Young Engineers Club Curriculum

Contents

Introduction

Traditionally, education in the field of engineering is not made available to students until they reach the college level. Even though primary school students may not be prepared to handle the advanced science and mathematics that are the typical domain of the engineering disciplines it's never too early to apply engineering principles to solving problems.

The Young Engineers Club is open to all ages attending the Saratoga Independent School and will expose students to engineering fundamentals on a level they will find engaging and fun.

Each club meeting will briefly introduce an engineering discipline and then pose an open ended engineering challenge in that realm. Sometimes the whole club will work together to solve a problem, other times we will break out in to teams for some friendly competition. This self-directed problem based approach is an enjoyable way to foster engineering fundamentals such as innovation and original thought.

Engineering areas that we'll be exploring include: Acoustical, Aerospace, Architectural, Biomedical, Chemical, Computer Aided Design, Electrical, Mechanical, Naval, Optical, Robotics, Rocketry, Software and more. As the school year progresses, club members will add skills from earlier topics to their toolkit which they may bring to bear for solving more interdisciplinary challenges. If students develop an affinity to certain activities then we'll find ways to incorporate those activities into the various subjects that we cover. We'll also include tangential topics based on student interest.

Club members will be using tools that may typically be labeled "Keep out of reach of children" (e.g. cordless drill, soldering iron, etc.). We'll be sure to closely supervise as necessary but also promote empowering students to use tools safely and effectively. On days where we use tools we'll always start out by emphasizing safety procedures and make sure participants are wearing appropriate safety gear. Additional precautions will be taken based on age.

Occasionally we may ask students to bring in craft supplies, various recyclables or broken gadgets from home for use in the club. If you have a technological household item that you are going to throw away, consider hanging on to it to send in when called for so that we can explore some reverse engineering and disassembling skills.

Club meetings will be weekly occurring after school on Tuesdays. Parents are welcome to attend meetings to help with organization and safety but remember, please try to participate only as a passive resource. The process of trying to solve a problem without boundary is part of the joy of engineering. As difficult as it may be to watch your child try to do something the "wrong" way, this more often than not can lead to a very clever solution that you will find wonderfully surprising.

Finally, we may plan an occasional weekend meet up at local events that are of interest to the club (for example, FIRST LEGO tournament).

Optional Materials Some optional materials you may consider supplying for your child include:

- Safety Glasses. We will have safety glasses on hand for every club member. But if preferred, students may bring in their own safety glasses. Please be sure they are labeled with their name. Alternatively if your child wears prescription glasses you may find compatible clip on side shields.
- Engineering Notebook. Keeping an engineering notebook is not required, but older students may want to keep one. Exactly what to use for an engineering notebook is a matter of personal preference. Typically graph paper type stationary is used (for instance, an engineering computation notepad and a 1" 3 ring binder).
- Tools. We'll have tools on hand for projects as needed though students are welcome to bring their own tools if available. A minimum tool set would be a small toolbox that includes Phillips and common blade screwdrivers, slip joint pliers, needle nose pliers, a ruler, a tape measure and diagonal cutters. Please clearly label everything with the student's name.

- Broken gadgets. Remember to keep an eye out for things that can be sent in for disassembly. Our reverse engineering workshop is planned for early January. Whatever you send in, be sure it's disposable as it will be thoroughly unusable once we're done with it.

Also please check with your child after each meetup for any additional preparation requests for the following week's club meeting. I will provide handouts with any additional supplies or actions requested as necessary.

Materials

Required materials are listed within each workshop decription. Alternative supplies may be substituted or often you can improvise around not having supplies by adjusting the workshop activities.

Part I

Curriculum Workshops

Chapter 1

Workshop 1: What is Engineering

2016-10-04

Note
First meeting

1.1 What is Engineering?

DISCIPLINES:

- Engineering Fundamentals

RESOURCES:

- What's an Engineer? Crash Course Kids
  - https://www.youtube.com/watch?v=owHF9iLyxic
- Engineering Process
  - https://www.youtube.com/watch?v=fxJWin195kU

Philosophy: For this and all ensuing workshops, prioritize allowing the students to steer the direction. These workshops are guidelines for providing a medium for exploration but there's no need to hold fast to them. If the class is motivated to do something totally different, encourage this even if it's not part of the plan.

For reference, Wikipedia defines Engineering as follows, (there's no need to actually read this to the class, but it may be helpful in case you get a few pedantic inquires):

> Engineering is the application of mathematics, empirical evidence and scientific, economic, social, and practical knowledge in order to invent, innovate, design, build, maintain, research, and improve structures, machines, tools, systems, components, materials, processes and organizations.
>
> The discipline of engineering is extremely broad, and encompasses a range of more specialized fields of engineering, each with a more specific emphasis on particular areas of applied science, technology and types of application.
>
> The term Engineering is derived from the Latin ingenium, meaning "cleverness" and ingeniare, meaning "to contrive, devise".
>
> — Wikipedia *Engineering*

In short: Engineering is the application of knowledge to invent, design and build systems.

RESOURCES:

- http://www-tc.pbskids.org/designsquad/pdf/parentseducators/DS_Act_Guide_complete.pdf
- http://www.mechatronics-mec.org/downloads/Engineering%20Notebook08.pdf

MATERIALS:

- Large whiteboard and dry erase markers
- Tape (e.g. masking tape that will be easily removable from whiteboard)
- Index cards
- Computer workstation with internet access
- Make Magazines and/or similar
- Various gears and other engineering like gizmos
- Ruler
- Various stickers and coloring sheets of technical items for students to choose for personalizing their engineering notebooks. Example coloring sheet ideas:
  - Gears, pulleys, clocks, Rube Goldberg
  - Vehicles: automotive, nautical, construction equipment, aerospace
  - Instrumentation
  - Computers
  - Drafting symbols/stickers

Location: Indoor classroom/lab environment

Preparation: Write the challenge "What is engineering?" on the board.

Draw five large circles on the board. At the top of each circle write each of the following categories:

- Mechanical
- Chemical
- Civil
- Electrical
- Software
- Interdisciplinary

For reference here are some definitions:

Mechanical engineering
: is the discipline that applies the principles of engineering, physics, and materials science for the design, analysis, manufacturing, and maintenance of mechanical systems. It is the branch of engineering that involves the design, production, and operation of machinery. It is one of the oldest and broadest of the engineering disciplines.

Chemical engineering
is a branch of engineering that applies physical sciences (physics and chemistry) and life sciences (microbiology and biochemistry) together with applied mathematics and economics to produce, transform, transport, and properly use chemicals, materials and energy. Essentially, chemical engineers design large-scale processes that convert chemicals, raw materials, living cells, microorganisms and energy into useful forms and products.

Civil engineering
is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like roads, bridges, canals, dams, and buildings.

Electrical engineering
comprises the study and application of electricity, electronics, and electromagnetism.

Software engineering
is the application of engineering to the design, development, implementation and maintenance of software in a systematic method.

— Wikipedia *List of engineering branches*

Wikipedia classifies the sub-disciplines as follows:

- Civil
  - Architectural, Construction, Earthquake, Hydraulic, Mining, Structural, Geotechnical, Transportation, Environmental
- Mechanical
  - Aerospace, Acoustical, Automotive, Marine, Mechatronics, Railway
- Electrical
  - Computer, Control, Electronics, Electromechanics, Optical, Power, Photonics, Telecommunications, Radio Frequency
- Chemical
  - Biochemical, Biological, Molecular, Nanotechnology, Process, Reaction, Thermodynamics, Transport phenomena
- Interdisciplinary
  - Audio, Engineering mathematics, Biomedical, Fire, Industrial, Materials science, Robotics, Military, Nuclear, Security, Systems, Privacy

Distribute the gears/gizmos, magazines and index cards across all the classroom tables. Don’t offer direction one way or another whether the kids are allowed to touch these things. When they do start playing/reading don’t make them stop when you move on to new activities.

Have a computer workstation set up and pointing at the webpage: http://spacefem.com/quizzes/engineer . During the challenge allow students to individually come up and take the quiz (with assistance if necessary). If you have engineering notebooks, have them log their results.

Consider starting the meeting seated among the students: "So, who’s going to teach us today?". If there are any volunteers, see where it goes before taking formal charge.

Engineering Notebook (Optional)
Have the students assemble an Engineering Notebook. Notify club members before this first meeting to bring the necessary notebook supplies. They can use a notebook of their own choice suitable to their tastes (spiral bound, composition, binder, pocket folder with brads, etc.). Absent any strong student preference though, suggest a 1" 3 ring binder with 3-hole filler graph or engineering pad paper. This way paper can be used for scratch work as necessary while archival worthy pages can be placed in the binder. Encourage doodling in their notebooks
A good engineering notebook is a valuable tool to a practicing engineer but assigning too much importance to it here may be of minimal value. Especially if it gets in the way of the creative process. It may be better to instead have a class notebook/binder that students can take turns writing in or that students can submit reports to.

Challenge: Pose the question "What is engineering?". Allow the discussion to be driven by the students. Invite the students to write down or draw something on the index cards that they think has to do with engineering. Let them make as many index cards as they want.

Also create cards (optionally extra large) with your own selection of engineering disciplines. My choices include: Acoustical, Aerospace, Architectural, Automotive, Biomedical, Chemical, Civil, Computer Aided, Electrical, Manufacturing, Marine, Mechanical, Optical, Robotic, Software.

Have the students tape their cards into as many of the 5 category circles drawn up on the board. For example an Automotive engineering card might well be placed in each of the circles whereas the gears would likely only be placed in the Mechanical circle.

Based on the results illustrate some Venn diagrams for various disciplines. Ask the students to pick some of their favorite cards and try to identify a discipline that they like.

Optional notebook activity Have the students log their favorite discipline in their notebook and compare that to their quiz results. Have them put their name and date on the page.

Redistribute the notebooks so everyone has somebody else's notebook. Invite the students to report on whose notebook they got and what kind of engineer their colleague is. As a "peer review" then they can sign and date their name at the bottom of the page and return the notebook to the owner.

1.1.1 Additional activities

Optionally bring the Straw Rocket materials as an additional activity for students.

Make worksheets that the students can populate Venn diagrams themselves. Make 1" - 1.5" diameter circular icon images on a printed page that can be punched out with a 1" - 1.5" punch. Each image can be an engineering related picture/term. The graphics can be line art and the students can be encouraged to color them as they please.

- Gears: mechanical, automotive
- Computer workstation: software and all disciplines
- Iconic lab glassware: chemical
- Optics, Laser: optical
- Rocket, airplane: aerospace
- Heart: biomedical
- Eyeball: biomedical optics
- Boat, Dam: Marine, mechanical
- Robot: electrical, software robotic
- Assembly line: manufacturing
- Bridge: civil, mechanical, architectural
- Computer chip: electrical
- skyscraper building: architectural, mechanical
- electrical symbols: resistor, capacitor, power supply, opamp etc
- drafting symbols: centerline, dimensional callout etc
- Also have some blank disks for the kids to draw their own pictures/terms

Chapter 2

Workshop 2: Unsinkable Boat

2016-10-11

Important
Notify students that meeting on 10/18 will be cancelled.

2.1 Unsinkable Boat

DISCIPLINES:

- Naval Engineering

RESOURCES:

- http://www-tc.pbskids.org/designsquad/pdf/parentseducators/DS_Act_Guide_complete.pdf
- http://pbskids.org/designsquad/parentseducators/resources/watercraft.html
- http://www-tc.pbskids.org/designsquad/pdf/parentseducators/DS_Act_Guide_Watercraft.pdf
- http://pbskids.org/designsquad/build/watercraft/
- https://www.schooltube.com/video/7100de854a0a40fead91/Bill%20Nye%20-%20Buoyancy

MATERIALS:

- 50 plastic straws per team
- 1 roll of tape per team
- 25 pennies
- 1 paper cup per team
- Plastic Wrap
- Additional coins/washers
- Large tub or large watertight storage bin

- Stopwatch
- Digital scale (or triple balance scale)
- Internet Media Access
- golf ball
- ping pong ball
- Clay

Location: Inside or outside on a warm day.

Preparation: Fill the tub with water.

FACILITATOR NOTES

- Buoyancy is the force of the water against the boat
- An object that floats displaces it's equal weight in water
- Increasing surface area will increase water displacement and increase buoyancy

Demonstration: Show the first 6.5 minutes of the Bill Nye video:

https://www.schooltube.com/video/7100de854a0a40fead91/Bill%20Nye%20-%20Buoyancy

Teaming: Teams of 2-3 making sure youngest are teamed with older student(s)

Challenge: Build a boat that can hold 25 pennies for at least 10 seconds before sinking

Discuss buoyancy. Inquire for some items to float test and try them. Demonstrate the golf ball and ping pong ball buoyancy.

Use a balled up blob of modeling clay that is about the same size as the golf ball. Demonstrate that it sinks. Reshape it to a boat shape and demonstrate that it floats.

Discuss the challenge and the provided materials to the class. Allow them to come up with some ideas in an open discussion ahead of time. Have them draw some sketches for their ideas.

Give each team tape, straws, a sheet of plastic wrap and a cup. The cups are there as a vessel for holding the pennies (but don't discourage students if they decide to use them in other creative ways). For those interested, try adding additional weight (coins and/or washers) to see how much their boats can take before sinking.

Students can weigh the coins/washers their boat held and log it in their notebook. If the scale is sensitive enough they might also weigh their boat.

Chapter 3

Workshop 3: Spooky Engineering

2016-10-25
Meeting before Halloween

3.1 Spooky Engineering

DISCIPLINES:

- Chemical Engineering

RESOURCES:

- http://www.weareteachers.com/blogs/post/2013/09/17/spooky-science-ideas
- http://www.science-sparks.com/2012/09/20/spooky-lava-lamps/
- http://www.weareteachers.com/lessons-resources/details/diy-slime
- http://www.instructables.com/id/Oobleck/
- https://en.wikipedia.org/wiki/Non-Newtonian_fluid
- Vi Hart Scary Sierpinski Skull: https://www.youtube.com/watch?v=z8ZWlUamNPI

MATERIALS:

- Food coloring
- Alka-seltzer
- Vegetable oil
- Dish soap

Per student:

- A clear plastic bottle or jar
- A bottle of vegetable oil
- Cup of water

- Dixie cup of corn starch
- Paper bowl
- Spoon

Location: Classroom/Lab

Warning
Collect all of the bottle/jar tops before beginning the activity. The students won't be able to resist capping their lava lamps after putting in the alka-seltzer which will cause pressure build up and potential explosion. You could also make a safety demonstration by putting water and alka-seltzer into a capped bottle made of lightweight plastic and then leaving it in a safe location where it can explode without injuring anyone (safety glasses recommended).

Teaming: Individual or teams based on amount of supplies available.

Challenge: Perform some spooky Mad Scientist Experiments.

"Make a Lava Lamp from varying density liquids"

"Make Oobleck: a Non Newtonian Fluid"

Standard lava lamp:

- Fill the bottle or jar a quarter full with water and fill the rest with vegetable oil.
- After the separation between the oil and water settles add several drops of food coloring.
- Add half an alka seltzer for a bubbling reaction.
- Add more bits of alka-seltzer to create a lava-lamp rising and falling of bubbles.

Let the kids design their own lava lamp using dish soap, water, vegetable oil and food coloring. Things to experiment with include:

- Order in which liquids are added
- Size of alka-seltzer tablets
- When to add food coloring

Class Inquiry: TODO: Education on reaction of alka-seltzer Discussion on density. Ask about why the oil and water separate. Can the class think of different density gasses?

Oobleck Non Newtonian fluid

Mix 1 cup water with 1.5-2cups corn starch (about 1:2 ratio water to cornstarch) and a few drops of food coloring in mixing bowl. Student's will have a Non Newtonian Fluid which acts like a liquid when poured but as a solid when touched.

- If the oobleck is too watery add a spoon of cornstarch and mix in thoroughly
- If it isn't watery when picked up, add a spoon of water
- Repeat until achieving proper consistency

Class Inquiry Unlike most fluids, a non-Newtonian fluid's viscosity is dependent on the shear rate it is exposed to. Silly Putty is another example. It will stretch and mold, but ball it up and throw it and it bounces.

Further Challenges: Prepare for a Ballistic Pumpkin challenge for the next meeting after Halloween. Have students bring in small pumpkins/Jack-O-Lanterns that may be launched across the field outside. Brainstorm some ideas for launching pumpkins. Watch some videos on Trebuchets and Punkin Chunkin.

Chapter 4

Workshop 4: Ballistic Pumpkins

2016-11-01

4.1 Ballistic Pumpkins

DISCIPLINES:

- Mechanical Engineering

Setup: Depending on available materials, you can either have teams build multiple trebs or build one trebuchet (let the whole class assemble it as 1 team) and then let them break out and compete on getting the best distance with their own customized sling designs.

Miniature pumpkin gourds or alternatively golf balls may be used for launching. You could get orange golf balls and or decorate them like jack-o-lanterns to keep with the pumpkin theme.

RESOURCES:

- https://www.punkinchunkin.com/
- http://www.sciencechannel.com/tv-shows/punkin-chunkin/
- Punkin Chunkin documentary:
  - https://www.youtube.com/watch?v=dmSyrGsqmg8
- http://www.real-world-physics-problems.com/trebuchet-physics.html
- MythBusters:
  - https://www.youtube.com/watch?v=9-Hwxw4fgqk
- http://www.instructables.com/id/Trebuchet-Project/
- http://www.pvcfittingsonline.com/406-005-1-2-schedule-40-pvc-90-ell.html
- http://parts.spearsmfg.com/ProductDetails.aspx?pid=41

MATERIALS:

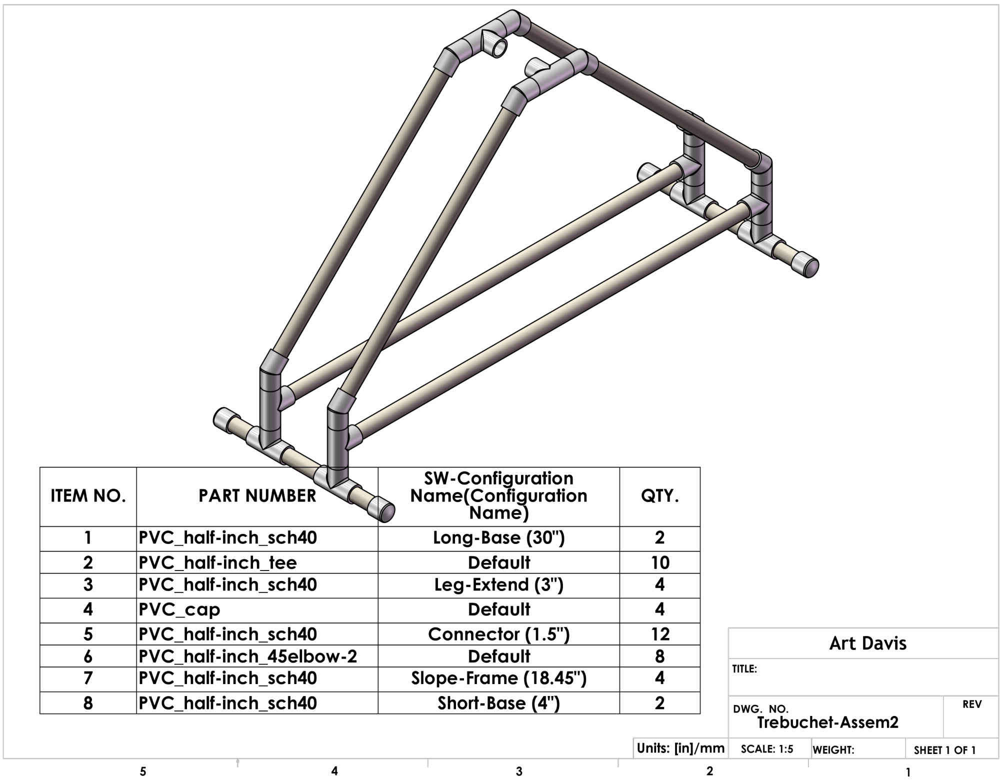
- Garbage bags for cleanup

- Trebuchet (see below)
- Minature pumpkins/gourds
- Tennis balls
- Golf balls
- Bouncy balls
- ≥100ft long tape measure
- Lawn Marking chalk
- Online media access
- Wastebasket or bucket

Location: Large field outside.

PREPARATION:

- Build PVC pipe trebuchet



ITEM NO.	PART NUMBER	SW-Configuration Name(Configuration Name)	QTY.
1	PVC_half-inch_sch40	Long-Base (30")	2
2	PVC_half-inch_tee	Default	10
3	PVC_half-inch_sch40	Leg-Extend (3")	4
4	PVC_cap	Default	4
5	PVC_half-inch_sch40	Connector (1.5")	12
6	PVC_half-inch_45elbow-2	Default	8
7	PVC_half-inch_sch40	Slope-Frame (18.45")	4
8	PVC_half-inch_sch40	Short-Base (4")	2

Some experimentation will be necessary to build the throwing arm and might be incorporated into a workshop. I made a throwing arm out of plywood with good success.

Demonstration: Show Mythbusters trebuchet prototype video:

- https://www.youtube.com/watch?v=9-Hwxw4fgqk

Teaming: Teams of 2-3 making sure youngest are teamed with older student(s)

Challenge: "Launch a mini-pumpkin as far as possible"

Warning
Be sure to use a rope to pull the trigger pin while everyone stands clear of the trebuchet.

For consistency, and if you don’t have mini-pumpkins, tennis balls may be used instead. See what modifications can be made to get the projectiles the farthest. Try launching different kinds of balls like golf balls and bouncy balls. See what happens when the sling is filled with several smaller bouncy balls.

Warning
Make sure to take necessary precautions to avoid having a projectile hit someone. Particularly with hard projectiles like golf balls.

Further Challenges: "Launch a mini-pumpkin into a target bucket"

Adjusting the pin on the sling arm can control the release angle. Changing the sling length will have an effect on distance. Safely increasing the conterweight will make the balls launch farther. Mounting wheels on the frame will make it launch farther.

Chapter 5

Workshop 5: LEGO Building Game Show

2016-11-08

Resources:

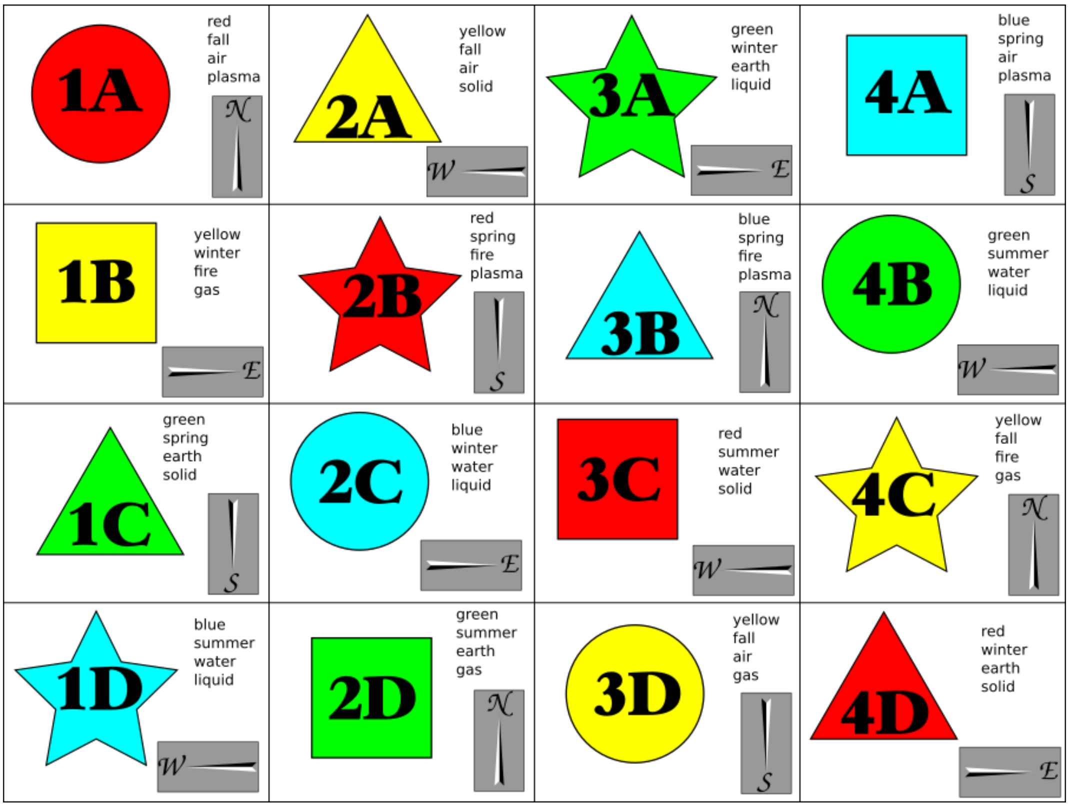
- http://www.bricklink.com/
- https://shop.lego.com/en-US/Pick-a-Brick
- https://education.lego.com/en-us/

5.1 LEGO Building Game Show

DISCIPLINES:

- Mechanical Engineering

Setup: You may come up with various ways to break the students into teams. For a class size of 16, print the team_cards document:



Cut out the cards and distribute one to each student. These will allow you to make 4 teams of 4 unique team members for up to 5 rounds. For example, starting with number, break the teams out into numbers 1, 2, 3, 4. Next round break the teams out by letter A, B, C, D. Unique teams with no students ever on the same team again can be made when the teams are broken out by: number, letter, color, shape and direction. If you have time for more rounds there's also season, element and phase but the teams won't be unique any more.

Divvy up the LEGO's so there's evenly distributed LEGO quantities at each team table.

RESOURCES:

- MythBusters LEGO Ball:
  - https://www.youtube.com/watch?v=KLWLTs90_po
  - https://www.youtube.com/watch?v=M8vdTXO0lpE
  - This is a great video to show the celebration of failure. Point out how many weeks of hard work it was building the ball and then what was everyone's reaction when it crumbled. Absolute joy!
  - Also see what else the class notices from the experiment. Another thing to call attention to was the safety precautions. Yes the experiment failed, but by making sure everyone is safe, nobody was in danger of getting hurt.
- LEGO Rube Goldberg ball run: https://www.youtube.com/watch?v=xwUg3sf4Lvo
- 10 most amazing LEGO machines: https://www.youtube.com/watch?v=3_q8O8xQnlQ

MATERIALS:

- Assorted LEGO's ($\geq$100 pcs assorted per student plus multiple figurines)
- LEGO Creationary cards or similar

Location: Classroom/Lab

Teaming: Teams of 2-4

Helpers Activities helper students may do: * Run time * Keep score * Sort/distribute/cleanup LEGOs * Judge

Preparation Show the MythBusters LEGO ball video and have a discussion about celebrating failute and practicing safety. What other comments do the students have on the experiment?

Explain that we're going to have a game show style challenge because a little competition makes it fun. But remember there's more to be learned by not winning. If another team gets more points, try not to get frustrated. Observe carefull what they did. Learn from your observations. Improve your own methods. Keep trying.

When something doesn't work shout "Hooray! Science!". Everybody together shout "Hooray! Science!". Maybe one more time louder. Then jump into the game.

Challenge: Play the LEGO Building Game Show

Pick a build time limit like 5 minutes.

Start with an easy level object card for each team. Each team should keep their card secret from the other teams. Also it may be helpful to pick objects with a given theme and make everyone aware of what that theme is.

Start the timer and have each team build their creation. The teams may use their LEGO minifigures as they see fit. You may pick build objects for the teams that would benefit identification via the use of minifigures.

At the end of the round, each team holds up their creations in turn while the others secretly write down what they think it is. Every team that gets a right answer gets a point. Every team that gets their creation judged correctly gets a point for every correct guess. The points can be tallied seperately and it will be interesting at the end to analyze which teams did the best guessing and which teams got the most correctly guessed builds.

For the next round teams may keep their creation and use it as part of their next build or take parts off of it as they need. You may want to distribute object cards specifically to encourage creative re-use or previous builds. Also you can tailor the object build difficulty as a handicap to help keep the scores fairly close.

Shuffle up the teams using the team cards after each round.

Keep track of the results entering the data in the lego_build_data_record spreadsheet each round. Save the data and run the Jupyter notebook data analysis program on the data.

FURTHER CHALLENGES:

- Decrease the allowed build time
- Only show the picture to the team and then take the card back instead of letting them keep it to look at the whole time
- Just tell the team what the object is without showing them the picture
- Provide multiple build objects per round
- Run a round where everyone works individually.
- Give everyone the same object and have each team rank every other teams build in order. Highest points to best rank.

Chapter 6

Workshop 6: LEGO Building Challenges

2016-11-15
Meeting on 11/22 is cancelled.

6.1 LEGO Engineering Challenge

DISCIPLINES:

- Mechanical Engineering

Setup: By selecting one building challenge activity for all of the teams to work on there is more opportunity for collaboration. If a team completes their project try to direct them on to additional challenges on the same project. They may also help out other teams or work on sorting the main LEGO collection.

Resources: The Educating Young Engineers website provides very good ideas for LEGO design challenges:

- http://www.educatingyoungengineers.com/lego-clubs/
- http://www.educatingyoungengineers.com/s/lego-club-how-to-guide-cagr.pdf
- http://www.educatingyoungengineers.com/lego-club-activity-ideas
  - Adam Savage LEGO Sisyphus: https://www.youtube.com/watch?v=U46Yo_6z_F4
  - MythBusters LEGO Ball:
- https://www.youtube.com/watch?v=KLWLTs90_po
- https://www.youtube.com/watch?v=M8vdTXO0lpE
- This is a great video to show the celebration of failure. Point out how many weeks of hard work it was building the ball and then what was everyone's reaction when it crumbled. Absolute joy!
- Also see what else the class notices from the experiment. Another thing to call attention to was the safety precautions. Yes the experiment failed, but by making sure everyone is safe, nobody was in danger of getting hurt.
  - LEGO Rube Goldberg ball run: https://www.youtube.com/watch?v=xwUg3sf4Lvo
  - 10 most amazing LEGO machines: https://www.youtube.com/watch?v=3_q8O8xQnlQ
  - Most amazing LEGO Sculptures: https://www.youtube.com/watch?v=dW9eHPkYLeo

MATERIALS:

- Assorted LEGO’s (≥100 pcs assorted per student plus multiple figurines)
- Meter stick/Tape Measure (Drop Test/Tallest Tower)
- Digital scale (Drop Test)
- Stop Watch or music source (Musical Monsters)
- Large plastic bins (Engineering Escapes)
- Tub of water (Boat Building)

Location: Classroom/Lab

Helpers Activities helper students may do:

- Measure
- Record data on whiteboard
- Sort/distribute/cleanup LEGOs

CHALLENGES:

- Drop Test
  - http://www.educatingyoungengineers.com/drop-test
  - Teaming: Individual
  - Combine exactly 20 LEGO bricks so that when dropped they do not break
    * If gathering 20 identical bricks for each student is too tall of an order, impose a minimum weight requirement (around the weight of 20 2x6 bricks).
    * Alternatively leave the requirements open and allow the students to record the number of bricks, drop height and weight of their creation. Evaluate correlations.
  - Use a meter stick to drop from progressively higher distances and record the max drop height before their structure breaks apart.
  - Have the students iterate to try to improve their height
  - Have a review discussion on successful strategies

Round	Number of Bricks	Weight	Drop Height
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

- Collaborative Monsters
  - http://www.educatingyoungengineers.com/musical-monsters
  - Teaming: Individual
  - Everyone starts bulding a monster. Use music or a stopwatch to indicate when to stop building and pass their creation off to their neighbor. Continue for several rounds and then review everyones creations.
  - Ask if any of the monsters turned out how they thought they would when they started building them.
- Engineering Escapes
  - http://www.educatingyoungengineers.com/engineering-escapes
  - Teaming: 3-5
  - Put a LEGO minifigure in a bin and have the team build a solution to get him out.
  - With each iteration, impose new challenges
    * No stairs
    * No elevators
- Tallest Tower
  - http://www.educatingyoungengineers.com/tallest-tower
  - Teaming: 3-5
  - See who can build the tallest tower.
  - Have teams request measurement checkpoints with a tape measure.
  - Discuss successful and unsuccessful strategies.
- Boat Building
  - http://www.educatingyoungengineers.com/boat-building
  - Reproduce the Uninskable Boat workshop except with LEGOS.

Chapter 7

Workshop 7: Cup Tower Battle

2016-11-29

7.1 Tower Build Battle

DISCIPLINES:

- Architectural/Civil Engineering

RESOURCES:

- Strong building towers with cups:
  - https://www.youtube.com/watch?v=iGRLY08Kn2o
- STEM Activities for Kids - Structure Building
  - https://www.youtube.com/watch?v=TycfVSTOI
- How tall can skyscrapers get?
  - https://www.youtube.com/watch?v=Cioj_KYMVP8

MATERIALS:

- Large Plastic cups
  - Alternatively building blocks, cut up 2x4's, paper/cardboard crafted blocks
- Tape measure
- Stopwatch
- Poster board for optional "earthquake" simulation activity.
- Materials for ball hurling contraptions
  - Spoons
  - Popsicle sticks
  - Rubber bands

- 10-20 foam balls or wiffle balls

Location: Gymnasium or outdoors

Preparation: Arrange tables so each team is on opposite ends. Be wary of students blocking ballistic projectiles between the build areas.

Demonstration: Brainstorm some ideas on the whiteboard with the class for good ways to build tall stable structures.

Teaming: Split the students into 2 evenly distributed teams or teams of 4-6 each. Having more than 2 teams may also be possible.

Challenge: "Build the best structure for a variety of challenges"

If you have enough materials, teams can build their architectural structures simultaneously. Otherwise one team can build their structure while the other teams constructs a ball hurling device that will be used to try to knock it down.

Start with a 5 minute limit. See who can build the tallest structure. Measure with a measuring tape and have the students make a schematic in their notebook of their structure and its dimensions.

If everyone was able to build their own structures at the same time then each team can be tasked with building it's own "wrecking ball" device to see who can knock down their tower with the fewest shots. Otherwise teams can pit their building again other teams wrecking contraptions. Be sure to encourage keeping track of the the results in the students notebooks.

Impose some limit on wrecking contraptions like "cannot be thrown" or must be launched from table using a mechanism.

For maximum pandemonium allow teams to launch their wrecking balls at each other during the build to help get their tower building team in the lead. Alternatively take build breaks and allow each team to take 3 shots at the other teams towers.

Further Challenges: An optional additional activity is to have the teams build their towers on a poster board. Then time how quickly they can move the poster board across the table without their tower falling.

Class Inquiry: What lessons were learned about building strong structures and effective projectiles?

Chapter 8

Workshop 8: Water Bottle Flip Optimization

2016-12-06

8.1 Water Bottle Flip Optimization

DISCIPLINES:

- Dynamics
- Data Analysis

RESOURCES:

- dy/dan BottleFlipping and the Lessons you throw back
  - http://blog.mrmeyer.com/2016/bottleflipping-the-lessons-you-throw-back/
  - https://s3.amazonaws.com/ddmeyer/bottle-flipping-media.zip
- Desmos water bottle flipping calculator
  - https://www.desmos.com/calculator/k54pcfbuy4
- https://en.wikipedia.org/wiki/Dynamics_(mechanics)

MATERIALS:

- 16-20 ounce water bottle per student
- Digital scale
- Measuring cups
- Water

Location: Cafeteria or large room with tables.

Preparation: Distribute data sheets for every participant.

Class Inquiry: Ask the class for ideas for the meaning of "Dynamics".

> Dynamics is a branch of applied mathematics (specifically classical mechanics) concerned with the study of forces and torques and their effect on motion.
>
> — Wikipedia *Engineering*

In other words, how something moves when acted on by forces.

Demonstration: Show the Desmos water bottle flipping calculator. Inquire of the class what they think it is demonstrating. Play with the various controls to change the motion. Point out the paths trace by the top and bottom of the model. Ask if anyone knows what the path is called. Introduce the parabola.

Show the Act 1 video from dy/dan's bottle flipping media. Ask the class to predict which of A,B,C,D trials will land standing.

Show the Act 2 video and pause on each trial. See if using the graph overlay and a parabolic path will help the predictions.

Show the Act 3 video for the results.

Teaming: Individual

Challenge: Find the optimum amount of water for successful bottle flipping.

Chapter 9

Workshop 9: Bridge Building

Further Challenges:
2016-12-13

Bridge Building Challenge

Chapter 10

Workshop 10: Hacking the Holidays

2016-12-20
Last meeting before Christmas/New Years break. Meeting on 12/27 will be cancelled.

Light up ornaments, noise makers, acoustic engineering. Tone beat frequencies. Snowman marshmallow cannons.

Chapter 11

Workshop 11: Reverse Engineering

2017-01-03

Reverse Engineering. Bring in broken gadgets from home/COG to disassemble.

Chapter 12

Workshop 12: Introduction to Electrical Engineering

2017-01-10

Electrical, Snap Circuits, Little Bits, Breakout Boards, Power supplies.

Chapter 13

Workshop 13: Electrical Engineering Projects

2017-01-17

Make Makey, soldering, electrical engineering

Chapter 14

Workshop 14: Software Engineering I

2017-01-24 This first workshop doesn't need a computer. Run challenges with Scratch programming using large foamboard cutouts of scratch command blocks, play Robot Turtle, get Marbles on Rails programming game put together. For the next workshop prepare by having kids get Scratch accounts with their parents. Next workshop will be in the computer lab.

Software engineering, coding, scratch, python, lightbot, TurtleArt

Chapter 15

Workshop 15: Software Engineering II

2017-01-31
LAST MEETUP FOR THE TERM

Chapter 16

Workshop 16: Computer Aided Design

2017-02-07

CAD, OpenSCAD, OnShape, Inventor

Chapter 17

Workshop 17: 3D Printing

2017-02-14 Meeting on 2/21 will be cancelled. Meeting is before Valentines Day.

3D Printing, Perler Beads, Foam Board layering, bring in printer, automation, plastics mfg.

Chapter 18

Workshop 18: Biomedical Engineering

2017-02-28

Biomedical engineering, 3D Printed hearts, Red blood siphon pump

Chapter 19

Workshop 19: Biomedical Optics

2017-03-07

Biomedical engineering, Optical Engineering Monoculight Maker Faire Edition

Chapter 20

Workshop 20: Optical Engineering

2017-03-14

Optical Engineering, telescope, microscope, Rochester cloak, giant Fresnel lenses

Chapter 21

Workshop 21: Mult-Disciplinary Engineering

2017-03-21

LED light mixer, multi-disciplinary, LEDs, Optics, Electronics, 3D Printing

Chapter 22

Workshop 22

2017-03-28

Chapter 23

Workshop 23: Crash Test Eggs Design and Build

2017-04-04

Egg Olympics build day. Egg drop, pine derby car. Zany categories: speed, force, egg survival, egg destruction

Chapter 24

Workshop 24: Crash Test Eggs Tournament

2017-04-11
Meeting on 4/18 will be cancelled Pre-Easter

Egg drop challenge Egg Olympics

Chapter 25

Workshop 25: Rocketry Design and Build

2017-04-25

RESOURCES:

- https://www.apogeerockets.com/
- https://www.amazon.com/Estes-1980-Designer-Special/dp/B0084JTDOS $60
- https://www.amazon.com/Estes-A8-3-Engines-Bulk-Pack/dp/B0006N6Z46 $55
- https://www.amazon.com/Estes-C6-5-Engines-Bulk-Pack/dp/B0006N6UIW $65
- https://www.amazon.com/Estes-Wizard-Rocket-Bulk-Pack/dp/B009EZPF02 $50
- https://www.amazon.com/Estes-302215-Porta-Pad-Launch-Pad/dp/B0006NAQ78 $15
- https://www.amazon.com/Estes-2230-E-Launch-Controller/dp/B0006MZKG6 $20

Rocketry, start build, Launch electronics

Chapter 26

Workshop 26: Rocket Launch

2017-05-02

Rocket Launch Zany contest categories: Longest air time, shortest air time, best crash, catch a recovery out of the air, loudest countdown, best decorated rocket, craziest flight pattern

Chapter 27

Workshop 27: Raspberry Pi Computer

2017-05-09

Raspberry Pi

Chapter 28

Workshop 28: Battling Robots Design and Build

2017-05-16

Battling Robots build

Chapter 29

Workshop 29: Battling Robots Tournament

2017-05-23

Battling Robots battle

Chapter 30

Workshop 30

2017-05-30

Chapter 31

Workshop 31: Engineering Showdown Games

2017-06-06
Last Day.

Engineering Showdown Games. Paper airplane challenge, egg toss etc. Challenges announced 15 minutes before each event. Each team then designs and constructs their entry before for competition.

Part II

Supplemental Workshops

Chapter 32

Supplemental 1: Straw Rockets

32.1 Straw Rocket

This demonstration can just as well be repurposed as a full class activity.

Attribution This rocket design is inspired by "Stefan" type Nerf darts: http://nerf.wikia.com/wiki/Stefan

DISCIPLINES:

- Aerospace Engineering

RESOURCES:

- http://buggyandbuddy.com/straw-rockets-with-free-rocket-template/
- http://www.pleasantestthing.com/make-straw-rockets
- http://www.instructables.com/id/Make-your-own-Nerf-darts.-AKA%3A-Stefans./
- https://www.youtube.com/watch?v=_kJodRNFphE

MATERIALS:

- Whiteboard
- Straw
- 5/8" Foam Backer Rod
- Business cards or thick index cards
- 3D Printed parts from: www.thingiverse.com/thing:1782060
- Optional: squishy bottle (a bottle that will survive stomping on and return to it's original shape)

Location: Large room or auditorium where all students have a good view.

PREPARATION:

- 3D Print the `Forming-Rod` in a rigid material such as PLA
- The `Straw-Holder` and `bottle-tube-coupler` are optional. Print these parts if you want to connect the straw to a squeeze bottle for launching.
- Print `Fin-Holder` and `nosecone-plug` in your material of choice.

  - Test the fit of a card in the slots of the `Fin-Holder`. Use a blade to clean out the slots for a good fit if necessary.

- Preferably print `nose-ogive` in a flex material for safety.
- Push the `nose-ogive` part onto the slotted side of the `nosecone-plug`. The friction fit should be sufficient or you may use glue if needed.

Challenge: "Design, Build and Launch a Rocket"

DEMONSTRATION

- Inquire of the group what are the parts of a rocket. Draw the parts on the whiteboard as they give them to you. Keep going until you get the key components:
  - Body tube
  - Fins
  - Nosecone
  - Engine
- For the body tube, cut a 3" (75mm) length of 5/8" foam backer rod.
- Use the 3D printed "Forming-Rod" to core a hole through the foam. Coring half way through from each side works well.
  - Alternatively a straw that has been cut with serrations may be used, but the 3D printed rigid tool is much more effective.
- Ask for ideas for how to make the nosecone.
- Introduce the 3D printed nosecone assembly and attach that to one end of the foam body tube.
  - Alternatives to the 3D printed nosecone might include a shaped piece of clay, candy corn or card stock formed into a cone.
- Announce that you plan to make the fins out of some business/index cards. Ask how you might cut 3 exactly identical fins.
- Stack three cards together and cut a fin shape of choice about 1" (25mm) in length.
- Ask how to attach the fins to the body tube.
- Slide the fin-holder onto the rocket body and attach the fins.
  - If you don't have the 3D fin-holder it should be possible to glue or tape the fins on. You may try scoring three a shallow slits in the foam body or folding the root edge of the fins to help attach them.
- Inquire for ideas about what to use for an engine.
- Bring out the straw and say that we'll use the straw as the engine. Slide the rocket on to the long end.
- Have the class do a countdown and on "blastoff" put the straw in your ear.
- Everyone should offer the suggestion that you need to blow into the straw.
- Do another countdown and blow into the straw like your saying "Ha" without closing your mouth around it.
- OK, this time for real, countdown an launch the rocket.

Optional If you've got a squishy bottle you can make a more powerful launcher. You'll just need a proper sized coupling to connect the bottle to the straw. The default bottle tube coupler included with on the thingiverse page will fit a 16mm diameter bottle opening.

Note
TODO: create a customizer for this to fit any bottle size.

- Slide the Straw-Holder onto the straw to secure it at a 90° angle.
- Connect the bottle and the straw together using the coupler.
- Get a volunteer to stomp on the bottle and launch the rocket after the class does the countdown.

Chapter 33

Supplemental 2: Siphon

33.1 Siphon

DISCIPLINES:

- Naval Engineering

MATERIALS:

- Large tub or large watertight storage bin
- 20ft of clear 1" diameter tubing
- Several large balloons
- Food coloring
- Step ladder

Location: Outside on a warm day near a water hose feed or in a lab/kitchen area with a large sink.

Demonstration Illustrate the workings of the siphon.

- Place the tub up on the step ladder and fill it with water.

Warning
STUDENTS MUST STAY CLEAR OF THE LADDER. A LARGE TUB OF WATER UP HIGH IS A FALLING HAZARD.

- Fill the hose with water, block it with your thumb and take one end out to demonstrate siphoning.
- Go to aim the end of the hose at the students but bring it up above the level of the tub as you do so and the water will stop flowing.
- Bring the hose down to look into the end "Huh I wonder why it's not working" to get sprayed in the face for raucous laughter.
- Partially block the tube output with your thumb to spray the water.
- Ask the class if they think you can spray the water back up into the tub and show what happens.

- Ask what will happen if an empty balloon is put at the end of the siphon. A balloon full of air? Hold the tube above the level of the tub to stop the flow of water and put a drop of food coloring in. Then try the different tests with the balloon.
- Fill the tube with water, add food coloring and plug it with your thumb. Bring it down below the level of the tub. Remove the end in the tub and allow some water to bleed out with your thumb so there is a large air gap on the tub side. Put the tube on the tub side back in the water. Ask the class what they think will happen when you remove your thumb and show them. Try it with different sized air gaps.
- Challenge the students for a way to get the siphon going without submerging the tube. If the water and the tube are clean enough, demonstrate sucking out the air in the tube to get the siphon started.

Important
WARN AGAINST ATTEMPTING THIS AS IT IS A CHOKING HAZARD AND SHOULD ESPECIALLY BE AVOIDED IF THE LIQUID IS TOXIC.

- Alternatively if there is a hose available to backfill the tube (or make a water balloon that can be used to back fill the tube) this also will get the siphon going.
- When demonstration is complete, drain the tub to a safe weight and take it down from the ladder.

Chapter 34

Supplemental 3: Ramp Racers

34.1 Ramp Racers

DISCIPLINES:

- Mechanical Engineering
- Automotive Engineering

RESOURCES:

- http://www.thingiverse.com/thing:1219729

MATERIALS:

- Ramp. A large board or table that can be tipped at an angle. You may even task the students to come up with a suitable ramp.
- Building materials on hand like gears, wheels, Legos, K'Nex. Let the kids find what they may.
- Stopwatch
- Ball
- Slingmobiles: http://www.thingiverse.com/thing:1219729
- Board or otherwise improvised road block

Location: Classroom/lab with materials on hand for improvised construction

Preparation: Write the challenge statement up on the whiteboard. Don't call the "racer" a "car" and don't call attention to the fact that it doesn't have to be a car. Many students may start out building cars.

Teaming: Students may form teams or work individually

Challenge: "Build a racer that is the fastest down the ramp."

As students complete their builds use the stopwatch to time their racer down the ramp. They should record each time in their engineering notebook. They are free to modify their racer and try again. Changes and new trial times are good details to keep records of in their notebook. Keep a leader board of times.

Ask them to review their notes to identify the changes that made the best improvement to their times.

CLASS INQUIRY:

- Why does the racer go down the ramp?

  - What is gravity?

- Put a car sideways on the ramp. Why doesn't it go down the ramp?
  - What is friction? Where is the friction? (High friction where the wheel meets the ramp, low friction on the wheel axles).
  - Can anyone come up with a racer that will slide (instead of roll) down the ramp?
  - How will larger or smaller diameter wheels affect the racer?

FURTHER CHALLENGES:

- Facilitator enter your own racer for a time trial. Start with just a ball. When the students object, point at the challenge on the whiteboard indicating that a "racer" doesn't need to be a car.
- Allow the kids to make a new round of "racers" and have them keep track of their new designs and times.
- Race your ball again this time giving it a strong rolling push at the starting line. Also not expressly against any rules.
- The kids will probably get carried away in the next round zooming their racers down the ramp.
- Add the constraint that the racers may no longer be pushed down the ramp.
- Bring out the Slingmobiles with their rubber band catapult and see how they do in the time trials.
- Invite the kids to build their own launching systems.
- Add a board or otherwise complete roadblock halfway down the middle of the ramp. See how the kids design around surmounting that challenge.

Chapter 35

Supplemental 32: Paddle Power

35.1 Paddle Power

DISCIPLINES:

- Naval Engineering
- Mechanical Engineering

RESOURCES:

- http://www-tc.pbskids.org/designsquad/pdf/parentseducators/DS_Act_Guide_complete.pdf
- http://pbskids.org/designsquad/build/paddle-power/
- Design Squad Season 2, Episode 8: Aquatic Robots

MATERIALS:

- Large tub or large watertight storage bin
- Stopwatch
- Internet Media Access
- Per team:
  - Chipboard cardboard (such as a cereal box)
  - Plastic tape
  - 2 paper cups ($\geq$8oz)
  - Plastic wrap
  - 5 rubber bands
  - Scissors
  - Straws
  - Washers
  - Dowels

Location: Inside or outside on a warm day

Preparation: Fill the tub with water.

Demonstration: Watch the Design Squad video when done. http://pbskids.org/designsquad/build/paddle-power/

Loop a 1x2" piece of cardboard through a rubber band hold taught between your fingers. Illustrate winding it up and letting it go to show how it spins.

Introduce potential (wound up rubber band) and kinetic energy (unwinding rubber band and spinning paddle).

CLASS INQUIRY:

- Where is the energy stored?
- How can the potential energy be increased?
- How can you tell when potential energy is being used?
- What are the different kinds of kinetic energy that occurs as the boat moves through the water?
- What other examples of potential and kinetic energy can you think of?

Teaming: Teams of 2-3. Partnering younger with older students.

Challenge: Build a boat that paddles itself using a rubber band as its power source.

Time how long it takes for the boat to travel across the tub. Have students keep records in their engineeering notebooks.

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