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Assessing with Learning Progressions in Science

FOSS LEVERS AND PULLEYS

Content Professional Development Tools| **Contributor: Brad Smith**

Northwest Educational Service District 189
Together We Can

Skagit Valley College
Where Learning Comes to Life

Funding information:
Mathematics & Science Partnership under Title II, Part B
Program Code: 62
CFDA 84.366B

Learning Progression

Levers & Pulleys

Prerequisite skill:

DEFINTION OF FORCE

DEFINITION OF ENERGY

Learning Target:

FORCE IS NECESSARY TO CHANGE SPEED AND/OR DIRECTION OF AN OBJECT

Success Criteria:
I can... IDENTIFY WHEN AND HOW FORCES ARE APPLIED TO CHANGE SPEED AND DIRECTION

Formative Assessment:
SOCCER BALL WHITEBOARD, TALKING HEADS FROM PET C2A2

Learning Target:

TORQUES ARE ROTATIONAL EQUIV-ALENT OF FORCE, REQUIRING CONCEPT OF LEVER ARM IN ADDITION TO FORCE

Success Criteria:
I can...BALANCE DIFFERENT TORQUES BY CHANGING FORCES AND LEVER ARMS

Formative Assessment:
LAB EXERCISE: COMPUTE TORQUES ON A ROD AND ARRANGE MASSES TO CHECK COMPUTATION.

Learning Target:

ENERGY, FORCE, AND TORQUES ARE DIFFERENT: ENERGY IS INHERENT TO THE SYSTEM, WHILE TORQUES AND FORCES ARE ONLY APPLIED.

Success Criteria:
I can...DISTINGUISH BETWEEN WORK DONE IN A MACHINE (F.d) AND TORQUES (Fxd)

Formative Assessment:
EXPERIMENT: PREDICT WORK DONE FOR DIFFERENT LEVER TYPES: LEVERS FROM THE KITCHEN.

Learning Target:

MACHINES WORK BECAUSE ENERGY IS CONSERVED: LARGE FORCES OVER SMALL DISTANCES = SMALL FORCES APPLIED OVER LARGE DISTANCES.

Success Criteria:
I can...IDENTIFY BEST ARRANGMENT OF LOAD AND EFFORT IN A SIMPLE MACHINE.

Formative Assessment:
COMPUTE TENSIONS IN A PULLEY SYSTEM (WORKSHEETS); IF TIME, WHITEBOARD HOW TO RAISE A PLATFORM; HOW TO RAISE A SUNKEN DOCK.

Learning Target:

MECHANICAL ADVANTAGE IS THE RATIO OF LOAD/EFFORT OR (DISTANCE INPUT/DISTANCE OUTPUT)

Success Criteria:
I can...CALCULATE MECHANICAL ADVANTAGE FOR NEARLY ALL (FIVE OF SIX) CLASSICAL SIMPLE MACHINES

Formative Assessment:
Deus ex Machine:
COMPUTE MECHANICAL ADVANTAGE FOR LEVER AND PULLEY ARRAYS. LEARNING GAINS EVALUATION.

Big Idea:

MACHINES ARE IDEALIZED SYSTEMS WHERE FORCES ARE MAGNIFIED THROUGH THE CONSERVATION OF WORK ENERGY.

Later big ideas that build on this big idea include:

FRICTION LIMITS IDEAL MACHINE ADVANTAGE

HEAT CAN BE USED TO DO WORK TOO: THERMODYNAMICS

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Levers and Pulleys Group
Lesson Plans and Schedule for Higher Ed Content Immersion

1:00-1:45 – Introductory stuff from Joanne, move to room, get settled

1:45 – 2:35: Forces. Physics for Everyday Thinking ("PET" – see references) Cycle 2 Activity 2 (pages 2-4 to 2-10) – Whiteboard activity of Initial Ideas, followed track measurement and computer simulation. Add mass etc. Watch kid video (PET, pages 2-65 to 2-71). Finish with scientists' ideas.

BREAK

2:45 – 3:35 Torques. Loyd (see references) Lab Activity 10 (Torques and Rotational Equilibrium) with meter stick and masses – finding center of mass and unknown mass. Complete parts two, three and four. Then measure vertical displacement of a lever compared to lever arm. Compare answers and perform "What are you doing/thinking now?" FA.

BREAK

3:45 – 4:35 Lecture: Work and energy. Difference between work and torque. Similarity of work displacement and lever arm (triangle exercise). Mechanical advantage. Lifting teacher with tiny student (how big are they compared to the other?). Cantilever bridges in Holland examples – how do they work?

BREAK

4:45 – 5:15 Introduce but don't complete Simple Machines Lab (access via http://www.mrfizix.com/home/worksimplemachines.htm). Other levers (type 2 and 3) and their advantages (NOT necessarily mechanical). The arm. Playing with simple and double pulley systems – drawings of different pulley systems, which students will compute effort. (Pulley system drawings available via http://www.enotes.com/topic/Pulley)

DINNER

5:45 – 6:35 Other machines. Measuring displacement vs. load on a pulley system set-up, and calculating mechanical advantage from work for different machines. Spanish Barton. Roved to advantage and disadvantage. Block and tackle systems, and Fool's Tackle (diagrams and readings). Fooling Around with Pulleys, Simanek, D. "Fooling Around with Pulleys." Lock Haven University. 2011 < http://www.lhup.edu/~dsimanek/TTT-fool/fool.htm>.

6:40 – End Windlass compared to pulley. Learning Goals Assessment.
[Time ran out here] Planned: Inclined plane, wedge, screw. Combination of machines.
Final assessment for Saturday: Deus ex Machina (handed out assignment from SVC Physics/Drama learning community).

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Levers and Pulleys

Big Idea: ***MACHINES ARE IDEALIZED SYSTEMS WHERE FORCES ARE MAGNIFIED THROUGH THE CONSERVATION OF WORK ENERGY.***

Formative Assessment Task Cover Sheet

Learning Target #1	
Assessment Task Details	**Teacher Background**
Brief Description of the Assessment Task: SOCCER BALL WHITEBOARD, TALKING HEADS FROM PET C2A2 p. 218 #75: Whiteboarding. Question on motion/forces using soccer ball and video of children's ideas from PET (page 2-4 on) p. 192 #61: Think Pair Share – "Talking Heads" discussion on force and motion (PET, page 2-8)	**Administration Tips:** *No tips.* **Suggestions for Instructional Adjustments:** *No adjustments noted.*
Learning Target #1: FORCE IS NECESSARY TO CHANGE SPEED AND/OR DIRECTION OF AN OBJECT	
Success Criteria: I can… IDENTIFY WHEN AND HOW FORCES ARE APPLIED TO CHANGE SPEED AND DIRECTION	
Student Task Sheet Included: no Student Work Samples Included: no	

Learning Target #2	
Assessment Task Details	**Teacher Background**
Brief Description of the Assessment Task: LAB EXERCISE: COMPUTE TORQUES ON A ROD AND ARRANGE MASSES TO CHECK COMPUTATION.	**Administration Tips:** *No tips.* **Suggestions for Instructional Adjustments:** *No adjustments noted.*
Learning Target #2: Magnetic and electric fields can be modeled using phenomena that cannot be seen or sensed, but which are consistent with observed behavior.	
Success Criteria: I can…model the domain structure of a magnet that gives rise to magnetism	

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Big Idea: ***MACHINES ARE IDEALIZED SYSTEMS WHERE FORCES ARE MAGNIFIED THROUGH THE CONSERVATION OF WORK ENERGY.***

Student Task Sheet Included: no Student Work Samples Included: no	

Learning Target #3	
Assessment Task Details	**Teacher Background**
Brief Description of the Assessment Task: EXPERIMENT: PREDICT WORK DONE FOR DIFFERENT LEVER TYPES: LEVERS FROM THE KITCHEN. p. 216 #74: What are you doing and Why? – during lever experiments to determine unknown mass (Loyd Lab 10, page 109)	**Administration Tips:** *No tips.* **Suggestions for Instructional Adjustments:** *No adjustments noted.*
Learning Target #3: ENERGY, FORCE, AND TORQUES ARE DIFFERENT: ENERGY IS INHERENT TO THE SYSTEM, WHILE TORQUES AND FORCES ARE ONLY APPLIED.	
Success Criteria: I can…DISTINGUISH BETWEEN WORK DONE IN A MACHINE (F.d) AND TORQUES (Fxd)	
Student Task Sheet Included: no Student Work Samples Included: no	

Learning Target #4	
Assessment Task Details	**Teacher Background**
Brief Description of the Assessment Task: COMPUTE TENSIONS IN A PULLEY SYSTEM (WORKSHEETS); IF TIME, WHITEBOARD HOW TO RAISE A PLATFORM; HOW TO RAISE A SUNKEN DOCK. p. 194 #62: Thought experiment – pulley handouts including Spanish Burton and Fool's Tackle (was to be whiteboarded but no time and too small of a group).	**Administration Tips:** *No tips.* **Suggestions for Instructional Adjustments:** *No adjustments noted.*
Learning Target #4: MACHINES WORK BECAUSE ENERGY IS CONSERVED: LARGE FORCES OVER	

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Big Idea: ***MACHINES ARE IDEALIZED SYSTEMS WHERE FORCES ARE MAGNIFIED THROUGH THE CONSERVATION OF WORK ENERGY.***

SMALL DISTANCES = SMALL FORCES APPLIED OVER LARGE DISTANCES.	
Success Criteria: I can…IDENTIFY BEST ARRANGMENT OF LOAD AND EFFORT IN A SIMPLE MACHINE.	
Student Task Sheet Included: no Student Work Samples Included: no	

Learning Target #5	
Assessment Task Details	**Teacher Background**
Brief Description of the Assessment Task: Deus ex Machina: COMPUTE MECHANICAL ADVANTAGE FOR LEVER AND PULLEY ARRAYS. LEARNING GAINS EVALUATION. p. 185 # 57: Student evaluation of learning gains	**Administration Tips:** *No tips.* **Suggestions for Instructional Adjustments:** *No adjustments noted.*
Learning Target #5: MECHANICAL ADVANTAGE IS THE RATIO OF LOAD/EFFORT OR (DISTANCE INPUT/DISTANCE OUTPUT)	
Success Criteria: I can…CALCULATE MECHANICAL ADVANTAGE FOR NEARLY ALL (FIVE OF SIX) CLASSICAL SIMPLE MACHINES	
Student Task Sheet Included: yes Student Work Samples Included: yes	

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Check off how well each of the following helped you learn during the Levers and Pulley unit	**Not at all**	**Only a little bit**	**Fairly useful**	**It helped me a lot!**
The whiteboard activity with forces				
Playing with the carts on the track				
The talking heads think pair share On force and motion				
Kids' ideas about force and motion				
Loyd's lab on torques				
Looking at different real world devices and their torques				
Lecture and demonstration on difference between work & torque				
Similar triangle exercise – relation of lever arm and work				
Lifting the teacher – mechanical advantage deomonstation				
Levers in the kitchen exercise (types 2 and 3)				
Pulley worksheets				
Playing with pulleys and other simple machines (ramp, windlass)				
The platform problem				
Combination of machines: the Deus ex Machina assignment.				
Other?				
Please share any ideas you have that could help me improve this unit:				

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Check off how well each of the following helped you learn during the Levers and Pulley unit	Not at all	Only a little bit	Fairly useful	It helped me a lot!
The whiteboard activity with forces			X	
Playing with the carts on the track				X
The talking heads think pair share on force and motion			X	
Kids' ideas about force and motion			X	
Loyd's lab on torques			X	
Looking at different real world devices and their torques NA				
Lecture and demonstration on difference between work & torque				X
Similar triangle exercise – relation of lever arm and work				X
Lifting the teacher – mechanical advantage deomonstation			X	
Levers in the kitchen exercise (types 2 and 3)			X	
Pulley worksheets				X
Playing with pulleys and other simple machines (ramp, windlass) NA				
The platform problem NA				
Combination of machines: the Deus ex Machina assignment. NA				
Other?				

Please share any ideas you have that could help me improve this unit:

Sometimes I need quiet to think things through and process instead of continuing to repeat or discuss the process.

Check off how well each of the following helped you learn during the Levers and Pulley unit	Not at all	Only a little bit	Fairly useful	It helped me a lot!
The whiteboard activity with forces				✓
Playing with the carts on the track				✓
The talking heads think pair share on force and motion				✓
Kids' ideas about force and motion		✓		
Loyd's lab on torques				✓
Looking at different real world devices and their torques				
Lecture and demonstration on difference between work & torque			✓	
Similar triangle exercise – relation of lever arm and work			✓	
Lifting the teacher – mechanical advantage deomonstation		✓		
Levers in the kitchen exercise (types 2 and 3)				✓
Pulley worksheets			✓	
Playing with pulleys and other simple machines (ramp, windlass)				
The platform problem				
Combination of machines: the Deus ex Machina assignment.				
Other?				

Please share any ideas you have that could help me improve this unit:

The things we did were really good.
Calculating torque was important but not enough time to feel confident.

Maybe point out formative assessments used – I don't know if I caught them.

I like how you referenced our Levers & pulleys kits for good activities info ~~k~~ not so good

Check off how well each of the following helped you learn during the Levers and Pulley unit	Not at all	Only a little bit	Fairly useful	It helped me a lot!
The whiteboard activity with forces				!
Playing with the carts on the track			✓	
The talking heads think pair share on force and motion				✓
Kids' ideas about force and motion			✓	
Loyd's lab on torques				
Looking at different real world devices and their torques				✓
Lecture and demonstration on difference between work & torque				
Similar triangle exercise – relation of lever arm and work			✓	
Lifting the teacher – mechanical advantage deomonstation				✓
Levers in the kitchen exercise (types 2 and 3)				✓
Pulley worksheets				✓
Playing with pulleys and other simple machines (ramp, windlass)				✓
The platform problem				
Combination of machines: the Deus ex Machina assignment.				
Other?				

Please share any ideas you have that could help me improve this unit:

Keep the experiments, hands-on, math involved
Real world examples
Great evening!

Check off how well each of the following helped you learn during the Levers and Pulley unit	Not at all	Only a little bit	Fairly useful	It helped me a lot!
The whiteboard activity with forces			✓	
Playing with the carts on the track			✓	
The talking heads think pair share on force and motion				✓
Kids' ideas about force and motion				✓
Loyd's lab on torques				✓
Looking at different real world devices and their torques X				
Lecture and demonstration on difference between work & torque X				
Similar triangle exercise – relation of lever arm and work			✓	
Lifting the teacher – mechanical advantage deomonstation				✓
Levers in the kitchen exercise (types 2 and 3)				✓
Pulley worksheets			✓	
Playing with pulleys and other simple machines (ramp, windlass) X			~~✓~~	
The platform problem X			~~✓~~	
Combination of machines: the Deus ex Machina assignment.				
Other?				

Please share any ideas you have that could help me improve this unit:

CHECK OFF HOW WELL EACH OF THE FOLLOWING HELPED YOU LEARN DURING THE LEVERS AND PULLEY UNIT	NOT AT ALL	ONLY A LITTLE BIT	FAIRLY USEFUL	IT HELPED ME A LOT!
THE WHITEBOARD ACTIVITY WITH FORCES				✓
PLAYING WITH THE CARTS ON THE TRACK				✓
THE TALKING HEADS THINK PAIR SHARE ON FORCE AND MOTION				✓
KIDS' IDEAS ABOUT FORCE AND MOTION			✓	
LOYD'S LAB ON TORQUES meter stick				✓
LOOKING AT DIFFERENT REAL WORLD DEVICES AND THEIR TORQUES				
LECTURE AND DEMONSTRATION ON DIFFERENCE BETWEEN WORK & TORQUE				✓
SIMILAR TRIANGLE EXERCISE – RELATION OF LEVER ARM AND WORK				✓
LIFTING THE TEACHER – MECHANICAL ADVANTAGE DEOMONSTATION			✓	
LEVERS IN THE KITCHEN EXERCISE (TYPES 2 AND 3)				✓
PULLEY WORKSHEETS				✓
PLAYING WITH PULLEYS AND OTHER SIMPLE MACHINES (RAMP, WINDLASS)				
THE PLATFORM PROBLEM				
COMBINATION OF MACHINES: THE DEUS EX MACHINA ASSIGNMENT.				
OTHER?				

PLEASE SHARE ANY IDEAS YOU HAVE THAT COULD HELP ME IMPROVE THIS UNIT:

Great job -- LOTS of information -- A bit difficult to digest, but I feel mostly successful in my understanding

Thank you!

NORTH CASCADES AND OLYMPIC Science Partnership

Key Findings from *How People Learn*

1. Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom.

2. To develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application.

3. A "metacognitive" approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.

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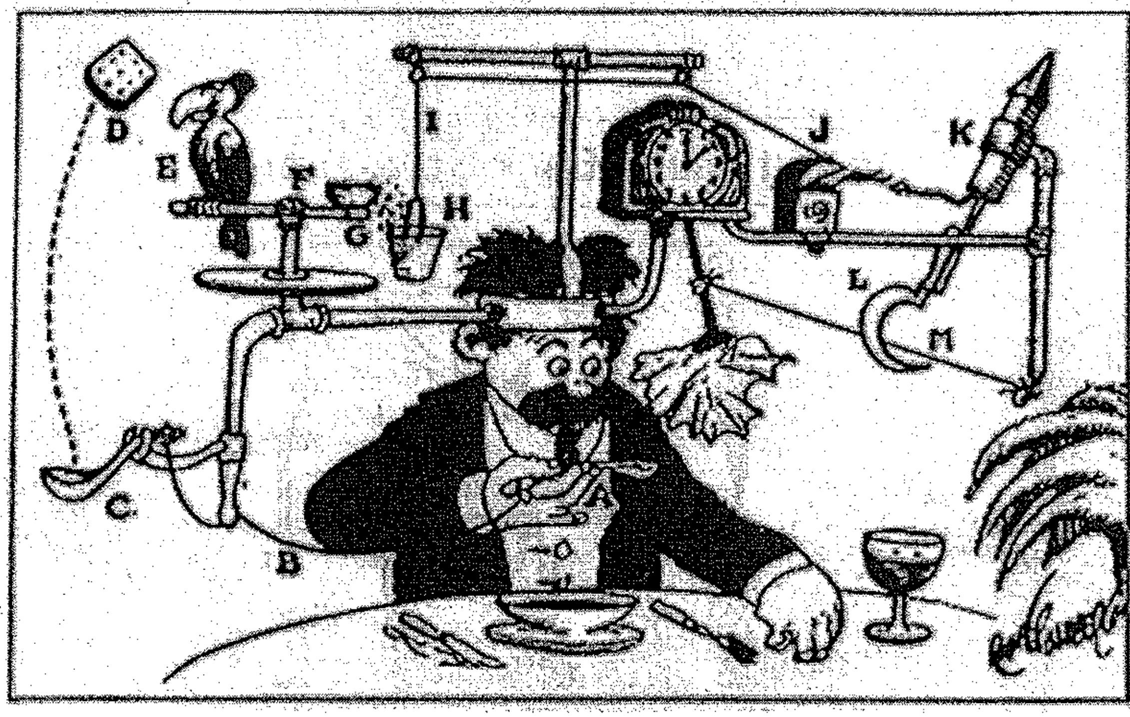
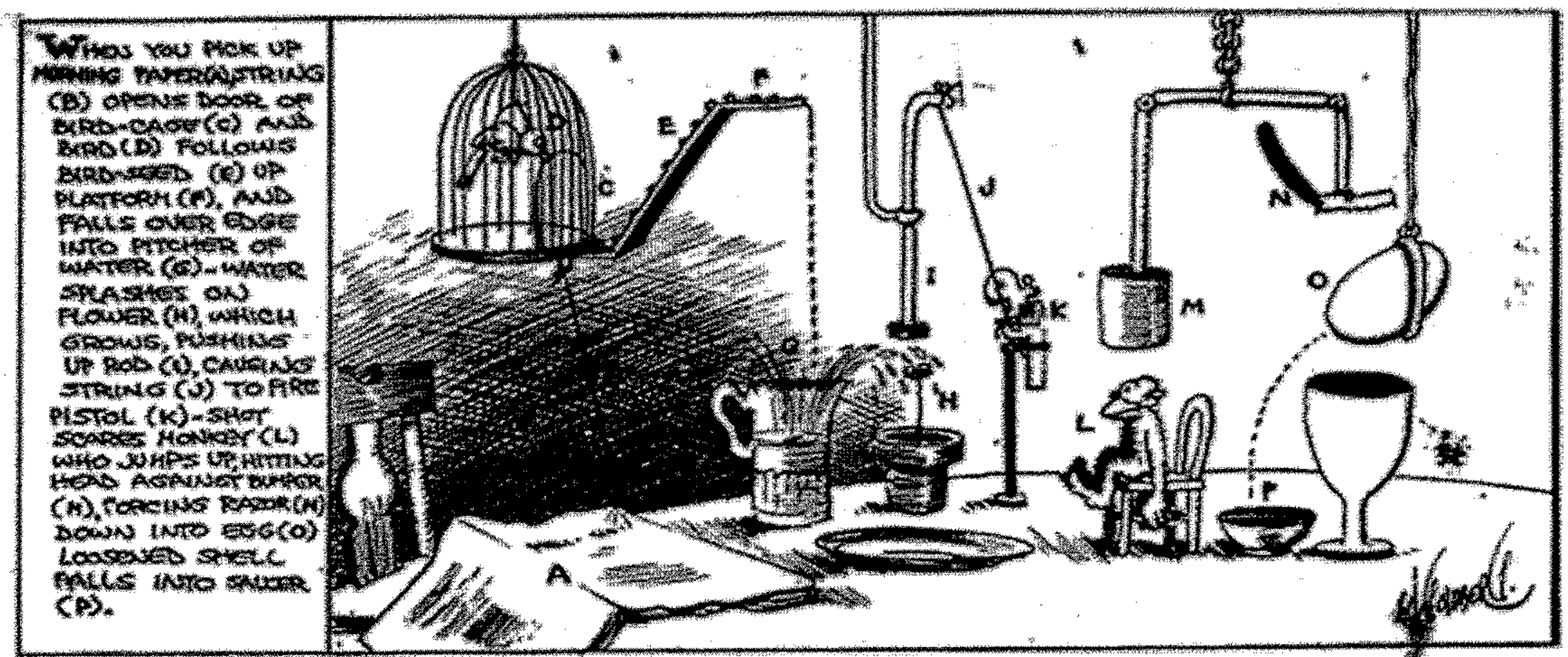
Self-Operating Napkin



- Rube Goldberg Machine Contest - College Level™
- Rube Goldberg Machine Contest - High School Level™
- International Online Rube Goldberg Machine Contest for Ages 11-14™



Simple way to open an egg without dropping it in your

Supplemental Web-based Assessments for Levers and Pulleys Content Session

Levers

The Dutch have devised many interesting uses of the lever to bridge the ubiquitous canals that crisscross the Netherlands. These so-called "cantilever bridges" may be as small as bike path bridges over a farmer's ditch to multi-lane, modern draw bridges over large waterways.

Use your favorite search engine on the Web to search for Images of Dutch bridges. You might have good success using a broad search target such as "Draw Bridges Netherlands" or you might try specific bridges that are good examples of different generations of bridges. For example, an excellent type of the traditional bridge can be found using a search for: *Zierikzee Zeeland Tower Bridge.* Other good examples of older bridges are the *Bathbrug Westerhof* or the *Loenen bridge.* Amsterdam has many, many good examples too. Try to find at least three examples that show the whole bridge, deck and superstructure.

In each example you find, be sure you can identify the fulcrum, effort, and load of the bridge mechanism. Note in particular that most older bridges, even large ones, only require one unassisted person to raise the bridge deck by pulling down on the large mass, usually with an attached rope – how does this happen?

Finally, take a look at a modern cantilever bridge by searching for images of *Slauerhoff Bridge Leeuwarden* – try to get several different views of this modern bridge. How is this bridge similar to and different from the older, traditional drawbridges you've studied?

Pulleys

Levers can require a fair amount of space in which to operate for a good mechanical advantage (compare, the increasing size of cantilever bridges above as the loads (roadways) get bigger and bigger). On the other had, pulleys are comparatively compact systems, and hence are ideal for lifting loads where space is at a premium, like on a boat. A series of pulleys rigged as in a block and tackle system are found everywhere on boats to reduce the effort in lifting or pulling a load (such as a wind-loaded sail or cargo pallet from a hold).

Go to your favorite search engine on the Web to find Images of *block tackle boats* or *block tackle sailboats* or some such (*mainsheet tackle* works well too). Try to find a complete pulley system ("top" and "bottom"), and try to find ones roved to advantage and also roved to disadvantage. For all your systems, try to compute how much line must be pulled through the block and tackle to move the load a given distance (say, 1 meter). Also try to estimate the ratio of effort to load for your system.

Look for at least three different systems, and try to span the range from a small system that might be pulled by hand on a sailboat to a large, cargo lifting system that might be found on the end of a crane in a shipyard. Good cargo lifting ones can be found as illustrations of some online encyclopedias under *Block and Tackle.*

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DEUS EX MACHINA PROJECT
DESIGNING A "GOD MACHINE"

The Deus ex Machina was a crane-like device used by the Greeks in their theatrical productions to bring a God onto the orchestra (the stage in a Greek theatre), and also off of it..

Greek theatres were large outdoor amphitheatres, some of them seating thousands of people. The seats were wooden or stone benches cut into a hill side. The orchestra (stage) was a stone circle on the ground measuring (for purposes of this exercise) 15 meters in diameter. The temple was immediately behind the orchestra. For the purposes of this exercise we will use the following dimensions: height of temple - 10 meters, depth of temple - 10 meters, length - 25 meters. Your machine should be mounted somewhere on the temple side of the orchestra and does not need to be concealed from the audience in any way.

Task: design a machine that will lower an actor on to and off of the stage in some way. Your design must include at least 2 of the simple machines that we have studied in class. Any technology available to the Greeks may be used (wheels, gears, windlass, pulleys, ropes, levers of all description), as may various energy sources (human or animal power, gravity, flowing water, heat, etc.). No modern technology may be used, however (for example: no electricity, magnets, nuclear power, gas, steam, or coal engines, computers, Mr. Coffee's). Assume that the components of your machine can be fastened together somehow and that they have infinite strength; in other words, don't worry about construction or engineering details.

IMPORTANT: your machine should accomplish this task in a theatrically interesting way.

A bad example: an actor climbs up a ladder onto a scaffold and slides down a rope. This does not involve any machines and is boring!
A good example: an actor descends in a basket covered with fabric looking like clouds (not too cheesy, of course) that hangs by pulleys from the arm of a crane that slowly rotates over the stage by means of a windlass and is lowered using a crank with a large handle.

Product:
1. a working drawing of your machine.
2. a written description of how your machine works, clearly identifying the artistic and technical elements of your design. This description should be written for a general audience in two well developed paragraphs, about 500 words total.
3. a table of calculations that show a) the total mechanical advantage of your machine, and b) estimates how fast the God is lowered to the stage or raised from the stage. The data and calculations need not be typed, but simply printed neatly in ink.

This project must be done in groups of two or three - everyone in the group receives the same grade.

One thing seldom addressed in textbooks is how to do estimates (back of envelope calculations) comparing efficiency of different systems. Suppose that each pulley, moving or not, had a force due to friction proportional to the weight its axle directly supports. Suppose also that each pulley that moves up and down had a non-negligible weight. Now what could possibly be the superiority of the Spanish burton over a block and tackle with the same ideal mechanical advantage? The block and tackle would have to have 32 pulleys compared to the six of the Spanish burton, and the block and tackle would have 16 pulleys moving, compared to five of the Spanish burton (moving at different speeds, of course). But the Spanish burton has geometric problems, as well as problems with rope stretch. The diagram is misleading, because the pulley spacing, bottom to top, must be 1, 2, 4, 8, ... at all times. This system is seldom seen with more than 2 or 3 movable pulleys. Leonardo took things to extremes, often drawing pictures of things that weren't practical.

I've raised some questions that you can easily answer by building such systems and testing their

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REFERENCES / SOURCES

Force experiment:
Goldberg F. et al.: Physics and Everyday Thinking. It's About Time (2008)

Lever experiment:
Loyd, DH: Physics Laboratory Manual (3rd ed.). Brooks Cole 2008.

Muscles in lever diagram:
Gastrocnemius (calf), Splenius capitis (neck), Biceps

Pulley experiment:
http://www.mrfizix.com/home/worksimplemachines.htm

Fooling around with Pulleys:
http://www.lhup.edu/~dsimanek/TTT-fool/fool.htm

All original images will be posted on Moodle in Levers and Pulley folder.
Others:

Very basic Inclined plane experiment (not included here but similar to what we did):
http://www.ge.com/press/scienceworkshop/docs/pdf/Inclined_Plane_with_Standards.pdf

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