What Was THAT Again?

The Role of Discrepant Events in Identifying Student Misconceptions in STEM

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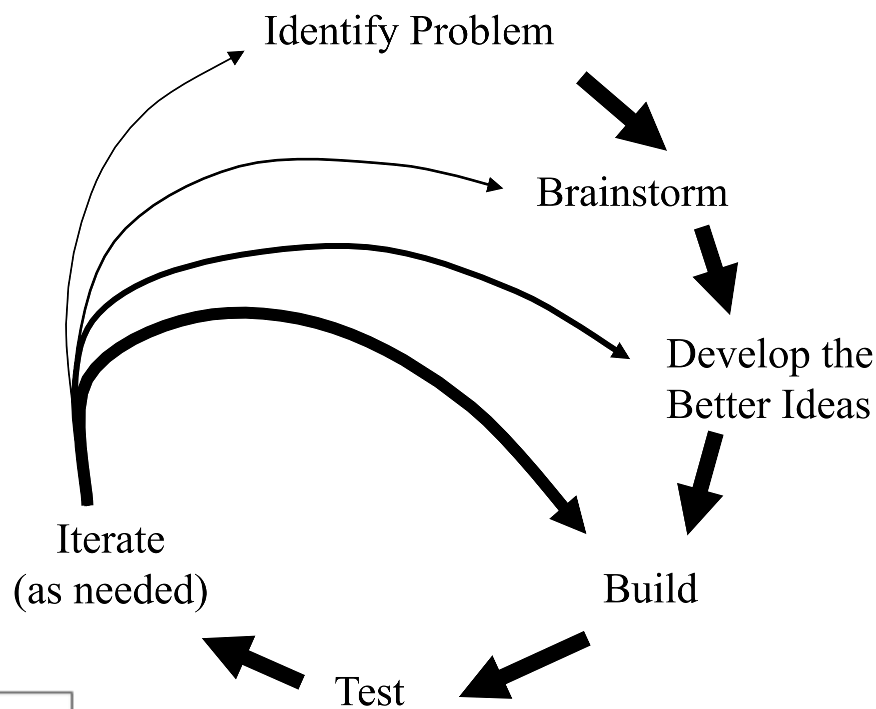
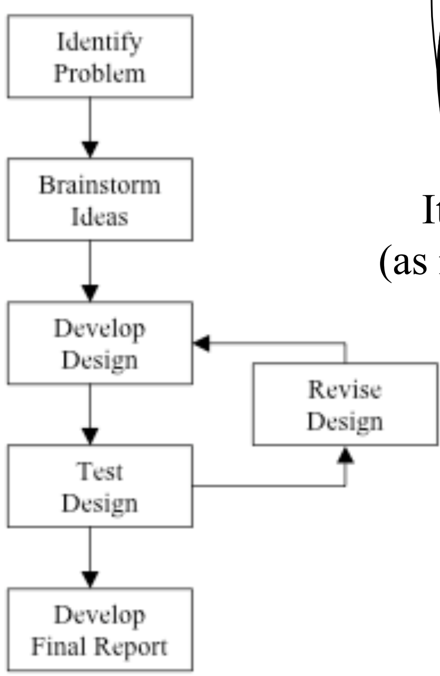
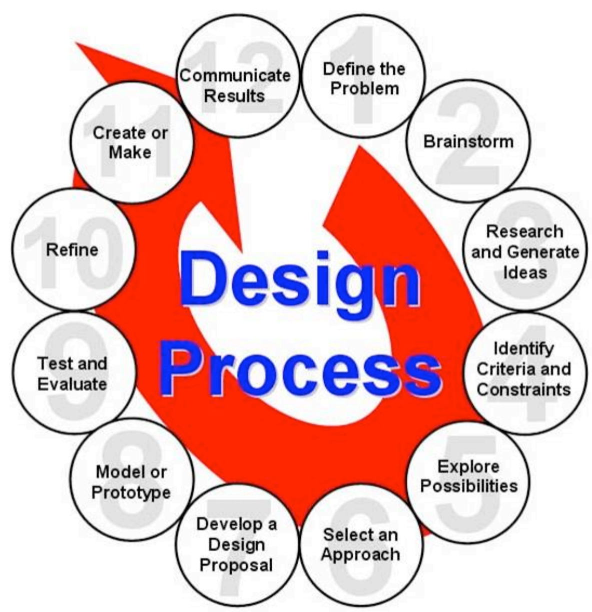
The Engineering Design Cycle

Various Methods



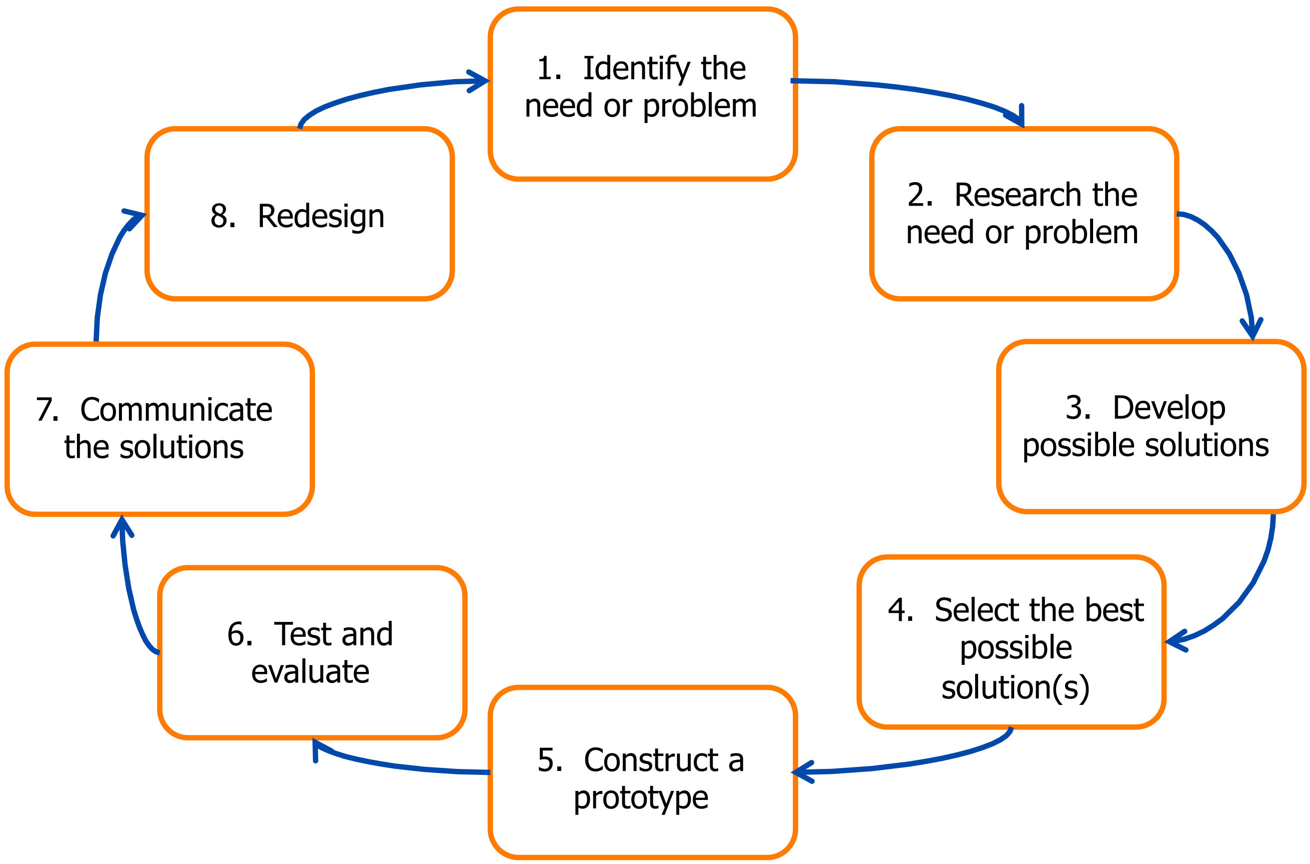


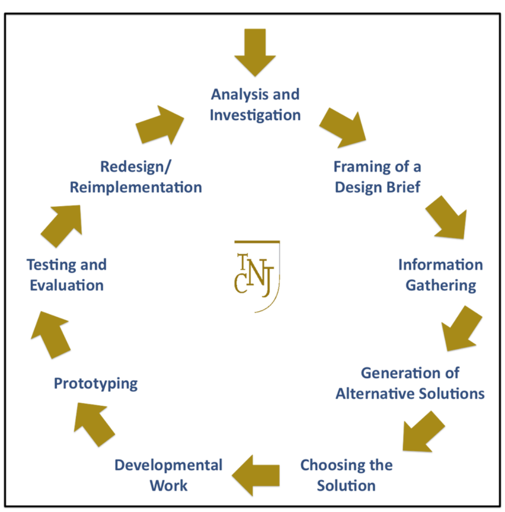


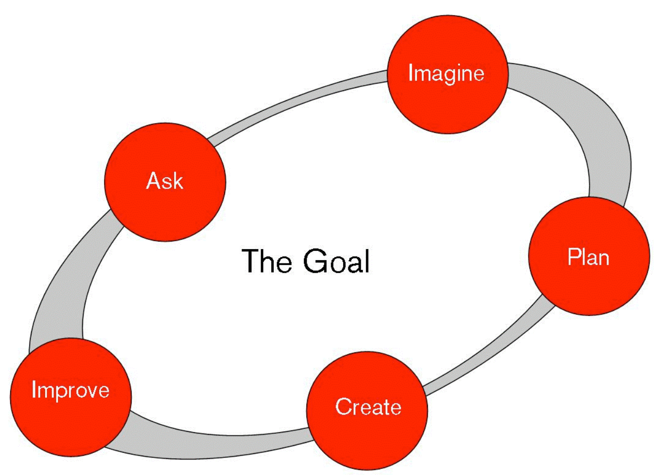
courtesy Larry G. Richards, Department of Mechanical and Aerospace Engineering, Uva; courtesy R. Reid Bailey, Department of Systems and Information Engineering, UVa; and davis.k12.ut.us

The Engineering Design Cycle

Various Methods







Massachusetts Science and Technology/Engineering Curriculum Framework, October 2006, page 84; www.mos.org/eie/engineering_design.php; and TCNJ Department of Technological Studies

Heat Transfer

An Introduction

Heat transfer

- Is the study of
  - processes by which thermal energy is exchanged between two bodies
  - related changes and resulting states of those bodies
- Is primarily focused on
  - *temperature*, or the amount of available thermal energy
  - *flow*, or the movement of that thermal energy
- Is driven by changes in temperature
  - heat flows from high to low temperature regions

www.efunda.com/formulae/heat_transfer/home/overview.cfm and en.wikipedia.org/wiki/Heat_transfer

Heat Transfer

Some Typical Misconceptions

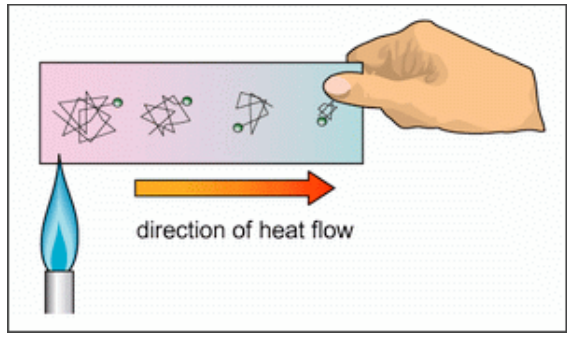
Students may think...	Instead of thinking...
Heat is a substance. Heat is not energy.	Heat is the transfer of thermal energy.
Temperature is a property of a particular material or object. (For example, students may believe that metal is naturally cooler than plastic.)	Temperature is not a property of materials or objects. Objects exposed to the same ambient conditions will have the same temperature.
The temperature of an object depends on its size.	Temperature does not depend on size.
Heat and cold are different.	Cold is the state of lower thermal energy. Even cold bodies can transfer thermal energy if there is a colder one nearby!
Cold is transferred from one object to another.	Thermal energy is transferred from one object to another. Thermal energy moves from the warmer object to the cooler object. When this occurs, heat is transferred. Heat is not a stationary thing; it is energy in motion, just as electricity is electrons in motion.
Objects that keep things warm (sweaters, mittens, blankets) are sources of heat.	Objects keep things warm by slowing the transfer of thermal energy.
Some substances (flour, sugar, air) cannot heat up.	All substances heat up, although some gain heat more easily than others.
Objects that readily become warm (conductors of heat) do not readily become cold.	Conductors gain (and lose) heat easily.

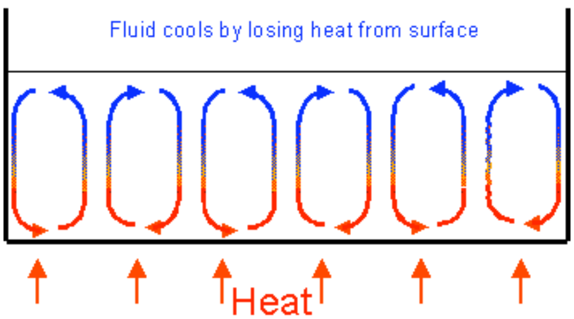
Heat Transfer

Good Terms to Know!

Conduction

- ✧ molecular transfer of heat via exchanges of kinetic energy
- ✧ density and conduction are directly proportional: the less dense the material, the lower its conductivity
- ✧ metals are typically the best conductors





Convection cell
Warm, low density fluid rises
Cool, high density fluid sinks

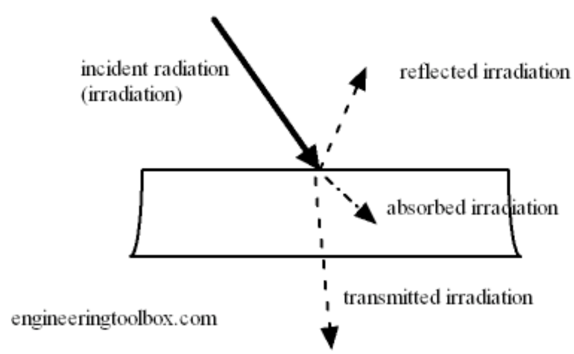
Convection

- ✧ mass transfer of heat by molecules moving from a warmer place to a cooler one
- ✧ transfer takes place between a surface and fluids and gases (air) only because the structure of solids doesn't allow for effective diffusion

There are three main methods by which heat is transferred…

Radiation

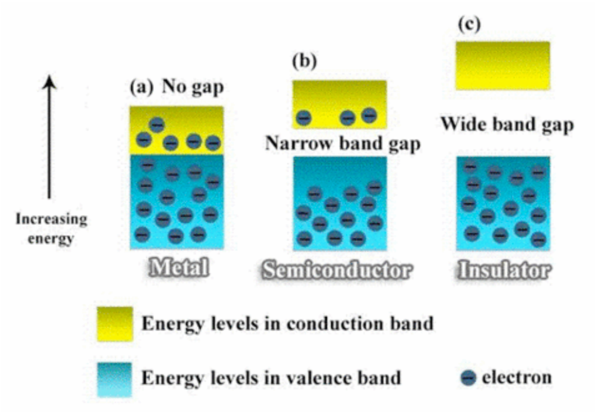
- ✧ transfer of heat by electromagnetic waves emanating from an object
- ✧ wavelength and temperature are inversely related: the warmer the temperature, the shorter the wavelength



engineeringtoolbox.com, knowledgerush.com, and phy.cuhk.edu.hk

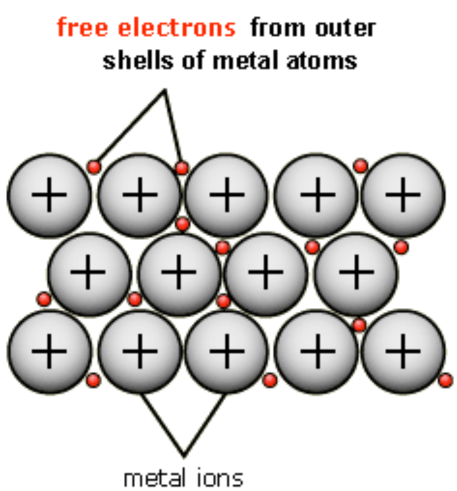
Heat Transfer

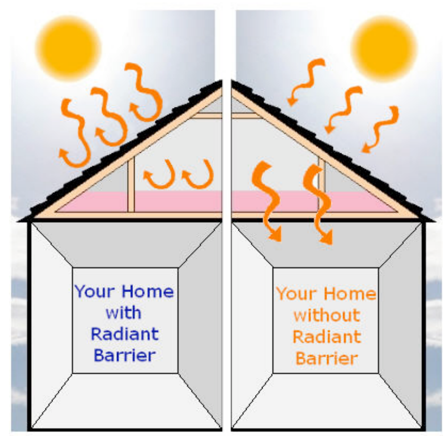
Good Terms to Know!

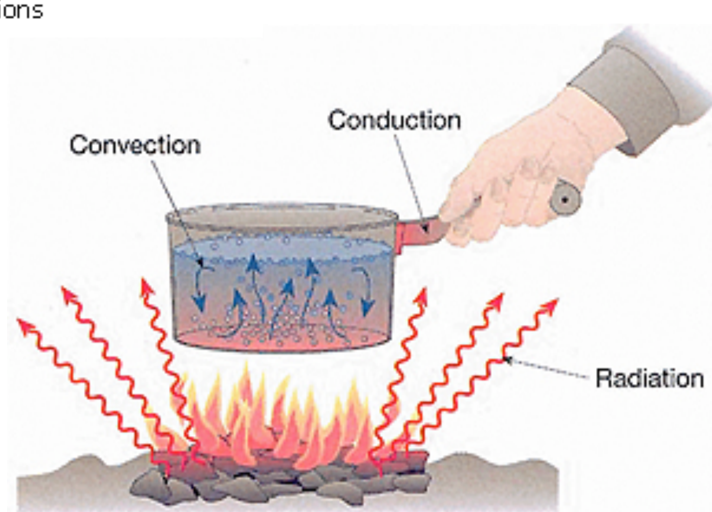


Insulator

- ✧ difference between insulator and conductor is that electric charges can move freely in a conductor (free electrons), but not in an insulator (few or no free electrons)
- ✧ energy is transferred at very, very low levels via conduction in an insulator







bbc.co.uk.com, discountsidingandwindows.com, mech.northwestern.edu, and physicaplus.org.il

Heat Transfer

Discrepant Event 1

This discrepant event addresses misconceptions regarding the effect of surface area on rate and amount of change in temperature.

You'll need
- ✧ Two 1000 ml beakers
- ✧ 1200 ml room temperature water
- ✧ 80 g crushed ice
- ✧ Two stir plates or autostir probes
- ✧ Two thermometers and timers OR two data collector thermocouples



- ✷ Fill each beaker with 600 ml of water
- ✷ Place the beakers on the stir plates
- ✷ Make a "snowball" with half the crushed ice
- ✷ Start data collectors/timers
- ✷ Simultaneously place the loose ice and "snowball" ice in the beakers
- ✷ Note the changes of temperature and the time in the process each change occurs
- ✷ Note the time at which no further changes of temperature occur and the final temperature

Pre-assessment
- ✧ Outline the activities you're going to perform
- ✧ Ask the students to record their answers to the following questions and the reason(s) for their choice
  - ✓ will the loose crushed ice cool the water faster, slower, or at the same rate as the ice ball?
  - ✓ will the end (steady-state) temperature of the water cooled by the loose crushed ice be higher, lower, or the same as the water cooled by the ice ball?

Post-assessment
- ✧ Ask the students to score their pre-assessments
- ✧ Facilitate discussion of correct and incorrect answers and reason(s)

Enrichment / Follow-up Activities
- ✧ Graph change of temperature *v.* time
- ✧ Discuss and calculate rate of change
- ✧ Investigate Newton's Law of Cooling
- ✧ Discuss how this knowledge informs design decisions
  - ✓ ETK – *Save the Penguins*

Prince, MJ; Vigeant, M; and Nottis, K (2009). A preliminary study on the effectiveness of inquiry-based activities for addressing misconceptions of undergraduate engineering students, *Education for Chemical Engineers* 4(2), 29-41; images from bigceramicstore.com, enasco.com, and restaurant-services.com

Heat Transfer

Discrepant Event 2

This discrepant event addresses misconceptions regarding conduction and insulation.

You'll need
- ✧ Six (aluminum) cans; your choice of soda or juice
- ✧ Six thermometers
- ✧ Ten rubber bands
- ✧ Insulators: paper towel, aluminum foil, plastic wrap, wool sock, and cotton sock

- ✷ Choose the same type of soda/ juice
- ✷ Refrigerate the cans overnight
  - ✧ Record the temperature in the refrigerator to provide a starting point
- ✷ Remove the cans from the refrigerator right before class
  - ✧ Use a cooler if you do not have access to a refrigerator before class
- ✷ Wrap five cans in the above insulators; leave one unwrapped as a control
- ✷ Open the cans and place a thermometer in each one
- ✷ Note the changes of temperature and the time in the process each change occurs
- ✷ Note the time at which no further changes of temperature occur and the final temperature

Pre-assessment
- ✧ Outline the activities you're going to perform
- ✧ Ask the students to record their answers to the following question and the reason(s) for their choice
  - ✓ Which material will keep the drink the coldest after the cans have been setting out for several hours?

Post-assessment
- ✧ Ask the students to score their pre-assessments
- ✧ Facilitate discussion of correct and incorrect answers and reason(s)

Enrichment / Follow-up Activities
- ✧ Graph change of temperature *v.* time
- ✧ Discuss and calculate rate of change
- ✧ Investigate Newton's Law of Cooling
- ✧ Discuss how this knowledge informs design decisions
  - ✓ ETK – *Save the Penguins*

Schnittka, CG; Bell, R; and Richards, L (2010). Save the penguins: Teaching the science of heat transfer through engineering design, *Science Scope* 34(3), 82-91; images from the article and emperor-penguin.com

Heat Transfer

Engineering Design Challenge

Build on these activities and findings by having students design a container which will protect an ice cube from melting when exposed to a heat source.

Motivate the students by placing this challenge in the context of climate change, reducing one's carbon footprint, and/or fuel conservation.

You'll need

- ✧ Shop lights
- ✧ Ring stands
- ✧ Small to medium cardboard box
- ✧ Aluminum foil
- ✧ Black cardboard
- ✧ Small paper cups
- ✧ Scales

- ✧ 2 – 3 sheets of aluminized Mylar
- ✧ Felt
- ✧ Cotton balls
- ✧ Paper
- ✧ Other types of insulator materials

- ✧ Ice cubes of identical size

- ✧ Ruler and scissors
  or
- ✧ Rotary cutter/ruler and cutting mat

Schnittka, CG; Bell, R; and Richards, L (2010). Save the penguins: Teaching the science of heat transfer through engineering design, *Science Scope* 34(3), 82-91; image from emperor-penguin.com

Heat Transfer

Engineering Design Challenge

Preparation

Line the sides of the box with aluminum foil. Cut a "floor" from the black cardboard and place in the bottom of the box. (Alternatively, paint the bottom black.)

Cut the insulator materials into 3"x3" pieces.

In-class Activities

Cover the types of materials available for use in designing and building their container. Focus first on material properties; price and amount constraints will become factors later.

Place students in teams of 3 – 4 members.

Ask them to brainstorm about the materials they could use and structures they can design. Have them draw up a list of materials and make sketches for two structures. Ask students to list pros and cons for both designs.

Have student teams present their designs, including their reasons for their choices.

Heat Transfer

Engineering Design Challenge

Introduce price and amount constraints. Ask teams to redesign their containers and create a bill of materials.

Model Number	Description	Unit Price	Quantity	Total Price	Source
n/a	Felt Square	$1.25	2	$2.50	Craft House
20207	Mylar Balloons	$0.55	1	$0.55	balloonsfast.com
Grand Total				$3.05	Comments: need by 6.25.11

Have the students build their containers. Place an ice cube in a paper cup, and have students place the cube and cup inside their containers.

Test the containers by placing them in the box, which has been pre-heated by the shop lights. Remove the containers after 20 minutes. Remove the cup from the container and have students weigh how much solid mass remains.

Notes

Time constraints, which are often a factor in engineering projects, may be added as age-appropriate throughout the design and construction activities.

Have students wear safety goggles when cutting materials.

The shop lights can become very hot. Do not let students look directly into the lights, or to touch or move them.

Heat Transfer

Engineering Design Challenge

Your ideas for activities…

Buoyancy

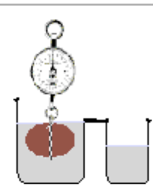
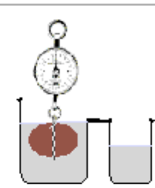
An Introduction

Archimedes' Principle

- A body immersed in a fluid is subject to an upward force equal in magnitude to the weight of the displaced fluid
  - Archimedes supposedly derived this principle from noting that the amount of water spilled from his bath was equal in volume to the submerged part of his body
  - He also reportedly used this principle to determine whether the King of Syracuse's crown was pure gold
- Alternatively, the mass an object loses in a fluid is equal to the mass of the water displaced

Archimedes' Principle of Buoyancy

An object weighs less in water than it does in the air. This loss of weight is due to the upthrust of the water acting upon it and is equal to the weight of the liquid displaced.
Because salt water is more dense than pure water the object displaces a greater weight of salt water and, therefore, weighs less.
The denser the liquid, the easier it is to float in it making it easier to swim in the ocean or a chemical filled pool than a mountain stream.

Object weighed in air is (say) 640 grams.	Object weighed in water is (say) 410 grams.	Object weighed in salt water is (say) 400 grams.
		
A minimal weight of air is displaced.	Weight of water displaced is 230 grams.	Weight of salt water displaced is 240 grams.

en.wikipedia.org/wiki/Buoyancy, www.grandpapencil.net/science/archimed.htm, and www.juliantrubin.com/bigten/archimedesprinciple.html

Buoyancy

Typical Misconceptions

Misconceptions		Supporting evidence	Counterevidence
I	Big/heavy things sink; small/ light things float.	A boulder sinks, while a leaf and a feather float.	*Small rocks or coins sink, although they are small.* *Objects made of floating wood will float in water regardless of size.* *Two pieces of floating wood bundled together still float.* *A piece of soap sinks in water. If cut into two unequal pieces, both pieces still sink in water regardless of size.*
II	Hollow things float; things with air in them float.	Balloons, beach balls, and basketballs float.	*A submarine sinks although it has air in it all the time.*
III	Things with holes sink.	A boat or ship with a hole in it sinks, e.g., *Titanic*.	*Objects made of floating materials (e.g., wood and foam) will float in water even if there is a hole in them.*
IV	Flat things float.	Water rafts and surfboards float.	*A flat piece of iron and a ceramic plate sink.*
V	The sharp edge of an object makes it sink.	Things with an edge are easier to push in snow, soil, and other solid materials.	*A piece of clay made into an edge shape will sink in water no matter how it is placed in water.*
VI	Vertical things sink; horizontal things float.	When we stand in water, we sink; when we lie on water, we float.	*If we put a piece of wood pencil in water, no matter how you put it in, it floats.*
VII	Hard things sink; soft things float.	Rocks sink, while balloons float.	*A piece of clay sinks in water although it is soft.* *A piece of wood floats in water although it is hard.*
VIII	Floating fillers help heavy things float.	Life preservers help people float in water.	*If a sealed container sinks, adding foam peanuts and resealing the container won't make it float.*
IX	A large amount of water makes things float.	Boats float in the ocean.	*Some things sink in the ocean although the ocean is huge.*
X	Sticky liquid makes things float.	A marble floats in corn syrup.	*Objects that sink in water will sink in cooking oil, although the oil is very sticky.*

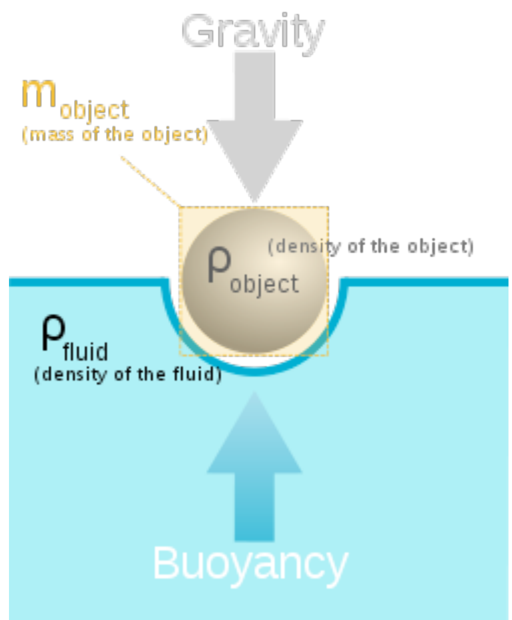
Yin, Y; Tomita, MK; and Shavelson, RJ (2008). Diagnosing and dealing with student misconceptions: Floating and sinking, *Science Scope* 31(8), 34 – 39.

Buoyancy

Good Terms to Know!

Buoyancy

- most simply, the ability of an object to float
- fluid's relative density > object's average density = float; if <, then sink
- buoyant force = fluid density * volume of displaced fluid * acceleration due to gravity (9.81 m/s^2)
  - ✓ Think Newton's Second (F = m*a) and Third (equal and opposite reaction) Laws of Motion



Density

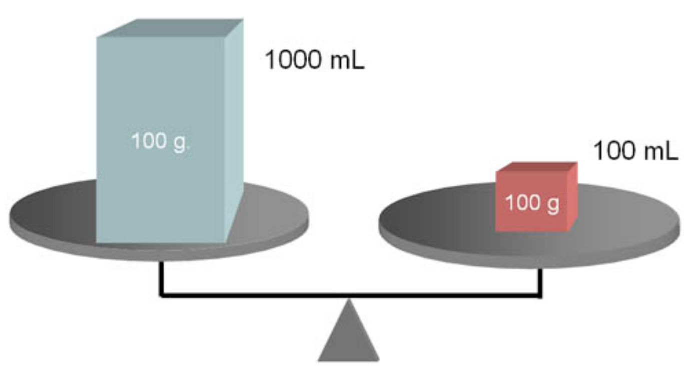
- degree of compactness
- mass / volume
- water's density is 1 g/cm^3
  - ✓ cm^3 = ml

Mass

- amount of matter in an object
- remains constant, while weight may vary

Weight

- force exerted by mass under gravity's influence
- mass * acceleration due to gravity



www1.appstate.edu/dept/physics/labs/QuickGuides/density.htm, and www.chemistryland.com/CHM130S/02-MMM/Measure/Measuring.htm, www.ehow.com/how_2101130_calculate-buoyancy.html, en.wikipedia.org/wiki/Buoyancy, knowledgerush.com, and rjdposters.com

Buoyancy

Density Matters!

- Completely submerged objects with equal masses but different volumes will experience different buoyant forces
- Buoyancy is also affected by the fluid's density
  - The more dense the fluid, the greater the upwards force because more fluid is displaced
- Buoyancy is also a factor in flight (air's a fluid, too!)
  - The higher an object rises, the less dense the atmosphere

FIGURE 4

a) Bottle filled with beads (yellow = plastic; red = stainless steel) of two different densities, prior to shaking.

b) Separation of beads by density occurs as a result of shaking.

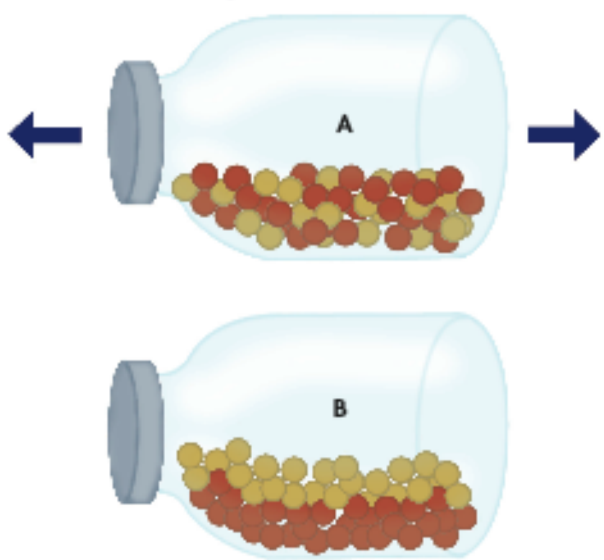
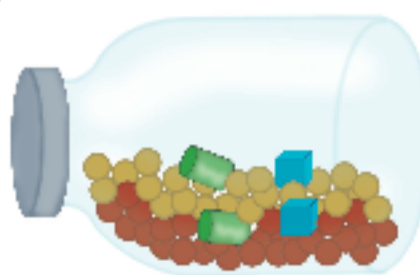


FIGURE 5

Density separation of objects of varying shapes and sizes can also be illustrated with solids. Here, plastic objects separate to the top, with steel objects beneath.



Libarkin, JC; Crockett, CD; Sadler, PM (2003). Density on dry land: Demonstrations without buoyancy challenge student misconceptions, *The Science Teacher* 70(9), 46 – 50; images from p. 49

Buoyancy

Discrepant Event

This discrepant event addresses misconceptions regarding buoyancy and density.

You'll need
- ✧ A tub or bucket
- ✧ Water
- ✧ A can of regular soda
- ✧ A can of diet soda (same brand)

- ✷ Fill the tub or bucket with enough water to cover the cans
- ✷ Place the cans in the tub or bucket at the same time
- ✷ Observe the results

- ✷ Have students calculate
  - ✧ Mass
    - ✓ Using weights of water and sweetner (40.5 g sugar v. 188 mg aspartame)
    - ✓ Using scales
  - ✧ Density

  of the two cans

Pre-assessment
- ✧ Outline the activity you're going to perform
- ✧ Pass the cans among the students
- ✧ Ask them to record their observations
- ✧ Ask them to record their answers to the following questions and the reason(s) for their choice
  - ✓ will the regular soda can float or sink?
  - ✓ will the diet soda can float or sink?

Post-assessment
- ✧ Ask the students to score their pre-assessments
- ✧ Facilitate discussion of correct and incorrect answers and reason(s)

Enrichment / Follow-up Activities
- ✧ Identify the sweetening agents
  - ✓ Look up the chemical formulae
  - ✓ Brainstorm why aspartame is sweeter than sugar
- ✧ Discuss how this knowledge informs design decisions
  - ✓ ETK - *Under Pressure*

Buoyancy

Engineering Design Challenge

Build on these activities and findings by having students design a “submarine” which will have neutral buoyancy.

You’ll need

- ✧ 1 20 oz. plastic soda/water bottle per team
- ✧ Scales
- ✧ 2 or 3 buckets partially filled with water
- ✧ Sand
- ✧ Rice
- ✧ Dried beans
- ✧ Gravel
- ✧ Marbles
- ✧ Cork

Motivate the students by placing this challenge in the context of their experiences with water sports or modes of transportation.

Ask them to brainstorm about what it means for an object to have neutral buoyancy. Lead them to the definition that an object’s mass equals the mass of fluid it displaces, or that the “submarine” will have the same density as water. Have them work through calculations to arrive at an estimate as to the mass the “submarine” should have.

Buoyancy

Engineering Design Challenge

Once students are comfortable with using the concepts and equations, have them design a filler for bottle. Have them draw up a list of materials.

Have students build and test prototypes.

Have student teams present their designs, including calculations of neutral buoyancy and the resulting mass of the "submarine."

Note

Check for allergies to the filler materials. Have students wear non-latex gloves when handling these materials if allergies are a concern.

Buoyancy

Engineering Design Challenge

Your ideas for activities…

Propulsion

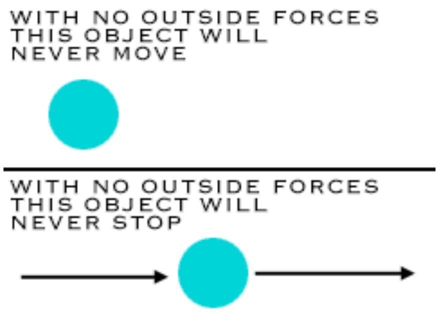
An Introduction

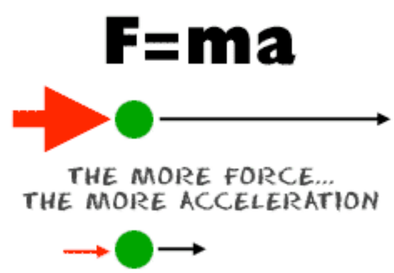
Newton's Laws of Motion

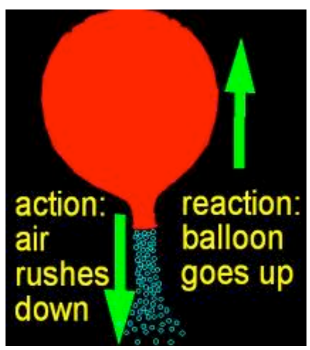
✸First Law (N1)
- ✧ Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it

✸Second Law (N2)
- ✧ The relationship among an object's mass *m*, its acceleration *a*, and the applied force *F* is F = m*a
  - ✓ Acceleration and force occur in the same direction.

✸Third Law (N3)
- ✧ For every action there is an equal and opposite reaction







Propulsion

Typical Misconceptions

KINEMATICS

Two objects side by side must have the same speed.
Acceleration and velocity are always in the same direction.
Velocity is a force.
If velocity is zero, then acceleration must be zero too.

FALLING BODIES

Heavier objects fall faster than light ones.
Acceleration is the same as velocity.
The acceleration of a falling object depends upon its mass.
Freely falling bodies can only move downward.
There is no gravity in a vacuum.
Gravity only acts on things when they are falling.

INERTIA

Forces are required for motion with constant velocity.
Inertia deals with the state of motion (at rest or in motion).
All objects can be moved with equal ease in the absence of gravity.
All objects eventually stop moving when the force is removed.
Inertia is the force that keeps objects in motion.
If two objects are both at rest, they have the same amount of inertia.
Velocity is absolute and not dependent on the frame of reference.

Propulsion

Typical Misconceptions

NEWTON'S LAWS

Action-reaction forces act on the same body.
There is no connection between Newton's Laws and kinematics.
The product of mass and acceleration, *ma,* is a force.
Fiction can't act in the direction of motion.
The normal force on an object is equal to the weight of the object by the 3rd law.
The normal force on an object always equals the weight of the object.
Equilibrium means that all the forces on an object are equal.
Equilibrium is a consequence of the 3rd law.
Only animate things (people, animals) exert forces; passive ones (tables, floors) do not exert forces.
Once an object is moving, heavier objects push more than lighter ones.
Newton's 3rd law can be overcome by motion (such as by a jerking motion).
A force applied by, say a hand, still acts on an object after the object leaves the hand.

Propulsion

Typical Misconceptions

FUNDAMENTAL FORCES

All forces have to be contact forces.
The gravitational force is the only natural force.
All forces are unique, so none are fundamental.
The gravitational force is the strongest force.
The gravitational and electromagnetic forces are more fundamental than the strong and weak nuclear forces.
Electricity and magnetism are two different forces.
The weak and strong nuclear forces are really the same force.
All forces are equally effective over all ranges.
None of the fundamental forces has been proven to exist.
The electrical force is the same as the gravitational force.

Propulsion

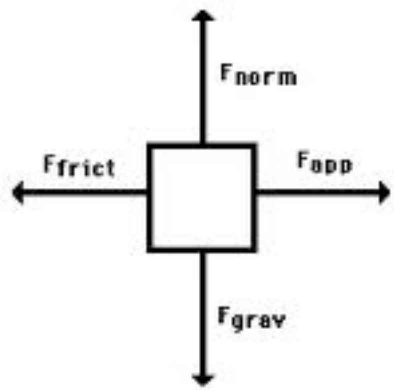
Good Terms to Know!

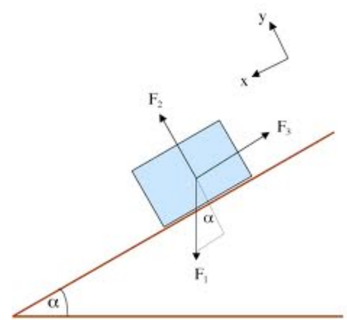
Friction

- resistive force between two surfaces in contact that tends to oppose relative
  - ✓ we are dealing with dry friction (two solid surfaces)
- static friction is the force opposing placing a body at rest into motion (non-moving surfaces)
- kinetic friction occurs when the surfaces of two objects are moving relative to each other; it acts to slow an object in motion

Propulsion

- force causing movement



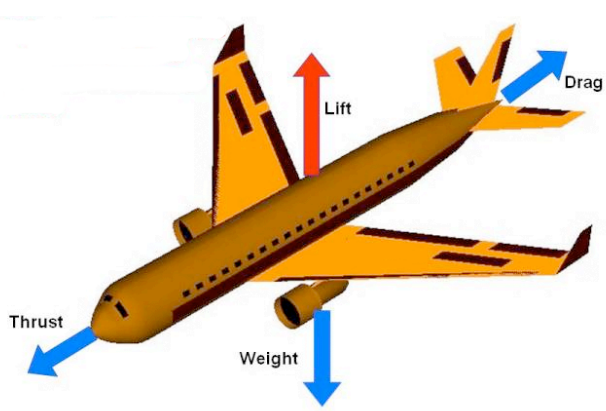


Drag

- force opposing (relative) movement of an object through a fluid
- directly proportional to fluid density: the more dense the fluid, the greater the drag
- also increases with area and speed
- acts in opposite direction of the motion

Lift

- force generated by an object coming into contact with a moving flow of fluid, causing it to turn
- amount of lift depends on the difference in velocity between the object and the fluid
- acts perpendicular to the motion



facstaff.gpc.edu/~pgore/PhysicalScience/forces-motion.html, ffden-2.phys.uaf.edu, www.grc.nasa.gov/WWW/K-12/airplane/lift1.html, knowledgerush.com, physicsclassroom.com, and physics.info

Propulsion

Discrepant Event 1a

This discrepant event addresses misconceptions regarding mass and gravity.

You'll need
- ✧ Two solid, smooth balls of different masses (e.g. a marble, a ball bearing, or a billiard ball)
- ✧ Ramp, track, or a long piece of wood or plastic
- ✧ Two blocks of wood

- ✷ Have the students hold the balls to confirm differences in mass
- ✷ Place the ramp/track at a slightly elevated angle to the horizontal
- ✷ Have students focus at the bottom of the ramp

- ✷ Release the balls at the top of the ramp/track at the same time
- ✷ Alternatively, video the balls falling from the same height
- ✷ Play the video frame by frame to reinforce that the rate of fall is the same

- ✷ Finally, have objects with small amount of friction positioned at the end of the ramps
  - ✧ The ball with more mass will push the object further because of its greater momentum

Pre-assessment
- ✧ Outline the activity you're going to perform
- ✧ Ask the students to record their answers to the following question and the reason(s) for their choice
  - ✓ When will the ball with less mass reach the end of the ramp: before, at the same time, or after the ball with more mass?

Post-assessment
- ✧ Ask the students to score their pre-assessments
- ✧ Facilitate discussion of correct and incorrect answers and reason(s)

Enrichment / Follow-up Activities
- ✧ Set up an Excel spreadsheet and have students create several scenarios to understand the relationships among mass, velocity, acceleration, and gravity
- ✧ Discuss how this knowledge informs design decisions
  - ✓ ETK – *HoverHoos*

Note: balls which are vastly different in size will arrive at the end of the ramp at different times; a ball with a large circumference covers distances more easily

facstaff.gpc.edu/~pgore/PhysicalScience/forces-motion.html, www.madsci.org/posts/archives/2001-02/981758059.Ph.r.html, and 123rf.com

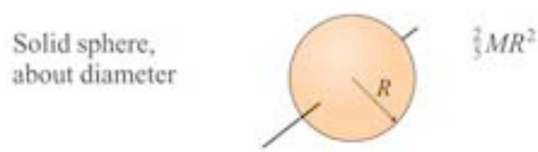
Propulsion

Discrepant Event 1b

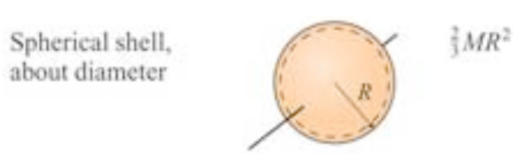
This version adds the concept of *moment of inertia* to the discussion.

You'll need
- ✧ One solid, smooth ball and one hollow ball of (near) equal masses (e.g. a marble and a ping pong ball)
- ✧ Ramp, track, or a long piece of wood or plastic

- ✸ An object's moment of inertia is a measure of how difficult it is to change its motion about a given axis
- ✸ With respect to an object's mass, you must consider both
  - ✧ amount of mass
  - ✧ distance of mass from the axis



- ✸ Have the students hold the balls to confirm similarities in mass
- ✸ Place the ramp/track at a slightly elevated angle to the horizontal
- ✸ Have students focus at the bottom of the ramp
- ✸ Release the balls at the top of the ramp/track at the same time



Pre-assessment
- ✧ Outline the activity you're going to perform
- ✧ Ask the students to record their answers to the following question and the reason(s) for their choice
  - ✓ When will ball 1 reach the end of the ramp: before, at the same time, or after ball 2?

Post-assessment
- ✧ Ask the students to score their pre-assessments
- ✧ Facilitate discussion of correct and incorrect answers and reason(s)

Enrichment / Follow-up Activities
- ✧ Identify and review tables of moment of inertia values
- ✧ Discuss how this knowledge informs design decisions
  - ✓ ETK – *HoverHoos*

en.wikipedia.org/wiki/Moment_of_inertia, facstaff.gpc.edu/~pgore/PhysicalScience/forces-motion.html, phys.unt.edu, and whs.wsd.wednet.edu

Propulsion

Discrepant Event 2

This discrepant event addresses misconceptions regarding friction and inertia.

You'll need
- ✧ Glass or plastic cup (preferably clear)
- ✧ Index card
- ✧ Coin

for each student team

- ✸ Place the card on top of the glass; place the coin on the card
- ✸ Move the card sideways slowly
- ✸ Observe what happens to the coin
- ✧ It will move with the card because static friction overcomes the coin's inertia (N1)
- ✧ Vertical forces have not changed
- ✸ Now flick the card off the top of the glass
- ✸ Observe what happens to the coin
- ✧ It will stay in place momentarily and then drop as gravity acts on it
- ✧ Videotape the activity and then play it back frame by frame to emphasize this result

Pre-assessment
- ✧ Outline the activity you're going to perform
- ✧ Ask the students to record their answers to the following questions and the reason(s) for their choice
  - ✓ What happens to the coin when you move the card sideways off the top of the glass slowly?
  - ✓ What happens to the coin when you move the card quickly?

Post-assessment
- ✧ Ask the students to score their pre-assessments
- ✧ Facilitate discussion of correct and incorrect answers and reason(s)

Enrichment / Follow-up Activities
- ✧ Repeat with objects of various masses (e.g., a set of metal washers) and note differences in force needed to dislodge card
- ✧ Discuss how this knowledge informs design decisions
  - ✓ ETK – *HoverHoos*

en.wikipedia.org/wiki/Moment_of_inertia, facstaff.gpc.edu/~pgore/PhysicalScience/forces-motion.html, sciencefairprojectshub.com, whs.wsd.wednet.edu, and stevespanglerscience.com

Propulsion

Engineering Design Challenge

Build on these activities and findings by having students build and operate a simple hovercraft.

You'll need
- ✧ 1 "poptop" plastic bottle cap
- ✧ CD
- ✧ balloon

per student team

- ✧ hot glue gun
- ✧ xacto knives
- ✧ scissors
- ✧ cutting boards
- ✧ paper (regular and stock)
- ✧ plastic bags

Motivate the students by placing this challenge in the context of their experiences with kites and paper airplanes, and with challenges in finding alternative fuels.

Assign students to teams of 3 – 4 students.

Have students build the basic CD hovercraft first.

- ✸ Hot glue the bottle cap to the CD, positioning the cap over the CD's hole
- ✸ When cap is dry and secure, inflate the balloon
- ✸ Twist the neck to prevent air from escaping

Gamespics.com, instructables.com, virginia.inetgiant.com, and 123rf.com

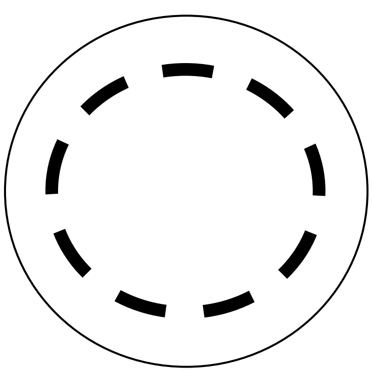
Propulsion

Engineering Design Challenge

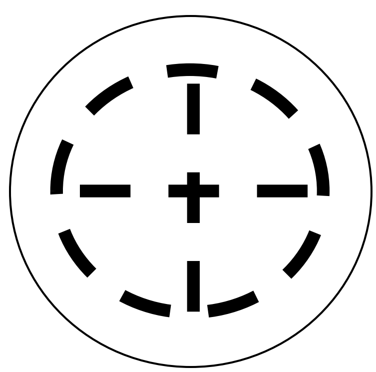
- ✸ Make sure the "poptop" is closed shut
- ✸ Place the balloon over the bottle top
- ✸ "Unpop" the top
- ✸ Watch the hovercraft go!

- ✸ Challenge students to improve their hovercrafts' performance

- ✸ What happens when…
  - ✧ A skirt of plastic is attached to the edge of the CD?
    - ✓ Cut a strip 1" wide from a plastic bag
    - ✓ Hot glue the skirt to the CD
    - ✓ Reinflate and reattach balloon
    - ✓ Test
  - ✧ Air flow is channeled to the edge of the CD?
    - ✓ Have students cut out and hot glue the following addons to the bottom of the CD
      - ⊙ Stock paper/plastic first and then regular paper



Regular plastic



Stock paper or thin plastic

www.ise5-14.org.uk/Prim3/New_Guidelines/Newsletters/41/Hovercraft.htm and www.instructables.com/id/Launch-It%3a-The-Improved-CD-Hovercraft

Propulsion

Engineering Design Challenge

- ✓ Reinflate and reattach balloon
- ✓ Test

- ✧ Ask students “why” their hovercrafts’ performance is better
- ✧ Guide them to recognition of the concept that lift is better when air is directed to the edge of the CD so that the whole disc benefits instead of just the center in the original design
- ✓ Reinforce this concept by having them place their hands under the three hovercraft designs while you release air from the balloon

Note

Have students wear safety goggles when cutting materials.

Propulsion

Engineering Design Challenge

Your ideas for activities…