Working with Watermills:
Harnessing the Energy of Water

IEEE ARIZONA SCIENCE LAB
www.arizonasciencelab.org

Workshop Focus:

Workshop focuses on how watermills generate power using the principles of the lever and mechanical advantage, and kinetic and potential energy exchange due to the conservation of energy. Students, working in teams of two, design and build a working water wheel out of everyday products and test their design in a test jig with a water jet from a fountain pump. Student water wheels must be able to sustain three minutes of rotation and lift a plastic cup containing a set of steel washers; the goal is to lift the heaviest load of washers. Students then evaluate the effectiveness of their water wheel, and suggest and test design enhancements, and present their findings to the class.

Workshop Synopsis:

The Working with Watermills workshop explores how watermills have helped harness energy from water through the ages, and how the design and operation of the water wheels is easily explained by the principles of mechanical advantage and the conservation of energy. Students work in teams of two "engineers" to design and build their own watermill out of everyday items. They test their watermill, evaluate their results, define and test design enhancements, and present to the class.

Age Levels:

8 – 15 years (grades 4 – 8)

Objectives:

- Learn about potential and kinetic energy, and the conservation of energy
- Learn about simple machines, the lever and mechanical advantage
- Learn about engineering design
- Learn about planning and construction
- Learn about teamwork and working in groups.

Anticipated Learner Outcomes:

As a result of this activity, students should develop an understanding of:

- structural engineering and design
- problem solving
- teamwork

Workshop Activities:

Students learn about simple machines, levers and the principle of mechanical advantage, and about potential energy, kinetic energy and the conservation of energy leading to the exchange between potential and kinetic energy. They learn how watermills have been used throughout the ages to harness the power of water and how the scientific principles they have learnt explain the design and operation of the water wheels. Students work in teams to develop their own water wheel out of everyday items, then test their water wheel while lifting a load of steel washers in a plastic cup, evaluate their own water wheels and those of other students, and present their findings to the class.

Alignment to Curriculum Frameworks:

Note: All Arizona Science Lab workshops are aligned to the National Science Education Standards which were produced by the National Research Council and endorsed by the National Science Teachers Association, and if applicable, also to the International Technology Education Association's Standards for Technological Literacy or the National Council of Teachers of Mathematics' Principals and Standards for School Mathematics. They will also be modified as necessary to be aligned to the Next Generation Science Standards (NGSS) when they are released.

- **National Science Education Standards Grades K-4 (ages 4-9)**

CONTENT STANDARD A: Science as Inquiry As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- Position and motion of objects

CONTENT STANDARD E: Science and Technology
As a result of activities, all students should develop

- Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives
As a result of activities, all students should develop understanding of

- Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science
As a result of activities, all students should develop understanding of

- Science as a human endeavor

- **National Science Education Standards Grades 5-8 (ages 10 - 14)**

CONTENT STANDARD A: Science as Inquiry As a
result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science
As a result of their activities, all students should develop an understanding of

- Motions and forces
- Transfer of energy

CONTENT STANDARD E: Science and Technology
As a result of activities in grades 5-8, all students should develop

- Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives
As a result of activities, all students should develop understanding of

- Science and technology in society

- **National Science Education Standards Grades 9-12 (ages 14-18)**

CONTENT STANDARD A: Science as Inquiry As a
result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science
As a result of their activities, all students should develop understanding of

- Motions and forces

- Interactions of energy and matter

CONTENT STANDARD E: Science and Technology
As a result of activities, all students should develop
- Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives
As a result of activities, all students should develop understanding of
- Natural resources
- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science
As a result of activities, all students should develop understanding of
- Historical perspectives

- **Standards for Technological Literacy - All Ages**

The Nature of Technology
- Standard 2: Students will develop an understanding of the core concepts of technology
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study

Technology and Society
- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology
- Standard 5: Students will develop an understanding of the effects of technology on the environment

Design
- Standard 9: Students will develop an understanding of engineering design
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving

Abilities for a Technological World
- Standard 11: Students will develop abilities to apply the design process
- Standard 13: Students will develop abilities to assess the impact of products and systems

The Designed World
- Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies
- Standard 20: Students will develop an understanding of and be able to select and use construction technologies

Internet Connections:

- TryEngineering (www.tryengineering.org)
- Waterwheel Factory (www.waterwheelfactory.com)
- U.S. Geological Survey Hydroelectric Power (http://ga.water.usgs.gov/edu/hyhowworks.html)
- Society for the Preservation of Old Mills (www.spoom.org)
- International Molinological Society (www.timsmills.info)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org)
- National Science Education Standards (www.nsta.org)

Recommended Reading:

- Cathedral, Forge and Waterwheel: Technology and Invention in the Middle Ages (ISBN: 0060925817)
- Windmills and Waterwheels Explained (ISBN: 1846740118)

Materials and Tools:

All materials and tools required for this workshop are provided by the Arizona Science Lab

Time Needed:

One four hour workshop (inclusive of lunch and restroom breaks).

ASL Staff Responsibilities:

The ASL staff is responsible for the conduct of the workshop:

- Setting up the workshop
- Presenting the lecture and teaching the science
- Performing the demonstrations
- Provisioning the materials and equipment to the student teams
- Supervising the construction project
- Supporting the students during the construction project
- Supervising the project testing
- Answering student questions about the science, the workshop, or any other related topic
- Clearing up the workshop after the students have left

School Teacher Responsibilities:

- **Managing the students during the class and the lunch and restroom breaks, and imposing discipline as necessary**
  - The ASL staff is NOT responsible for the class management or for student discipline!
  - **The restroom breaks will require at least one male and one female teacher be present from the school**
- Assisting the ASL staff in the teaching of the science
  - This could comprise asking the students questions about what had just been explained, presenting what had just been explained in another fashion, and so on
  - The ASL staff are not necessarily trained teachers and the school teachers know their students very well, so they can provide valuable insights and help to the ASL staff
- Assisting the ASL staff during the project construction and testing