Design Technology and Engineering Education for Bilingual English Learner Students (DTEEL)

Teacher Handbook

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1. Introduction

In the following DTEEL lessons, students in K-5th grade work as engineers to learn concepts and apply what they have learned to solve design problems. The lessons are structured according to the 5E format, and include Design Briefs, or short challenge statements, which the students work in teams to solve. Each grade level has a series of units focusing on different aspects of engineering: Materials, Structures, Mechanisms, and Work & Energy. The last two grade levels add units that synthesize these engineering components with a focus on Systems. Importantly, each lesson includes instructional strategies to strategically integrate language use and engineering content. The curriculum is thus designed to build on the assets that emergent bilingual students (García, 2009) bring to the classroom and provide them with research-based instructional supports for their meaningful participation and learning in engineering education.

Goal

This curriculum will provide all students with a rigorous sequence of activities that develops practical problem solving skills with real materials. It will capitalize on bilingual English Learner (EL) students' strengths as problem-solvers (Bialystok & Majumder, 1998) through linguistically engaging STEM instruction. Students will also develop teamwork skills and an appreciation for differences and talents, as well as a critical appreciation for the human thinking that has created technology to solve problems, at times resulting in the creation of other, unforeseen problems. The introduction to and immersion in the engineering problem solving process works to support EL students' overall achievement and timely exit from the EL program, ultimately improving their opportunities to learn STEM effectively. The DTEEL project capitalizes on bilingual students' problem solving advantage[1] and the systems thinking orientation of engineering education to identify a curricular and systematic approach to improving bilingual EL students overall academic achievement and STEM competence in particular (Figure 1).

[1] For a brief review of bilinguals' advantages, problem solving and otherwise, see Callahan @ TheConversation.com, *Know more than one language? Don't give it up!*

Rationale

Curriculum in elementary science needs to engage children in more rigorous, interesting, and practical experiences. Such a challenge has been outlined in the Texas (TEKS) and Next Generation Science Standards (NGSS). Moreover, traditional approaches to teaching EL students often prioritize the English language over content learning, thereby contributing to disparities in their access to engaging and challenging STEM content. In response, DTEEL adopts a cross-disciplinary approach that weaves together research findings on inquiry-based science (Buxton, Lee, & Santau, 2008; Lee & Maerten-Rivera, 2012) and bilingual problem solving (Bialystok & Majumder, 1998; Secada, 1991) in alignment with the Texas English proficiency standards (ELPS). This approach suggests that EL students and other emergent bilinguals, well-versed in analyzing their worlds from multiple perspectives, may particularly benefit from an engineering systems thinking approach.

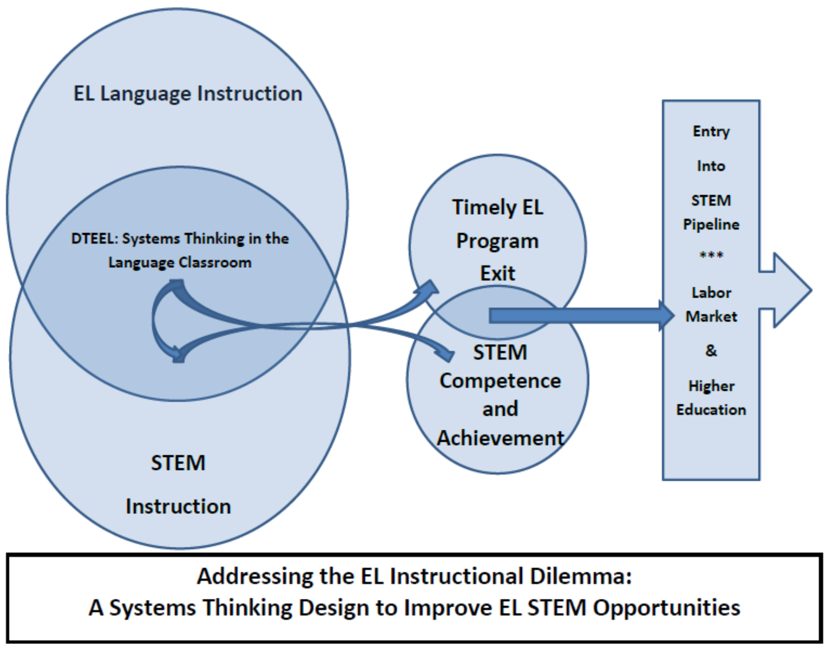


Figure 1: DTEEL Conceptual Model

Curricular Overview

Each grade level, kindergarten through 5th, contains between 8 and 9 units, each focusing on one of the following areas of engineering: Materials, Structures, Mechanisms, and Work & Energy. Later units in 3rd, 4th and 5th grades synthesize previous content in Systems thinking. All grade levels contain engineering activities designed to maximize collaboration, communication, and systems thinking (Katehi, Pearson, & Feder, 2009). Specifically, the activities:

- structure the use of language for **communication**—verbal, non-verbal, and text-based—to integrate students' STEM and linguistic development without compromising one to the other.
- incorporate a **collaborative focus** to facilitate the social, as well as STEM, integration of EL students necessary for their overall academic success.
- develop **systems thinking**, the ability to see a problem from different perspectives and view an issue from multiple angles.
- articulate clear **language objectives** for emergent bilingual EL students at varying levels of English proficiency.

Please refer to Table 1 for a visual overview of the DTEEL curricular units Grades K-5.

Acknowledgments
The DTEEL curriculum is a revision of the DTEACh curriculum, originally developed by Dr. Marilyn Fowler and colleagues, including but not limited to Drs. Richard Crawford, Kristin Wood and Jerold Jones, mechanical engineering professors at the University of Texas at Austin, and . Bobbie Sanders, former coordinator for gifted education in the Austin ISD. DTEEL lessons have been rewritten to follow the 5E format and to align with the New Generation Science Standards (NGSS), as well as the Texas Essential Knowledge and Skills (TEKS) in Science, and the Texas English Language Proficiency (ELPS) Standards by Dr. Rebecca Callahan, and Graduate Research Assistants Luis Fernandez, Andrew Hurie, Desirée Pallais, and Jasmine Welch-Ptak. Current work on DTEEL has been supported by the NSF DRK-12 Project #1503428 (PI: Callahan).

Table 1, Part 1 of 2: DTEEL Curriculum Grades K-2

	KINDERGARTEN			FIRST GRADE			SECOND GRADE	
1	**Materials: Our Material World**	Explore school to collect, observe and analyze materials.	1	**Materials: Natural, Processed and Synthetic Materials**	Identify and sort materials that are natural, processed, synthetic, and then recyclable and non-recyclable.	1	**Materials: Special Properties of Materials**	Classify materials according to properties of elasticity, shear strength, and tensile and compressive strength; name positive ways to communicate.
2	**Materials: Properties of Matter-Elasticity**	Test and sort objects that bend.	2	**Materials: Properties of Natural, Proceseed and Synthetic Materials**	Explore properties of durability, strength, and elasticity.	2	**Materials: Designing Experiments for Properties of Materials**	Use planning map to design portfolio; design a test to find materials that have certain properties.
3	**Materials: Making a Bendable Toy**	Work in teams to make bendable toy with 3 materials.	3	**Materials: Combined Materials and their Properties**	Explore combinations of materials, or composites, and find mixtures of materials around the classroom.	3	**Structures: Making a Strong Frame**	Use cardboard corners and adhesive to construct a basic wood frame. Add to their wooden frames to make a box out of their frame a box out of their frame.
4	**Structures: Containers and Boxes**	Compare faces of solid figures and match shapes to the containers and boxes they came from.	4	**Structures: Triangles and Trusses**	Find out how well different structures resist pushing and pulling forces.	4	**Mechanisms: Weird Wheels and their Axles**	Explore different places of connection with axles and describe the motion that results.
5	**Structures: Flat Space**	Predict shapes of boxes when flat by using cut paper rectangles.	5	**Structures: Making Strong Structures**	Explore how structures can be made stronger and weaker.	5	**Work & Energy: Black Box Thinking**	Identify input and output components of everyday situations; make side-view sketches of simple work systems; use "Black box thinking" to infer an event/ system by its input & output.
6	**Structures: Inside-Out Boxes**	Use reverse-box construction to make new structures.	6	**Mechanisms: We Use Balancing**	Explore the balance and pivot points of levers.	6	**Mechanisms: A See-Saw Playground**	Analyze input/output of a hidden lever system in terms of work and motion; infer the placement of the pivot point(s).
7	**Mechanisms: Exploring Wheels and Axles**	Explore shapes that do and do not roll.	7	**Mechanisms: A Card That Moves with Levers**	Draw mechanisms that will make a moveable card move. Make moveable cards.	7	**Mechanisms: Pop-Up Moving Scenes**	Make pop-up pictures that use cams and levers to illustrate a scene.
8	**Mechanisms: A Frame that Rolls**	Try different ways to make wheels and axles that will roll.	8	**Mechanisms: Mechanimals-Toys that Move Using Levers**	Make “mechanimals”, models of animals or characters that move using levers.	8	**Work & Energy: Technology Fair**	Make a toy that is safe, pleasing to look at, and has at least one moving part.

Table 1, Part 2 of 2: DTEEL Curriculum Grades 3-5

THIRD GRADE

1	**Materials: Changing Materials**	Use tools to change plastic, wood, paper, metal (foil) and cloth.
2	**Materials: Connecting Materials**	Use adhesives, nuts and bolts, paper fasteners and tape to connect materials.
3	**Structures: Models We Can Make**	Make a small model of a big structure and play a game guessing other teams' models.
4	**Structures: See-Saw Shoemobile!**	Find balancing points on a big mobile and draw free-body diagrams showing forces.
5	**Structures: Stable Structures**	Explore with simple structures and design stable structures that do not blow over in heavy winds.
6	**Mechanisms: Bean-Ho!**	Use black box modeling to design and make a device that will launch a bean a distance of at least 5 meters.
7	**Mechanisms: Linear and Back-and-Forth Motion**	Explore linear and back and forth motion with lever linkages and slider mechanisms.
8	**Work & Energy: Power-Full Things**	Find and label examples of work being done and differentiate systems that can do more work than others and systems that amplify input work.
9	**Systems: If-Then Logic**	Make models that demonstrate a chain of 3 connected events.

FOURTH GRADE

1	**Materials: The Materials Cycle**	Understand the production of some materials and demonstrate the Materials Cycle.
2	**Structures: Investigating Types of Loads**	Investigate properties of a variety of structures and forces, and lead a structural tour of the school.
3	**Structures: Testing Construction Techniques**	Explore ways to make and join structural members, then present on construction techniques.
4	**Mechanisms: Rotary Motion-Exploring with Gears**	Explore how gears work in various combinations to change direction and size of motion.
5	**Mechanisms: More Rotary Motion-Exploring with Pulleys**	Explore how pulleys work to change direction of motion and increase power in lifting.
6	**Work & Energy: Hydraulics-Exploring Water Power**	Explore transmission of power with water through syringe systems and waterwheels.
7	**Work & Energy: Pneumatics-Exploring Air Power**	Explore transmission of force with air by using and analyzing systems of syringes; discuss valves as mechanisms to control flow of water and air in systems.
8	**Work & Energy: Power-Full Toys**	Create a toy that moves by hydraulic or pneumatic power.
9	**Systems: If-Then Chains in a Gadget**	Reverse-engineer a toy and analyze the If-Then chain of events; make a diagram of the system.

FIFTH GRADE

1	**Materials: 'Green Music Makers**	Investigate properties of materials and create a musical instrument, and rate its green design.
2	**Structures: Bridges on a Budget**	Make a bridge that meets a cost constraint; use equivalent scales to determine value of bridge characteristics and score bridges' performance.
3	**Mechanisms: Mechanimals Design Project**	Make a toy or device that changes linear to rotary motion or vice-versa.
4	**Mechanisms: Reverse Engineering**	Reverse engineer a device and plan how it could be improved for certain uses.
5	**Work & Energy: Measuring Elasticity**	Determine the elasticity of different rubber bands and use one to find the weight of an object.
6	**Work & Energy: Elastic Launcher**	Design and make elastic systems that launch a ball to a target; select rubber bands and predict the distances based on their data about elasticity.
7	**Systems: Inventing with Control Logic**	Design new gadgets with two or more moving parts.
8	**Systems: Rube Goldberg Greetings**	Design and make a device that meets specifications.

2. Background Information

This section includes general information about scaffolding instruction for emergent bilingual EL students and about engineering education in the elementary classroom. Before offering this overall, we would like to acknowledge the fundamental importance of teacher attitudes and beliefs, especially about working with bilingual students. We applaud the work of teachers who consider the strengths that their students, particularly their bilingual students, bring to their classrooms and use this as the center of their curriculum.

5E Lesson Model

The 5E instructional model is widely used in science classrooms and other settings to promote inquiry learning. It is based on the constructivist notion that students develop their own knowledge and understanding through shared experiences (Dewey, 1938/2015). We present an overview of Bybee et al.'s (2006) model, adjusted for the goals and orientations of engineering in the elementary classroom:

Engage	•Makes connections between past and present learning •Promotes curiosity
Explore	•Attempts to preliminary solution (prototype) to the design challenge •Facilitates conceptual change
Explain	•Focuses on particular aspects of design challenge •Includes explanations from teacher
Elaborate (or Extend)	•Promotes the application of new understandings to previous designs •Challenges conceptual understanding and skills
Evaluate	•Assesses understanding and abilities •Provides opportunities for teachers to evaluate students' progress toward content and language objectives

(Adapted from Bybee et al., 2006)

Working with Emergent Bilingual Students to Support Academic & Linguistic Development

Many effective instructional techniques for all students also are important for emergent bilingual EL students. At the same time, instruction must be designed to meaningfully build on the assets that EB students bring to the classroom, and to facilitate their simultaneous learning of language and content (Goldenberg, 2008). The DTEEL curriculum incorporates various instructional approaches and strategies across the grades, which can also be employed in other subjects. We highlight a few of these below. Some strategies appear directly in the DTEEL curriculum, while others relate more to how teachers explain the lesson content and respond to the complex situations that arise within their unique classroom contexts.

Language Objectives

The language objectives in DTEEL help teachers focus on specific language **forms** and **functions** in each unit. Language forms refer to the structure of language, and include vocabulary often used in US academic settings (what some people refer to as 'academic vocabulary'), as well as other forms of the language like past tense verbs, prepositional phrases, and coherent paragraphs. Language function refers to the ways that language is used for different purposes. Some uses include persuasion, description, and explanation. These functions are employed across the language domains of speaking, listening, writing, and reading.

Promoting Home Language

A fundamental strength of EB students, the developing knowledge of two or more languages encourages the transfer of knowledge and concepts between the languages. If we know something in one language, we will know it in another, but we may need assistance articulating the specific ideas in the second language. Accordingly, DTEEL lessons encourage students to think about vocabulary and annotate their Design Briefs using their various languages and *all* of their linguistic resources.

Sentence frames

Using sentence frames as a regular part of instruction can greatly facilitate the transfer of knowledge between languages and the acquisition of new language forms and functions. These cloze (fill-in-the-blank) sentences provide students with a clear example of the language needed to successfully participate in the lesson activities. Oftentimes, these sentence frames are directly aligned with a unit's language objectives and employ specific language forms and functions. The following example comes from second grade unit 4, *Weird Wheels and their Axles*. For the two language objectives: 1) Describe actions using target vocabulary: *axle, cam, center, off-center, edge, near*; and 2) Describe spatial relationships using prepositional phrases in writing, the sentence frame encourages students to use the target vocabulary in order to compare the position of the axle and the resulting wheel movement:

When the axle is __________, the wheel ___________________.

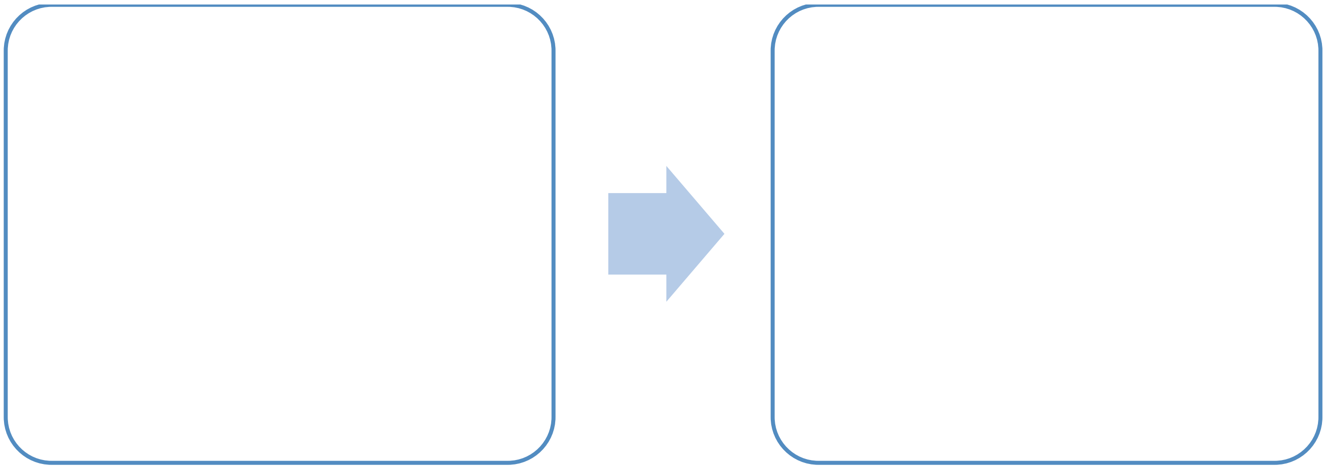
Turn & Talk

A key component of the DTEEL curriculum is collaboration among students, and the meaningful use of language to resolve engineering challenges. This requires the active discussion and debate among the students. The Turn & Talk is an instructional strategy in which the teacher usually poses an open-ended question to the group, and then the students discuss for a brief period of time (usually between 30-90 seconds). Not only does this involve conversation, it also gives EB students an opportunity to rehearse their ideas before sharing in a large group. Furthermore, it provides the teacher with an opportunity to quickly assess the students' understanding and possibly revisit a lesson concept if needed.

Graphic Organizers

A common tool in many US classrooms, graphic organizers help EB students visually organize information. Extending the example above from the second grade unit, Weird Wheels and their Axles, the graphic organizer below encourages students to contrast how the placement of the axle affects a wheel's movement. Notice how the exit slip below includes a graphic to emphasize this contrast, as well as sentence frames to structure students' written responses:

Describe the changes in motion produced by working the cam.



When the axle is __________, the wheel _________________.

Collaborative Dialogues

To emphasize student language production, the DTEEL curriculum includes collaborative dialogues, which serve as a way for the teacher to encourage and scaffold students' exploration of lesson ideas and use of academic language in a small group setting. Collaborative dialogues most often occur during the Explore phase of the 5E cycle while students are working collaboratively with their peers to resolve the design challenge. These dialogues are based on the idea of 'instructional conversations' (Goldenberg, 1992; Saunders & Goldenberg, 2007) whereby teachers seek to promote discussion among students, respond to their contributions, and maintain connected discourse focused on the lesson theme. In addition, the Collaborative Dialogue template (on the next page) includes question stems that increase in specificity to help guide student responses (Levine & McCloskey, 2012). It is important to remember that in these dialogues, the teacher is not the main talker, but rather s/he encourages students to voice their own ideas by posing questions, rephrasing, and synthesizing ideas. The goal is for students to talk at least 80% of the time (Diaz-Rico, 2013).

Additional strategies to consider include:

- Using photos, videos, and realia (real life objects) to help illustrate ideas
- Adjusting rate of speech
- Using gestures and movements
- Encouraging students to use gestures and movements

Collaborative Dialogue Template for Teacher

Increasing Specificity

Open-Ended Questions (OE)	Tell me what you know about… What did you discover about…? What did you find out about…? What can you tell me about…?
Wh- Questions (WH)	What happened when you…? What caused the…?
Either/Or Questions (EO)	It happened because ____ or ____? The ______ or _____?

(Adapted from Levine & McCloskey, 2012)

Focus Students

Student	**Content Objective**			**Language Objective**		
	OE	WH	EO	Own	Prompt	Model

Engineering in the Elementary Classroom

The DTEEL curriculum encourages students to design their own solutions to engineering challenges in the form of design briefs. A Design Brief is a problem statement that presents the challenge to be designed. In this curriculum, Design Briefs ask students to create products that apply engineering content they have learned within context of their interests and experiences, literature, social studies, or other sciences. The teacher must encourage an atmosphere in which diverse thinking is valued, in which students are trusted to come up with ideas, even if the time frame for completion is not what the teacher expects. The notion of quality should be emphasized. Students should be shown that the solving of a problem by teams is not competitive, that the whole class shares a problem and everyone has a part to play in helping other teams solve the problem.

Teachers should model the safe use of equipment and announce that only teachers use certain tools. Teachers should not model, however, what student products should look like, for the teams should make their own mental image of what they want. Children who see the teacher's design of an object must be encouraged to make something that looks different. Students are given the opportunity to learn through their mistakes, for this is the nature of trial-and-error, the cornerstone of progress in science, technology and invention. The teacher is a guide. By giving the students only the basic information that applies to structures, for example, the students are free to carry out their conceptualization of what a structure is to their most creative ability. By asking questions that require the students to evaluate their own products and their work in teams, teachers direct students' attention toward monitoring themselves and their progress.

With this general description of the engineering classroom, we offer some definitions of important concepts and practices that will support implementation.

What is technology?
Technology is a body of knowledge and actions used in applying resources, developing, producing, and using artifacts and systems, extending the human potential, and controlling and modifying the natural and human-made environments. (International Technology Education Association, 1993).

What is engineering?
Engineering is the application of scientific and mathematical knowledge and problem solving skills in order to develop technological systems. Examples include the changing, connecting and combining of materials in structures and mechanisms.

What is design?
Engineering design is the process of devising a system, process or component to meet desired needs. It is a decision-making process in which basic science, mathematics and human needs criteria are applied in order to best use resources in meeting an objective. The design process involves steps to use when given design briefs, beginning with asking questions in order to clarify the problem, planning and creating a model, and eventually testing a prototype against the specifications in the design brief.

Design process
The ways in which people solve design problems are very different. Experts such as artists, architects, city planners, repair technicians, and engineers may say they have different approaches, but they all start with a "fuzzy situation," then clarify and define a problem, then test new ideas. They also modify and re-visit their plans. The figure below shows the design process we use in DTEEL trainings that was adapted from what is taught to engineering students.

Identify the problem
Clarify the task
Elaborate expectations

Develop specifications
Identify functional requirements
Identify constraints

Conceptualize
Brainstorm possible solutions
Evaluate ideas against specifications
Make preliminary sketches
Evaluate and refine
Select best idea

Plan and select materials

Produce a Model

Evaluate and test feasibility

Modify

Reflect

I	**I**

Planning with Blueprints and Sketches

In these activities, planning is an important part of the design work. Students who do not sketch may cut paper shapes and paste them into a pattern that shows what they plan to do. Though these collages may seem unrelated to the final product, the children know what they are and often can explain them. Once children have made a picture, in some way, of their plan, they should label the parts as well as the materials they plan to use in the construction. They should then show the plan to the teacher for an okay to begin making the model.

Working Portfolios

The purpose of the portfolio, a collection of design plans, sketches, ideas, and notes, is to let children review their progress and their work together. It may also give the teacher some evidence for unusual skills and creative abilities of some students. Though the intention is for one portfolio to be kept during the lessons presented here, children may have their work in more than one portfolio. Teachers may use folders or envelopes, letting the children decorate them as they wish.

Plan to have each team keep a portfolio until they have completed one Design Brief, then start a new portfolio. If teams remain together, they can carry through with a portfolio into the next project. All portfolio materials, planning sketches, etc., should be displayed with the Design Brief projects.

Portfolio work can inform parents and educators on student progress and skills and give authentic evidence of abilities in writing, research, mathematics, and thinking.

Assessment of Design Work

Several aspects of design work can be assessed and converted into scores or grades. Students should be involved in determining assessment criteria. At the outset of project work, the teacher can present the content and skills she will be looking for and ask the children how she might know if they have those abilities. Together the class can create an assessment instrument with a rubric for content, skills, product, and other dimensions of interest.

For example, to assess the teams' responses to the first design challenge, to "make a small model of a big thing," the class' rubric might look like Figure 1.

e rnin o l	ect tion nd tin	erfor nce	
	es e les of odels		
	Excellent	Shows 3 things that are models	
	Fair	Shows one thing that's a model	
	Identifies t e of teri ls		
	Excellent	Shows three examples of each materials group.	
	Fair	Shows one example of each materials group	
	es se er l different tools to c n e teri ls.		
	Excellent	Names 5 tools	
	Fair	Names 3 tools	
I	**or s ell it rtner**		
	Excellent	Shares all work and ideas.	
	Fair	Shares some work and ideas.	
	ses tools s fel		
	Excellent	Uses all tools correctly.	
	Fair	Uses some tools correctly.	
	Meets s ecific tions of c llen e		
	Excellent	Makes a model of a big thing; shows natural and processed materials.	
	Fair	Makes a model of a big thing; cannot show natural and processed materials.	
	Meets constr ints of c llen e		
	Excellent	Finishes within time limits, uses available materials.	
	Fair	Takes extra time or materials.	
	roduct is le sin to loo t		
	Excellent	Edges are even; no loose tape, colors and design are interesting.	
	Fair	Some loose parts or uneven edges, not much color.	
		TOTAL	

I M I I

Design Briefs

A Design Brief is a problem statement or challenge that presents the challenge to be designed. In this elementary curriculum the Design Briefs ask students to create products that apply the science content they have learned within context of their interests and experiences, literature, social studies, or other sciences.

The Class Log

The Class Log is a record of the class' experiences in which the teacher writes the students' stories about the day's work. The Log provides evidence of improvement the class can witness, such as an increase in idea diversity or material use, or better teamwork. Teachers might use the Log to summarize the day's work during a class discussion. The Class Log may also be a Big Book that the teacher creates for the class.

The Design Gallery

The Design Gallery is a bulletin board or table set up in the hall upon which student teams place their products and display their dictated stories about the products and teamwork. The Design Gallery should be located where other classes can see the work, especially classes who will be involved in the Technology Fair.

M teri ls

I ort nt once ts out M teri ls

Materials can be changed by cutting, shaping, expanding, folding, sanding, molding, melting, and many other processes.

Materials can be connected by gluing, pasting, hooking together, snapping together, using nuts, bolts, screws, rivets, string, heating and melting, and other ways. Use your imagination and look around you: the evidence is everywhere!

Materials are combined because it improves their properties, feasibility and the economy of making the product. Paper plates are coated with plastic to make them waterproof. Steel is painted so it won't rust. Clothing is treated so it won't wrinkle. Wood is covered with plastic and used as countertops. Layers of wood veneer are glued together with grains crosswise to make a stronger wood product.

In the DTEEL lessons, students gain awareness of natural, processed, and synthetic materials around them.

ro erties of M teri ls

Durability is a material's ability to last a long time without losing other desirable properties such as strength, color, elasticity.

Strength of a material is measured in several ways, including *tensile strength*, which is the ability of the material to resist pulling forces (tension), and *compressive strength*, the ability to resist pushing forces (compression). You might write on the chart: Something is strong if you can push and pull it and it won't break. Materials are also subjected to *shear* forces, forces applied in opposition such as wringing a wet washcloth or tearing; and *torsion* forces are twisting forces.

Elasticity is the property of being able to stretch and then return to original dimensions. Materials that are elastic will return to their shape after loads are applied. Some materials are *plastic* in nature, that is, they are flexible to a certain point, and after that they won't return to their original shape.

Materials have many other properties such as electrical conductivity, magnetism, opacity to light, resistance to high-temperature, density, and a host of additional characteristics that play into the engineer's planning and design.

o osite nd o ined M teri ls

Composite materials are very common in our daily lives. Ceramic materials (pottery, concrete, china, glass or brick) might be combined with metal for decoration or for strength. In addition to mixing particles to make a new material, materials are often adhered to each other for special purposes. Wood is often used as a backing for vinyl tabletops. Sand is glued onto heavy paper to make sandpaper. By combining materials, we improve the properties of products that need better strength, durability or elasticity.

M teri ls nd ec clin

Natural materials generally are recycled by wearing-down processes (weathering and erosion). The minerals that make up natural materials are returned to nature and eventually may be incorporated in other materials. For example, the carbon in wood returns to the soil and may make its way into new plants, and minerals may be cemented together by sediment or pressure.

Processed materials are those that have natural origins but have undergone some change in a factory or other place where people work. Plywood, for example, is made of wood, a natural material, but it is layered and glued for strength in assembly or processing. Ceramics are made of natural clays or sand, but are melted and/or combined with chemicals to produce products we know as "china," pottery, and glass. Many processed materials are eroded by weathering in nature and return to the soil as minerals.

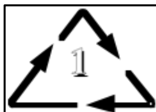
Synthetic materials, in contrast, are entirely fabricated by people, and are not recycled by natural wearing down processes. The plastic milk jug can remain in a landfill for years and years, simply breaking down into smaller bits of milk jug: The minerals, the petrochemicals used in its manufacture, will not return to the soil.

In most communities many materials can be recycled. Plastic containers bear a recycling numeral inside the international recycling symbol (a triangle made of arrows).

Plastic Container Code for a #4 plastic container

The numeral, from 1 to 7, indicates the type of plastic used in the container. The types of plastic acceptable for recycling vary with market demands. Check with your local recycling group to determine current plastics they will accept.

Plastic grocery and produce bags can be returned to grocery stores for recycling.



Green and clear plastic soda bottles,
made of PET plastic (polyethylene terephthalate)

Milk jugs and water jugs, made of HDPE (high density polyethylene)

Bottles or containers made of PVC (polyvinyl chloride)

Lids or containers made of LDPE (low density polyethylene)

Containers made of PP (polypropylene)

Containers made of PS (polystyrene), may be hard like yogurt cartons or styrofoam, if injected with air.

e c in t e ot l M teri ls cle

The *Total Materials Cycle* shown in Figure 4 can be used as an organizational aid for teaching the *whys* of reducing, re-using, and recycling, the “three R’s” of wastestream reduction education.

ner is t e otto ine

The further a raw material must go in the Materials Cycle, the more energy is used in its processing. This energy can be expressed as “solar dollars,” a term that encompasses the entire spectrum of energy consumption beginning when the raw materials were created. These solar dollars include the energy that allows the creation of the original biomass or mineral, the energy used to prospect, mine, and transport materials, *and* the energy needed to train, feed and transport the human resources involved in the process.

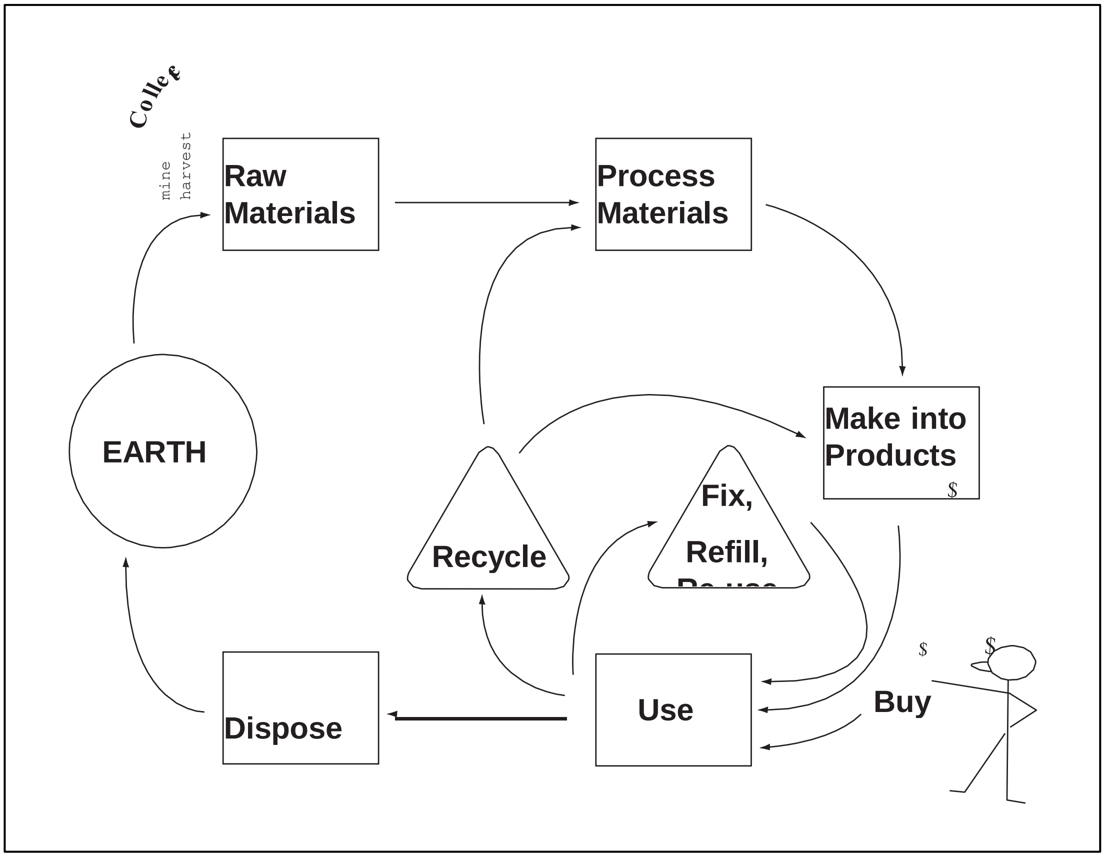
Along every stage of processing, additional solar dollars are consumed. Sometimes these dollars are not reflected in the actual cost of the finished product. Costs of replenishing (if possible) the supply of raw materials are not often figured into product costs, for example.

Consumers who want to conserve energy will *reduce* their purchase of non-recyclable packaging and products, *re-use* packaging and products, and *recycle* organic and inorganic materials so that as few items as possible enter the DISPOSE phase of the Total Materials Cycle.

sin t e cle in t e l ssroo

Make a bulletin board of the Total Materials Cycle. When you ask students to bring in examples of materials, attach the samples to the bulletin board at the appropriate processing phase. Have students research the production of different materials and add their information to the bulletin board. You may have to guess about where to place some materials. For objects such as toys made of a variety of materials, you might like to use yarn to connect parts to different places on the cycle. Collect articles or headlines related to materials processing and attach them to your bulletin board also.

Ask the students if any can find activities people do in the Materials Cycle that help prevent pollution and filling up the Earth with waste. You might call this section of the Materials Cycle the “Green Loop.” The Recycle-Fix-Refill-Re-use actions allow materials to skip the step of disposal.



I M I <u>**tructures**</u>

once ts out tructures

<u>Structures</u> are objects built to provide support. Structures can also be rigid or flexible, durable or breakable, permanent or temporary. In the Level B lessons, Equilibrium is explored as a structural concept.

Equilibrium is balance. Objects are in equilibrium when forces pushing down and up and around are equal. An excellent tool for demonstrating equilibrium is the math balance. When the force of masses on one side is equal to the force on the other arm of the balance, we have equilibrium.

<u>Mec nis s</u>

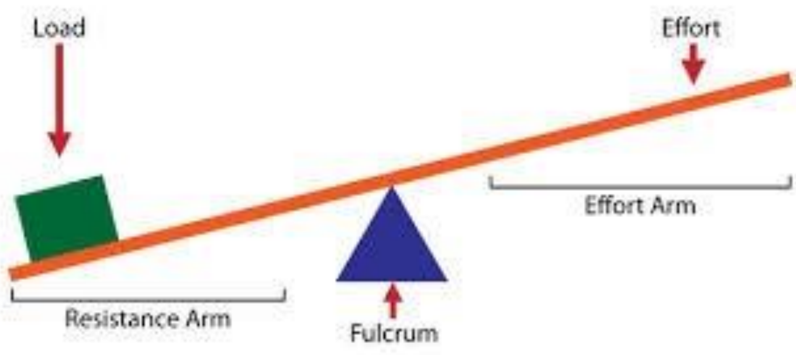
once ts out Mec nis s

<u>Mechanisms</u> are the parts of machines that allow motion. Wheels, levers, linkages, cams, pulleys, and gears are examples of simple mechanical components that can be used by children to create projects that move.

In Level B, levers, linkages, and cams are the mechanisms explored.

e ers

The purpose of introducing levers at this level is to give experience with levers in many applications, and to see the change in direction of motion afforded by this simple mechanism.



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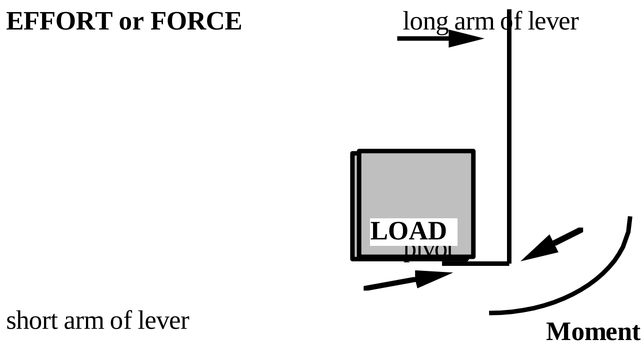
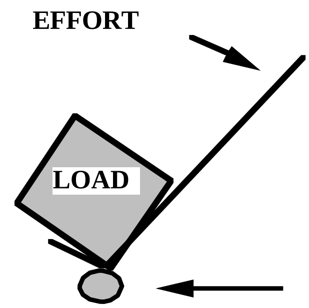
Levers are beams with a fixed point, called a pivot or fulcrum. They are mechanisms that change direction of motion and, most importantly, can give an advantage when lifting heavy objects. When a LOAD (the weight) is at one end of a lever, EFFORT (pushing down on the opposite arm of the lever) must equal the force of the LOAD in order to lift it. If, however, the fulcrum is moved so that the EFFORT is exerted on the longer arm of the lever (is further from the fulcrum) and the LOAD is on the shorter arm (closer to the pivot), less effort is required to lift the load.

When a mechanism gives an advantage such as this, we say it has provided "mechanical advantage." A box that is full of books might be too heavy to lift, but you can use a hand truck (below) as a lever, and, with the aid of wheels, can not only lift the box from the ground but also take it to the bookroom.

GETTING THE BOOKS TO THE BOOKROOM:





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s

Cams are “eccentric wheels,” mechanisms that rotate about an axis like a wheel, but the motion is uneven either because the axle is placed off-center or because the cam is not round. Look at these examples:

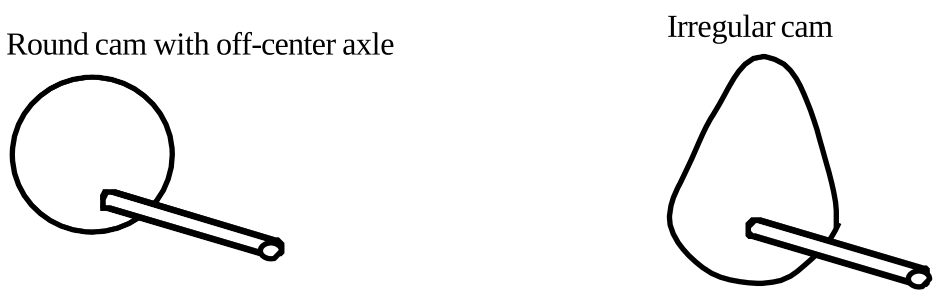


FIGURE 7. ROUND AND IRREGULAR CAMS

Cams are paired with “followers,” levers or shafts that move in a rocking or up-and-down fashion as the cam turns. Figure 8 shows sequential steps of a cycle of two cams—round and irregular—and its follower (in this case the follower is a lever).

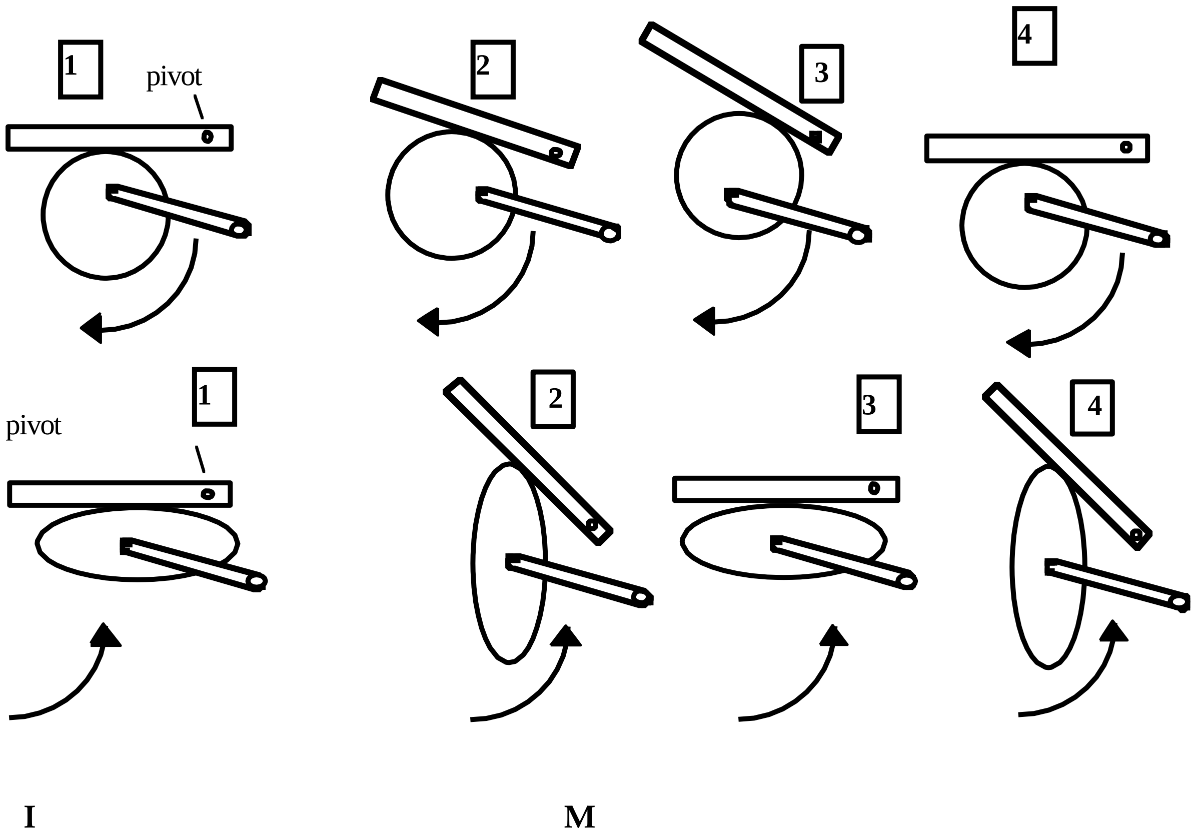
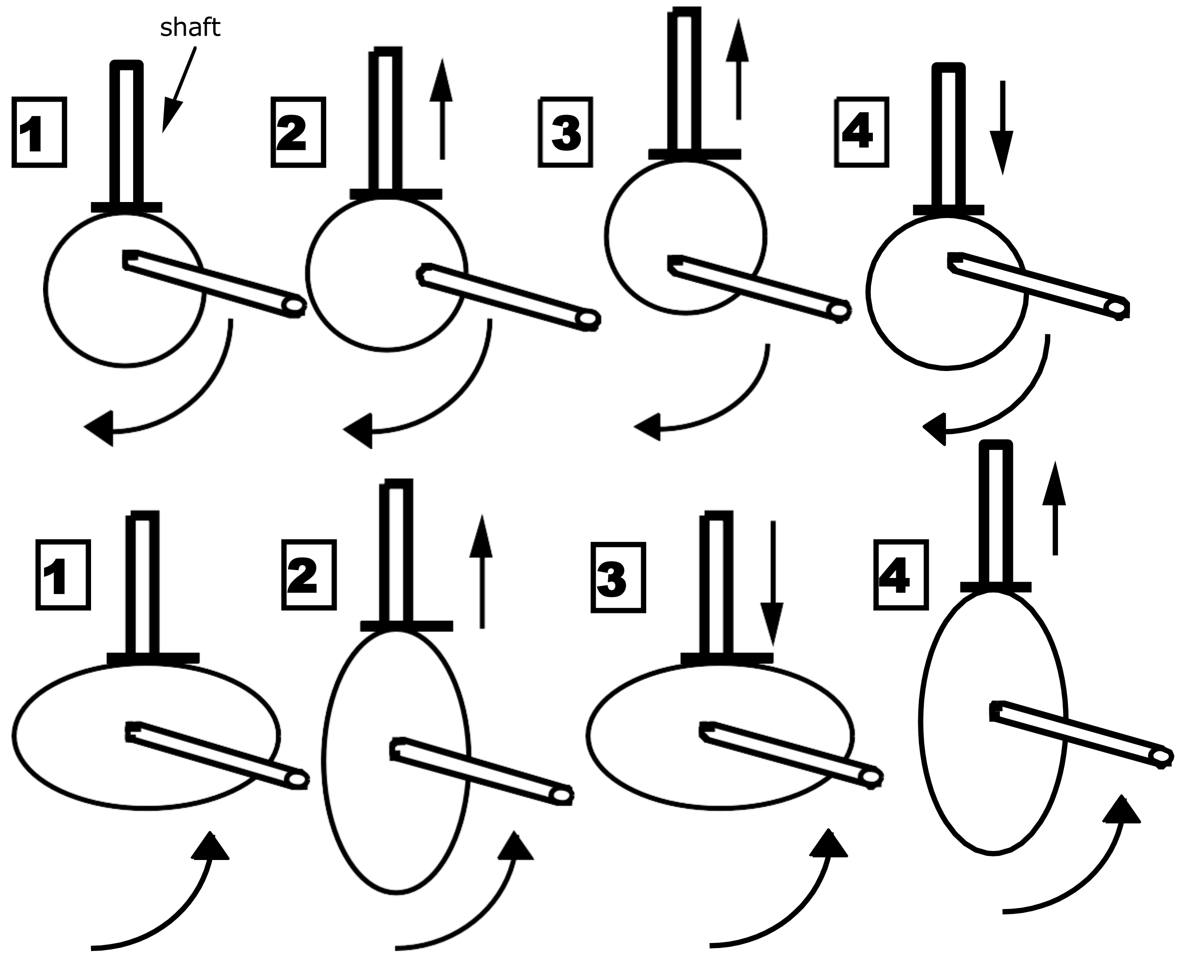
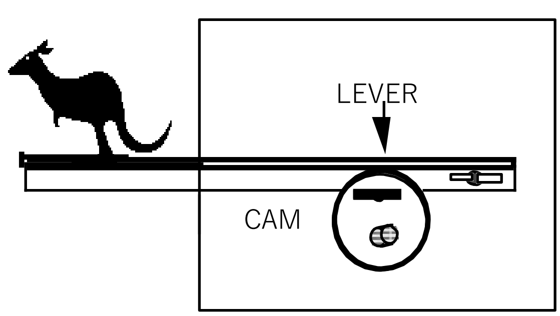


Figure 9 shows the same cams with shafts rather than levers as followers.

Cam-and lever systems can be made on posterboard such as the example in Figure 10. Cam-and-shaft model systems are best made in a cereal or other box, for the shaft needs a guide which can be incorporated into the space within a box easily:



I s it c s fts s follo ers



I c odel de on oster o rd

ner

once ts out Motion

Linear motion is motion in one direction (example: pushing a lever forward).

Reciprocating motion is linear motion that goes back and forth (example: pushing and pulling a lever back and forth; the piston in an engine moving up-and-down).

Rotary motion is motion in a circle (example: the hands of a clock moving, or a wheel on an axle).

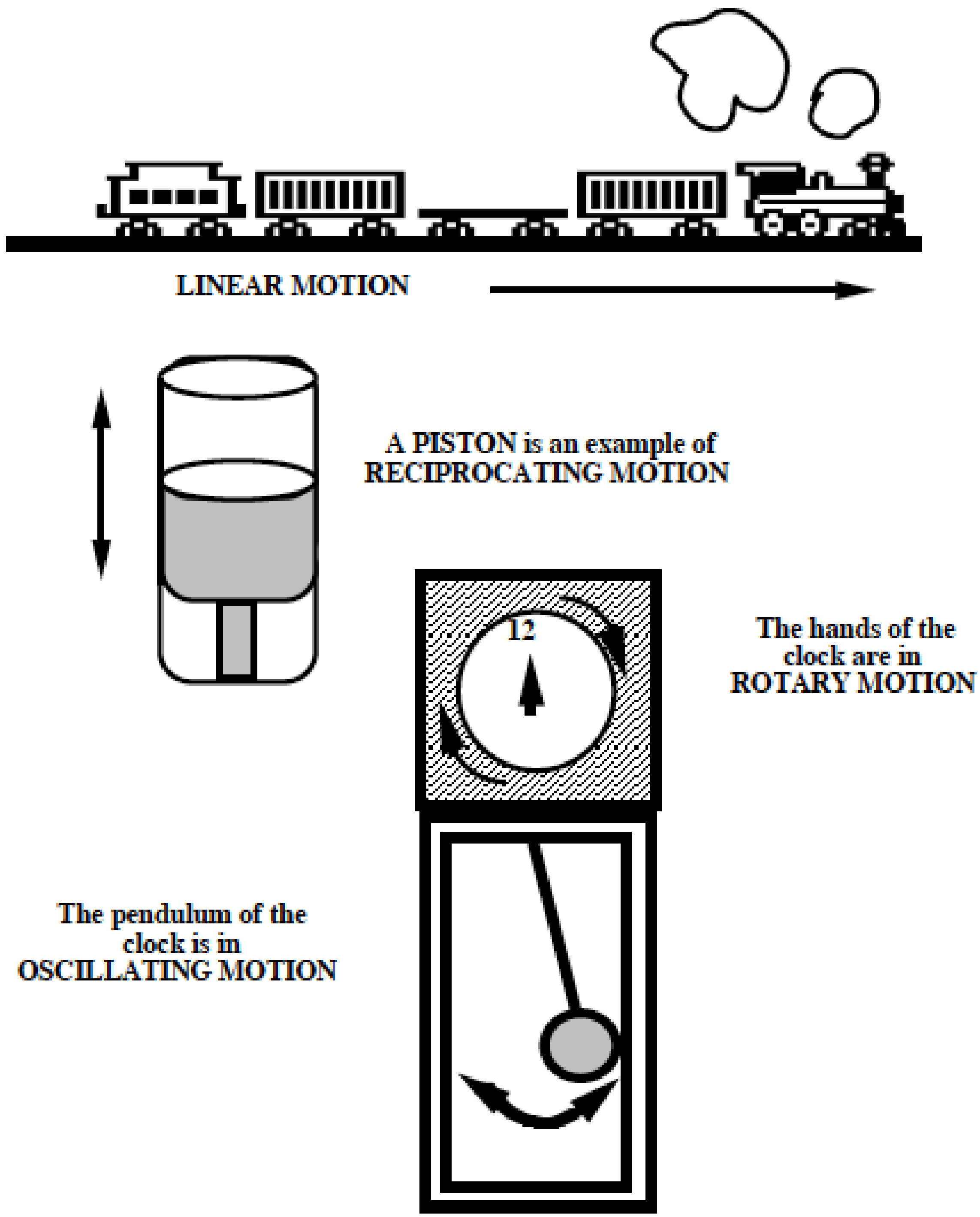
Oscillating motion is circular or arc-motion back and forth (example: the swing of a pendulum or the turning and release of a doorknob).

once ts out ner

Energy is usually thought of as energy of motion, or *kinetic* energy, or the energy stored in mechanisms like springs or in elastic items like rubber bands. The stored energy is called *potential* energy. Students work with potential energy stored in rubber bands in Level B by making rubber band-powered paddleboats or other vehicles.

The following terms are used frequently when describing motion. The purpose of their inclusion here is for the teacher's information and as a resource to students who inquire about the terms during work with design and technology.

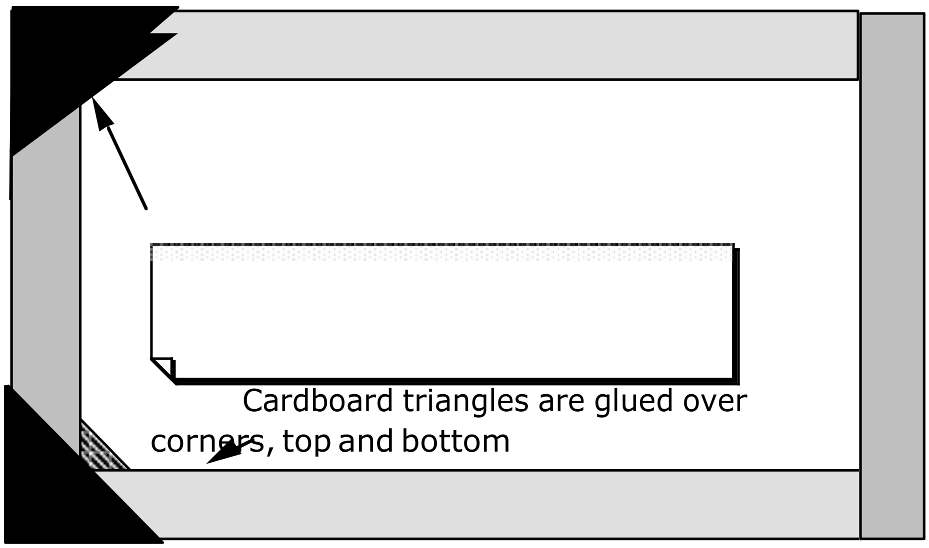
Speed: The time rate at which a distance is covered by a moving object
Velocity: The speed of a body or object and its direction
Acceleration: The rate at which a velocity changes with time
Kinetic energy: Energy of motion
Potential energy: Stored energy that a body possesses because of its position with respect to other bodies

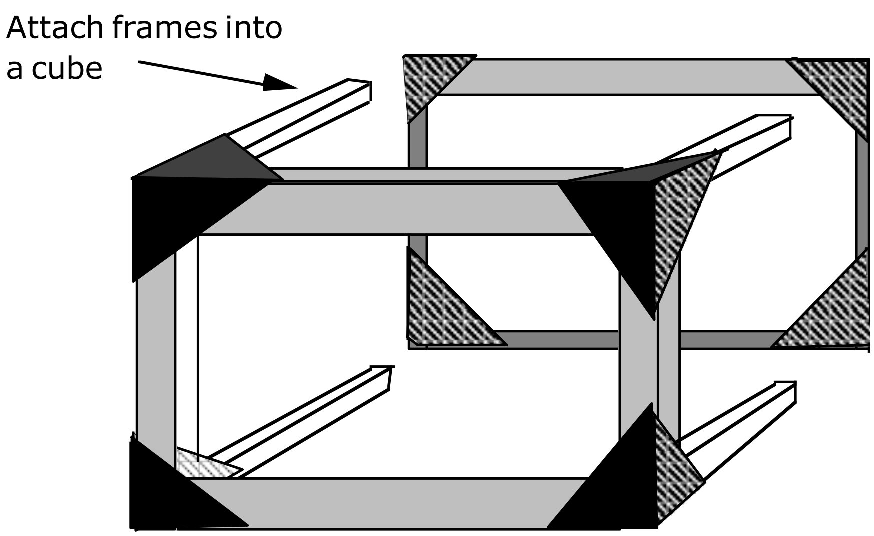

LINEAR MOTION
A PISTON is an example of
RECIPROCATING MOTION
12
The hands of the
clock are in
ROTARY MOTION
The pendulum of the
clock is in
OSCILLATING MOTION

I **M** **I**

Instructions for Making Models

Basic Wood Frame with Cardboard Triangle Corners





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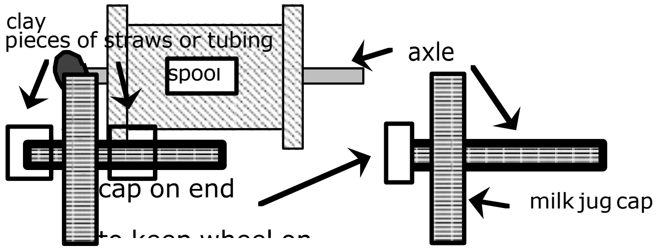
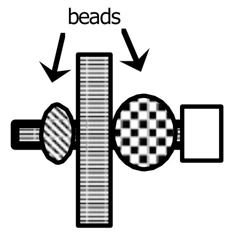
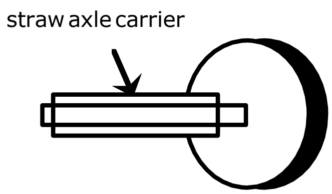


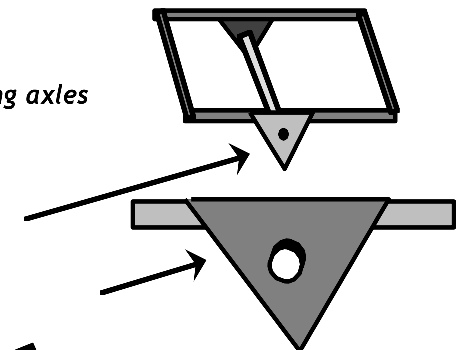
Free- rotating wheels on fixed axles



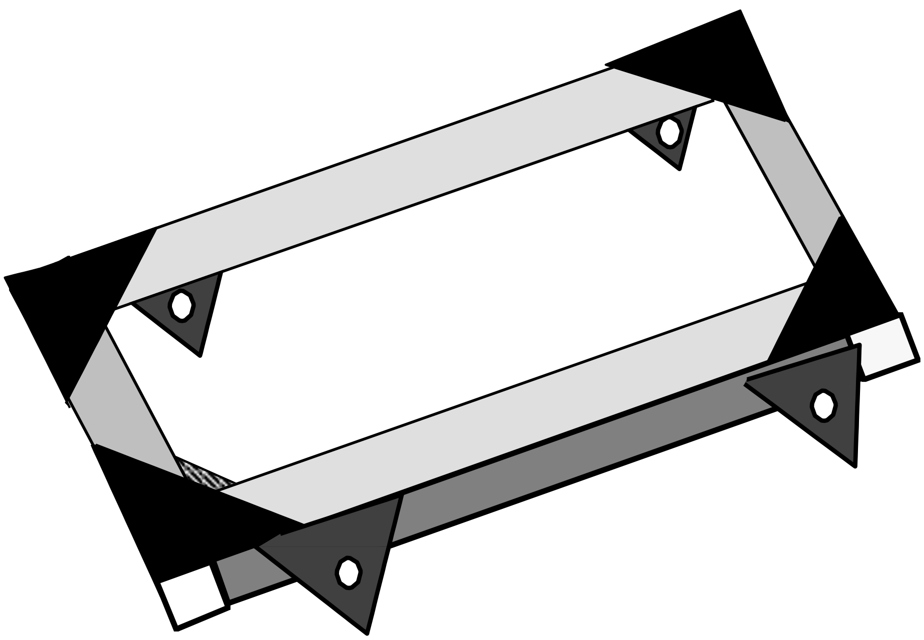
Spacers and bearings



Wheels fixed on free- rotating axles



cardboard triangle axle carrier

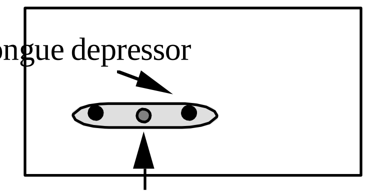


I s to do eels les nd s cers

les to M e for t e e el essons

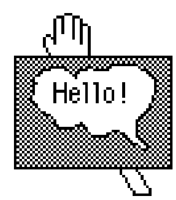
Need:
Strip of posterboard or a tongue depressor w/3 holes drilled
Large paper fastener (brad)

Posterboard piece for backing



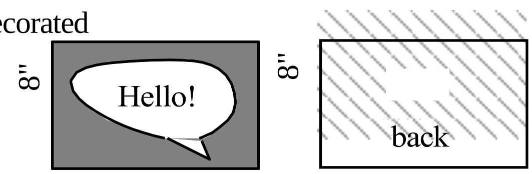
I M

Card that moves with levers
Need: Manila folder or posterboard, strip or stick for lever
Exacto knife, paper fastener, pieces of straws, glue



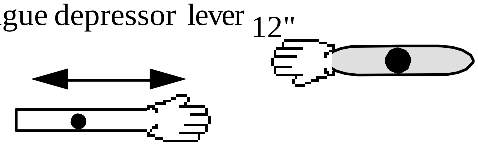
Front is decorated

10"

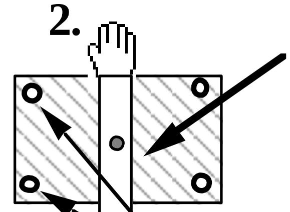


1. Attach hand to posterboard
strip or tongue depressor lever

12"

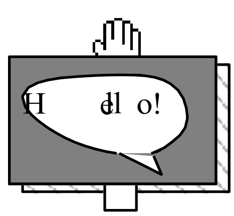


2. pivot



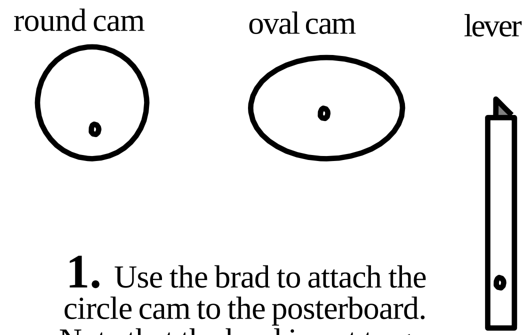
Glue 1/2" pieces of straws upright onto back edge to be spacers

3. Glue front onto tops of straw pieces



I M I

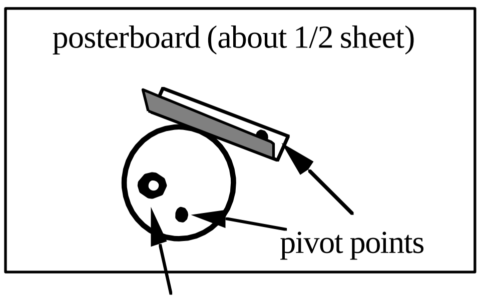
Need:
Posterboard, about 14" x 9" or 1/2 sheet
Circle and oval cut from posterboard
Lever made from folded posterboard
Glue
Paper fastener
Piece of straw or short stick for handle



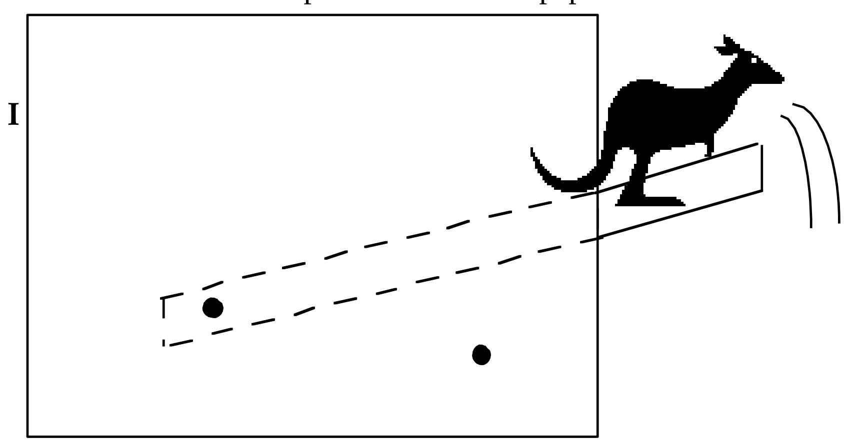
1. Use the brad to attach the circle cam to the posterboard. Note that the brad is not to go through the center of the circle.

2. Glue the straw piece to the cam as a handle. Let dry.

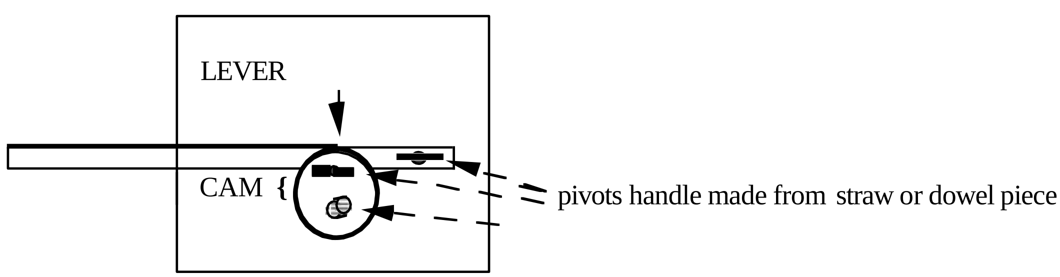
3. Place the lever where it rests upon the top edge of the cam.



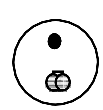
Attach one side of it to the posterboard with a paper fastener.



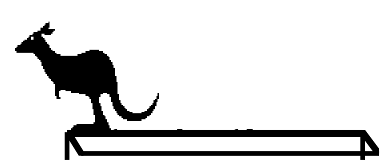
1. Construct model in a cereal box or on stiff posterboard.



2. Cam is a thick cardboard wheel or plastic container lid, with hole punched for an off-center pivot.



3. Lever is a folded strip of posterboard or a tongue depressor. It must be thick.



Turn the handle and the rabbits go up and down!

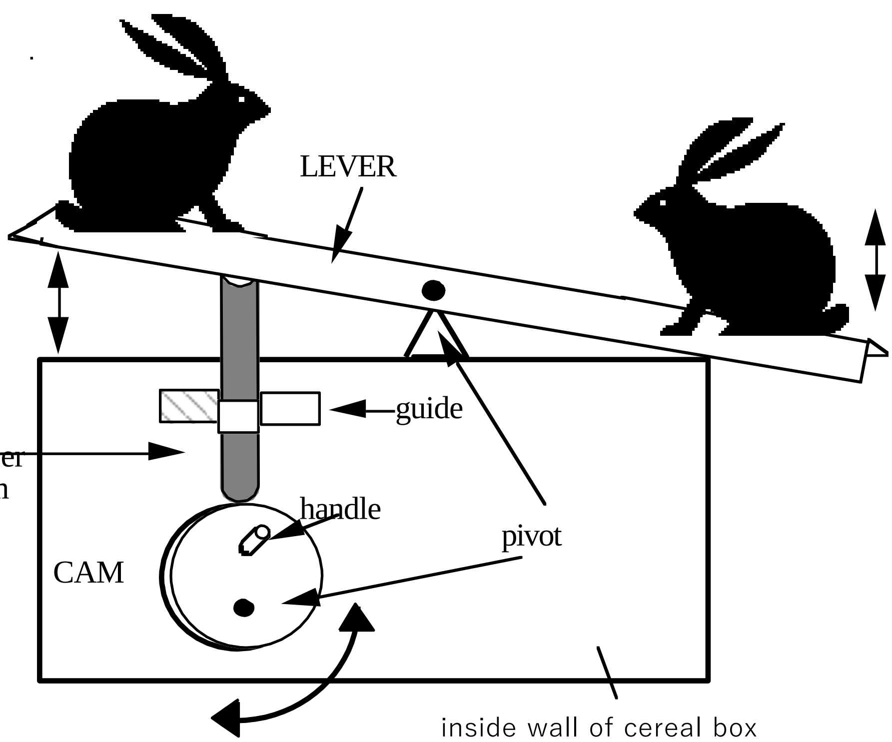
LEVER:
Make this from folded posterboard.

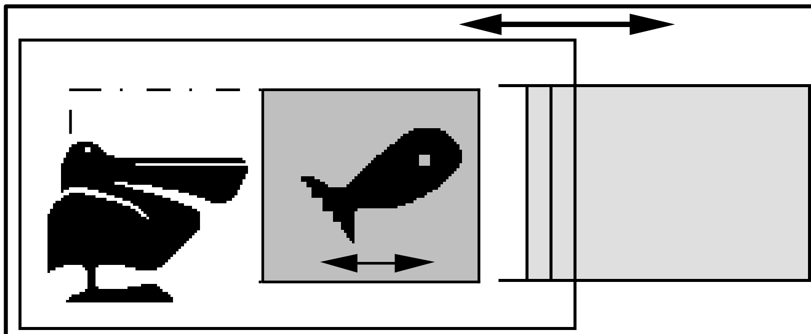
CAM:
This is a thick cardboard wheel or container lid, with off-center hole, and a handle to turn it with.

CAMSHAFT, OR FOLLOWER:
Made from a toilet paper tube, it rests on the cam and goes up and down.

GUIDE:
This is a strip of tagboard or paper that

keeps the camshaft going in a straight





Materials:

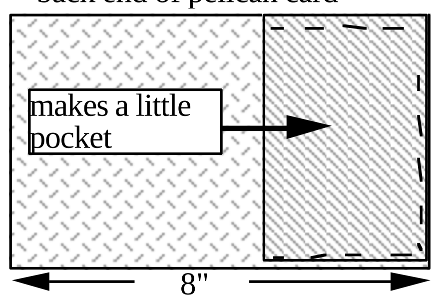
2 index cards, 5 x 8"
Scissors

Glue, staples, or tape
Exacto knife

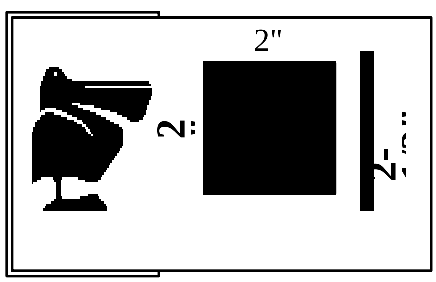
Strip of posterboard

1. Cut one index card to 2 x 8"

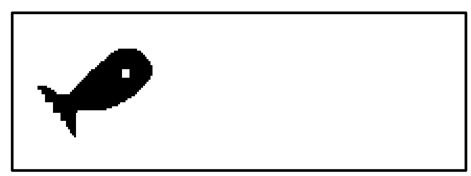
2. Glue, tape, or staple three edges of card section around back end of pelican card



3. Turn card over and cut window and slit, as shown:

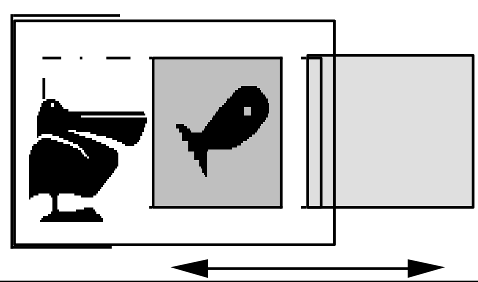


4. Paste fish picture onto strip of posterboard.



5. Insert strip with fish picture

into pelican card through slot and into little pocket. Fish should move through window when strip slides.



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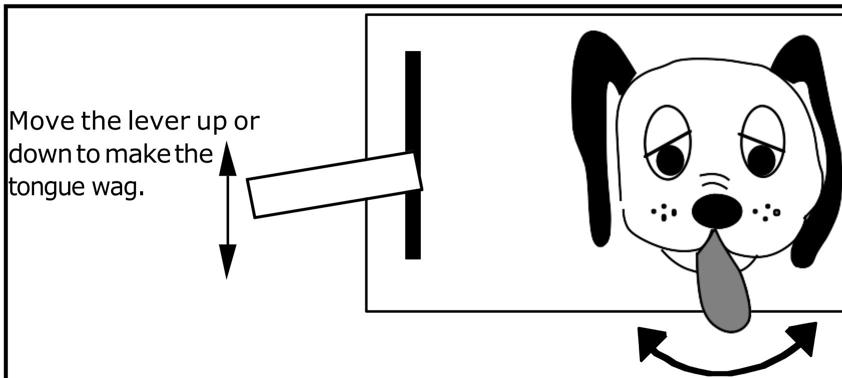
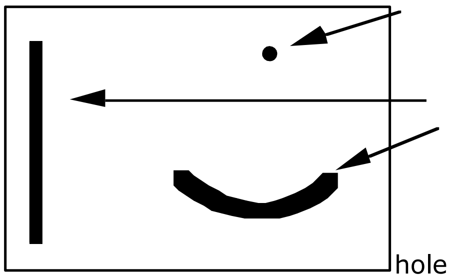
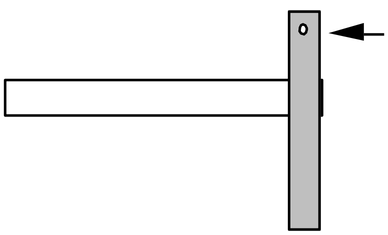
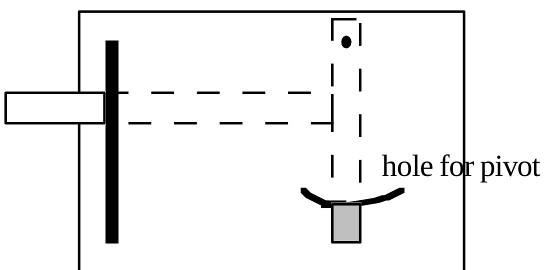


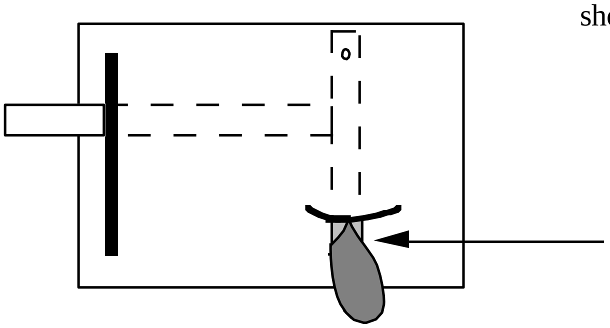




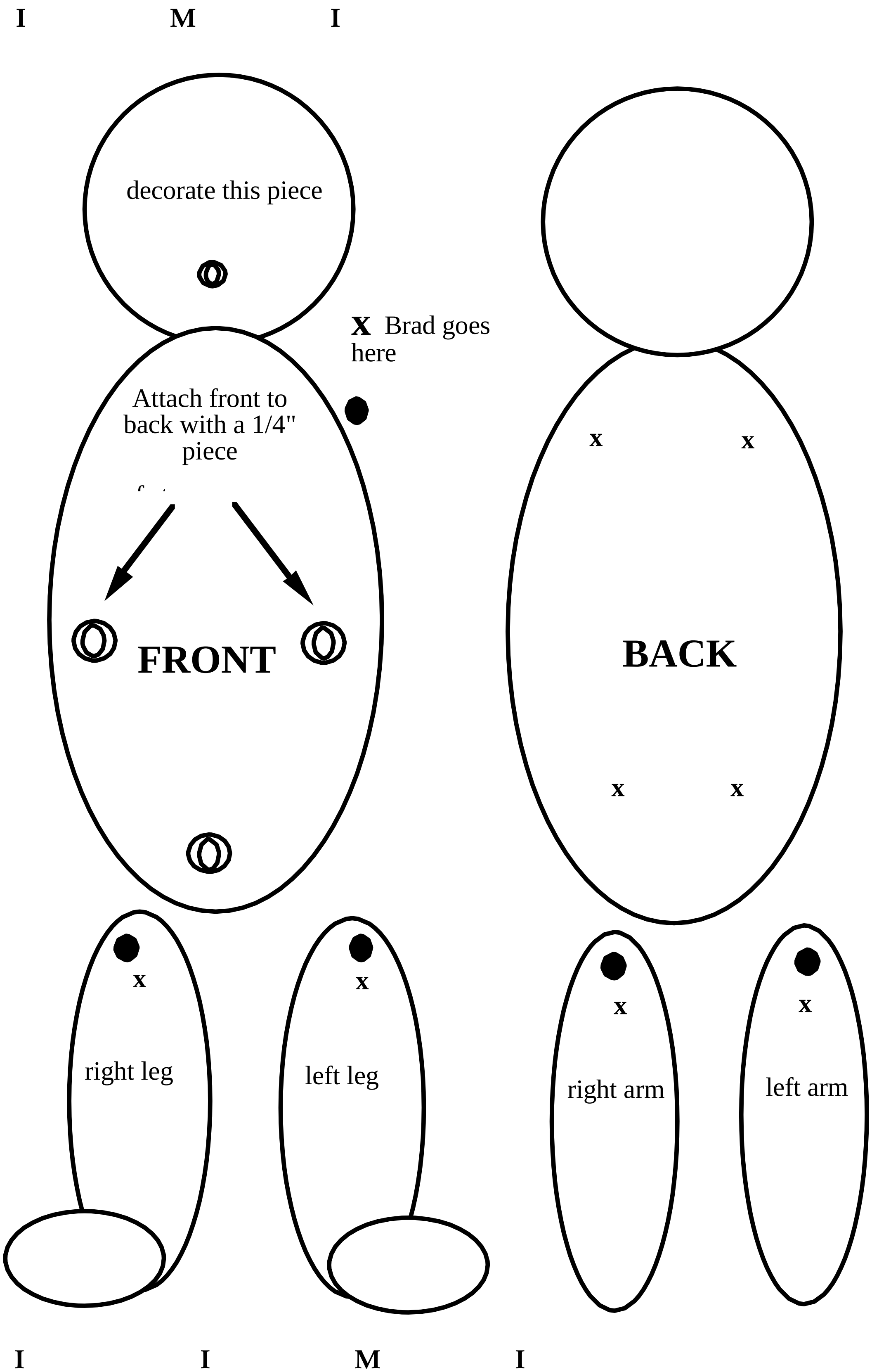
1. Using Exacto knife, cut slot for lever and curved slot for tongue path in a piece of posterboard. Make a hole as indicated for a paper fastener pivot.



2. Attach two strips of posterboard as shown by gluing at intersection.



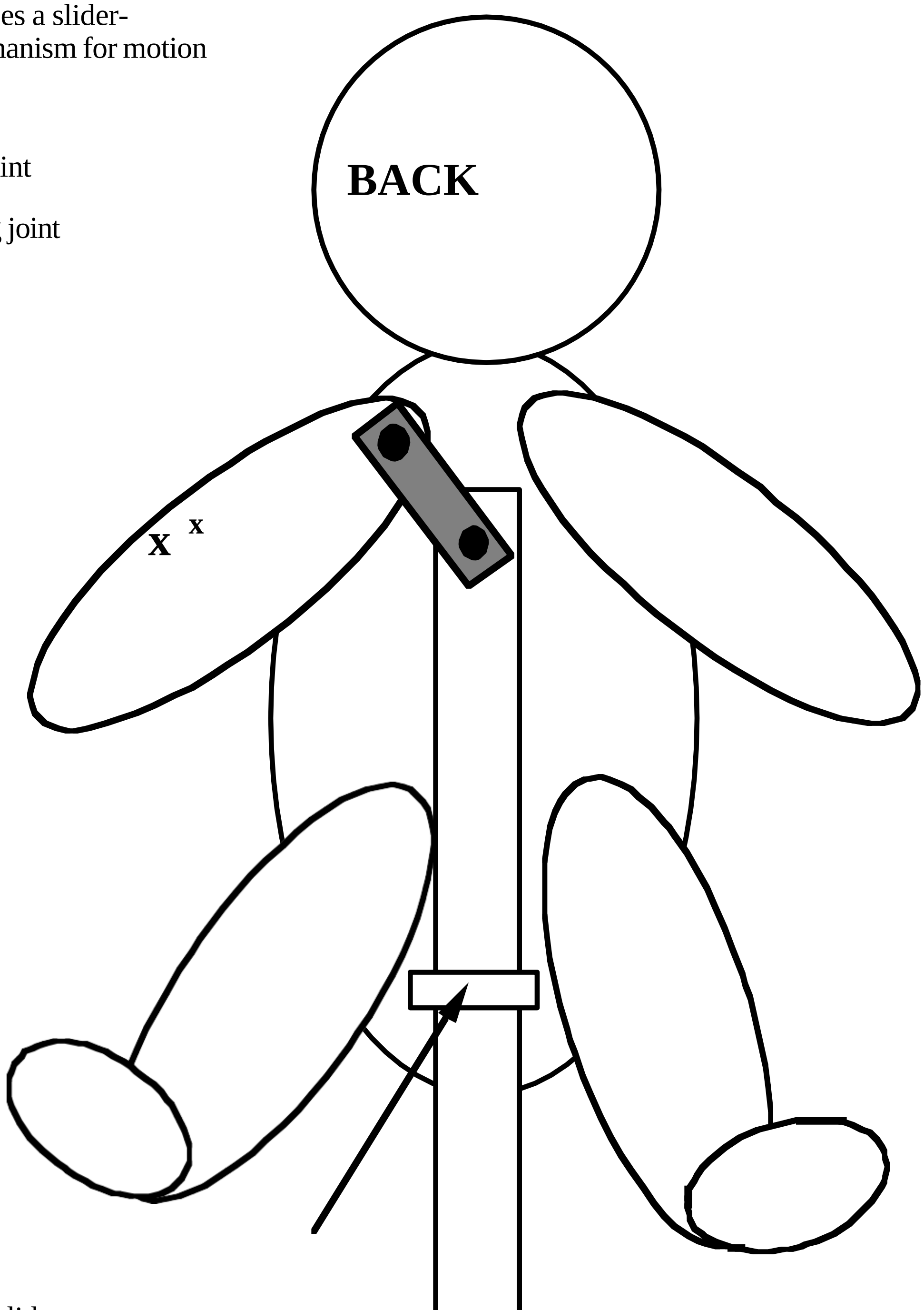
I **DOG'S**


I M I
decorate this piece
X Brad goes here
Attach front to back with a 1/4" piece
FRONT
BACK
x x
x x
x
right leg
x
left leg
x
right arm
x
left arm
I I M I

This toy uses a slider-
crank mechanism for motion

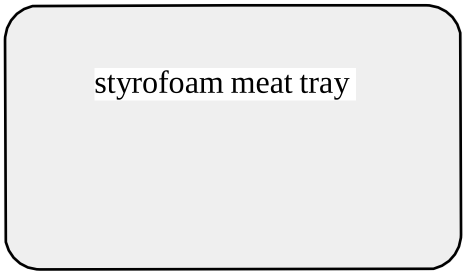
X Fixed joint

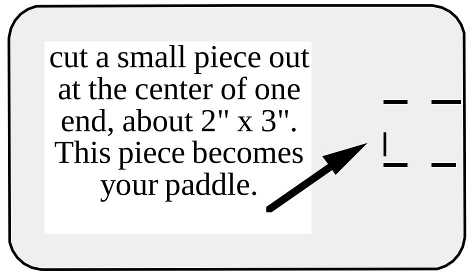
Pivoting joint



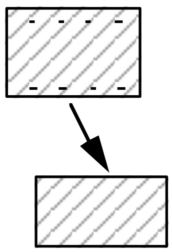
Guide for slider

I **I** **I**

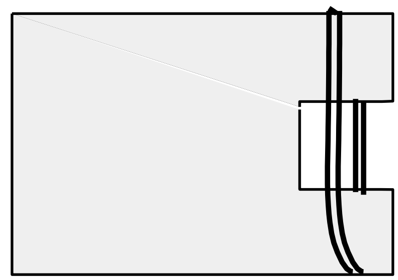




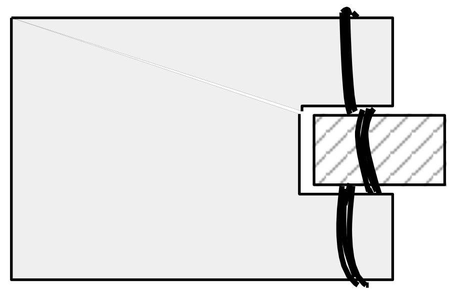
Trim about 1/4" off from the long edges of the cut-out piece

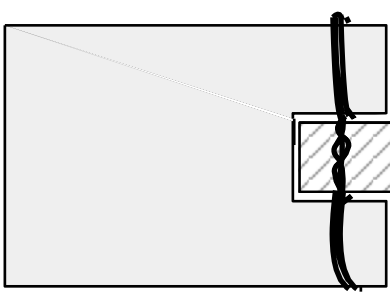


stretch a rubber band around ends

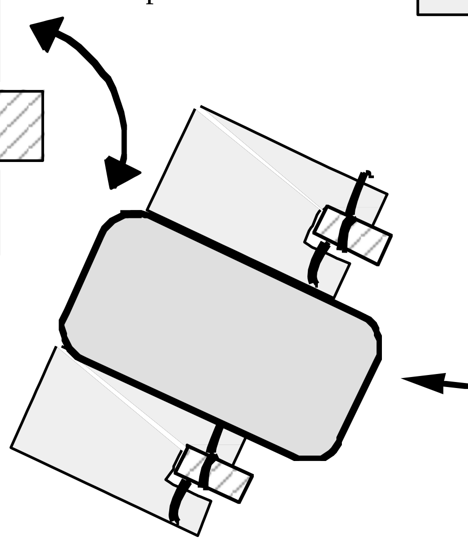


Insert paddle between rubber band sides.





Wind it up!



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