe is controlled by forces, like how planets move around in space, how the tide comes in and out, and how you and animals move. You use force when you move your arm, throw a ball, or drink a glass of water.

Ask students to give examples of things they think involve forces. What are some forces that cause objects to move?

Forces don't work alone. When you throw a ball, there is the force of your throw. Then, the force of gravity pulls it to the ground. Forces can be put into two groups, field forces and contact forces. **Field forces** are forces that travel through space that occur even when two objects are not touching each other, like gravity. **Contact forces** are forces from two objects that are touching each other. You pushing your pencil around is applied force. Tension is a pulling force that stretches something, like a string, rope, or muscle. Dragonflies are special because, unlike other insects, they have something called direct flight muscles. This means that each wing has its own pair of muscles that move it up and down. This lets them move each wing separately, which gives them lots of control over how fast they can change speed and direction. Each wing is controlled by two muscles, one closer to the base than the other. The muscle closer to the base of the wing contracts (or shortens) to raise the wing. The muscle further from the base of the wing contracts to pull the wing back down.

Have participants do the demo and make their dragonflies. Do the dragonfly dance (extension activity)! Ask them to brainstorm and write down what kinds of forces are acting on the dragonfly wings. An example of the muscles is shown here:



Isaac Newton was a scientist who discovered rules that describe how objects move. The **1st Law of Motion** says that an object will stay not moving or at constant speed until a force is put on it. While this may seem crazy, it means that if you throw a ball, it will keep going forever unless forces are acting on it. **Newton's 2nd Law of Motion** says that the heavier something is, the

more force it takes to change its speed or get it moving. Finally, **Newton's 3rd Law of Motion** says that for every action there is an equal but opposite reaction.

Have students discuss in small groups and then share with a larger group:

What forces do you think make a ball stop from going on forever?
What are some forces that cause an object to move?
What would be examples of Newton's laws in action?
What happens when you throw a heavy object versus a light object?

Something cool about dragonfly wings is that they are patterned with Voronoi tessellations. **Voronoi tessellations** are a pattern that divides a space into chunks based on the location of random dots. Each chunk is the area around a dot.

Have participants draw Voronoi tessellations on the wings of their dragonflies! Can they think of any other things that have this pattern (leaves, garlic cloves, giraffe print)? Do some more decorations. Give the dragonflies faces and names. Encourage students to give their dragonflies personalities.

- Forces cause motion.
- Forces work together.
- There are specific rules that talk about how objects move.

Middle School (ages 11-13) and general public:

A **force** is something that changes how an object moves, like a push or a pull. Everything in the universe is controlled by forces, like how planets move around in space, how the tide comes in and out, and how you and animals move. You use force when you move your arm, throw a ball, or drink a glass of water. Forces always have magnitudes and directions. The magnitude, or strength, is described in **Newtons**, where 1 Newton is one kilogram per metre squared. The direction is described with vectors.

Ask students to give examples of things they think involve forces. What are some forces that cause objects to move?

Forces don't work alone. When you throw a ball, there is the force of your throw. Then, the force of gravity pulls it to the ground. There are two types of forces: field forces and contact forces. **Field forces** are forces from a field that occur even when two objects are not in physical contact, such as gravitational or magnetic force. **Contact forces** are forces from two objects in physical contact, such as applied force, tension, and normal force. Applied force is a force applied on an object by a person or object, such as if you pushed your pencil around. Tension is a pulling force that stretches something, like a string, rope, or muscle. Normal force supports the weight of an object on a surface. It acts in the opposite direction to gravity. Unlike many other insects, dragonflies have direct flight muscles. Each wing has two separate muscles connecting it to the body, allowing them to move each wing independently. This gives them lots of control over how fast they can change speed and direction. One muscle is closer to the body than the other. The muscle closer to the base of the wing contracts (or shortens) to raise the

wing. The muscle further from the base of the wing contracts to pull the wing back down.

Have students discuss in small groups and then share out to a larger group:

What forces do you think make a ball stop from going on forever?

Have participants do the demo and make their dragonflies. Ask them to brainstorm and write down what kinds of forces are acting on the dragonfly wings. Do the dragonfly dance (extension activity)! An example of direct muscle movement is shown above.

Isaac Newton was a scientist who discovered rules that describe how objects move. We call these Newton's Laws. The **1st Law of Motion** says an object will remain at rest or constant velocity until a force acts on it. While this may seem absurd, it means that if you throw a ball, it will keep going forever unless forces are acting on it. **Newton's 2nd Law of Motion** says that the heavier an object is, the more force it takes to accelerate. This is described in the equation $F = ma$, where 'F' is the net force, 'm' is the object's mass, and 'a' is the object's acceleration. Finally, **Newton's 3rd Law of Motion** says that for every action there is an equal but opposite reaction. We often describe the forces on things by drawing **free-body diagrams**, diagrams that show the relative magnitude and direction of all the forces acting on an object.

Demonstrate drawing a free-body diagram. Ask participants to draw free-body diagrams of the dragonfly wings and of different points on their model.

Something cool about dragonfly wings is that their wing patterns are Voronoi tessellations. **Voronoi tessellations** are a geometric structure that divides a space into chunks based on distance from a set of points called 'seeds'. Every chunk is an area closer to one specific seed than any other. These patterns are in lots of different disciplines: to calculate the rainfall of an area, to model muscular tissue, and to find out which old statue some severed statue heads belong to.

Have participants draw Voronoi tessellations on the wings of their dragonflies! Do some more decorations. Give the dragonflies faces and names. Encourage students to give their dragonflies personalities.

- A force is something that changes how an object moves.
- There are contact forces and field forces.
- Newton's Laws of Motion are rules for how objects move.

High School (ages 14+):

A **force** is something that changes how an object moves, like a push or a pull. Everything in the universe is controlled by forces, like how planets move around in space, how the tide comes in and out, and how you and animals move. You use force when you move your arm, throw a ball, or drink a glass of water. Forces always have magnitudes and directions. The magnitude, or strength, is described in **Newtons**, where 1 Newton is one kilogram per metre squared. Vectors describe the direction of the force.

Ask students to draw examples of forces.

Forces don't work alone. When you throw a ball, there is the force of your throw. Then, the force of gravity pulls it to the ground. There are two types of forces: field forces and contact forces. **Field forces** are forces from a field that occur even when two objects are not in physical contact, such as gravitational or magnetic force. **Contact forces** are forces from two objects in physical contact, such as applied force, tension, and normal force. Applied force is a force applied on an object by a person or object, such as if you pushed your pencil around. Tension is a pulling force that stretches something, like a string, rope, or muscle. Normal force is perpendicular to a surface an object is in contact with and prevents solid objects from passing through each other. Balanced forces are two or more forces acting on an object that cancel each other out. When the magnitude of one force is greater, the motion changes.

What forces do you think make a ball stop from going on forever?

Unlike many other insects, dragonflies have direct flight muscles, meaning they have a flight muscle attached directly to each wing. This allows them to move each wing independently, which gives them lots of control over how fast they can change speed and direction. Each wing has two muscles, one closer to the base of the wing than the other. The muscle closer to the base of the wing contracts (or shortens) to raise the wing. The muscle further from the base of the wing contracts to pull the wing back down.

Have participants do the demo and make their dragonflies. Ask them to brainstorm and write down what kinds of forces are acting on the dragonfly wings. Do the dragonfly dance (extension activity)! An example of direct muscle movement is shown above.

Isaac Newton was a scientist who discovered rules that describe how objects move. We call these Newton's Laws. The **1st Law of Motion** says an object will remain at rest or constant velocity until a force acts on it. While this may seem absurd, it means that if you throw a ball, it will keep going forever unless forces are acting on it. **Newton's 2nd Law of Motion** says that the heavier an object is, the more force it takes to accelerate. This is described in the equation $F = ma$, where 'F' is the net force, 'm' is the object's mass, and 'a' is the object's acceleration. Finally, **Newton's 3rd Law of Motion** says that for every action there is an equal but opposite reaction. The equation for this is: $\vec{F}_{12} = -\vec{F}_{21}$, where '$\vec{F}_{12}$' is the force on object 1 by object 2 and '$\vec{F}_{21}$' is the force on object 2 by object 1. We often describe the forces on things by drawing **free-body diagrams**, diagrams that show the relative magnitude and direction of all the forces acting on an object.

Demonstrate drawing a free-body diagram. Ask participants to draw free-body diagrams of the dragonfly wings and of different points on their model. Do this in groups, and then pair groups up to share and explain their free body diagrams with each other.

Something cool about dragonfly wings is that their wing patterns are Voronoi tessellations. **Voronoi tessellations** are a geometric structure that divides a space into chunks based on distance from a set of points called 'seeds'. Every chunk is an area closer to one specific seed than any other. People write algorithms to create Voronoi tessellations more efficiently. These patterns describe biological structures. They are used to find the nearest airport if planes are

diverted. Voronoi tessellations are used to calculate the rainfall of an area, to analyse plant structures, and to find out which old statue some severed statue heads belong to.

Have participants draw Voronoi tessellations on the wings of their dragonflies! Do some more decorations. Give the dragonflies faces and names. Encourage students to give their dragonflies personalities.

- A force is something that changes how an object moves.
- Newton's Laws of Motion describe how objects move.
- Free body diagrams can be used to analyse the forces on an object.

Patterns: