Unit D: Mechanical Systems (Science and Technology Emphasis)

Overview: Machines are used for many purposes in our daily lives when we need to transfer energy into motion or move materials in a controlled way. In learning about mechanical devices, students investigate how components are linked so that energy is transferred efficiently and desired functions are performed. A comparison of past and present technologies helps students recognize that different approaches have been used over time to meet common needs. Evaluations of efficiency, effectiveness and impacts on daily life, the community and the environment are important considerations in this unit.

Focusing Questions: How is energy transferred in mechanical devices? How do mechanical devices provide for controlled application of energy in ways that are efficient, effective and responsible?

Key Concepts

The following concepts are developed in this unit and may also be addressed in other units at other grade levels. The intended level and scope of treatment is defined by the outcomes below.

- design and function
- systems and subsystems
- transmission of force and motion
- simple machines
- mechanical advantage, speed ratios and force ratios
- hydraulics and pneumatics
- measurement of work in joules

Outcomes for Science, Technology and Society (STS) and Knowledge

Students will:

1. Illustrate the development of science and technology by describing, comparing and interpreting mechanical devices that have been improved over time
   - investigate and provide examples of mechanical devices used in the past to meet particular needs *(e.g., describe and interpret devices developed to move water or be moved by water, such as the Persian wheel, Archimedes' screw, mill wheel)*
   - illustrate how a common need has been met in different ways over time *(e.g., development of different kinds of lifting devices)*
   - illustrate how trial and error and scientific knowledge both play a role in technological development *(e.g., development of aircraft)*

2. Analyze machines by describing the structures and functions of the overall system, the subsystems and the component parts
   - analyze a mechanical device, by:
     - describing the overall function of the device
     - describing the contribution of individual components or subsystems to the overall function of the device
     - identifying components that operate as simple machines
   - identify the source of energy for some familiar mechanical devices
   - identify linkages and power transmissions in a mechanical device, and describe their general function *(e.g., identify the purpose and general function of belt drives and gear systems within a mechanical device)*

3. Investigate and describe the transmission of force and energy between parts of a mechanical system
   - analyze mechanical devices to determine speed ratios and force ratios
   - build or modify a model mechanical system to provide for different turning ratios between a driving and driven shaft, or to achieve a given force ratio
   - compare theoretical and actual values of force ratios, and propose explanations for discrepancies *(e.g., identify frictional forces, and estimate their effect on efficiency)*
   - identify work input and work output in joules for a simple machine or mechanical system *(e.g., use a device to lift a measured mass an identified distance, then calculate the work output)*
   - describe fluid pressure qualitatively and quantitatively, by:
     – explaining how forces are transferred in all directions
     – describing pressure in units of force per unit area
   - describe how hydraulic pressure can be used to create a mechanical advantage in a simple hydraulic jack *(e.g., describe the relationship among force, piston size and distance moved, using different sized syringes linked by tubing)*
   - describe and interpret technologies based on hydraulics and pneumatics *(e.g., applications in hydraulic lifts and air-driven tools)*

4. Analyze the social and environmental contexts of science and technology, as they apply to the development of mechanical devices
   - evaluate the design and function of a mechanical device in relation to its efficiency and effectiveness, and identify its impacts on humans and the environment
   - develop and apply a set of criteria for evaluating a given mechanical device, and defend those criteria in terms of relevance to social and environmental needs
   - illustrate how technological development is influenced by advances in science, and by changes in society and the environment

Skill Outcomes (focus on problem solving)

Initiating and Planning

Students will:

Ask questions about the relationships between and among observable variables, and plan investigations to address those questions

- identify practical problems *(e.g., identify problems related to the effectiveness or efficiency of a mechanical device)*
- identify questions to investigate arising from practical problems *(e.g., "What is the efficiency of this device?")*
- propose alternative solutions to a practical problem, select one, and develop a plan
- select appropriate methods and tools for collecting data to solve problems *(e.g., develop or apply appropriate methods for measuring speed ratios and force ratios; plan and conduct a search, using a wide variety of electronic sources)*
- formulate operational definitions of major variables and other aspects of their investigations *(e.g., define "frictional force" by identifying a method to be used for measuring it)*

Performing and Recording

Students will:

Conduct investigations into the relationships between and among observations, and gather and record qualitative and quantitative data

- research information relevant to a given problem

- select and integrate information from various print and electronic sources or from several parts of the same source
- construct and test prototype designs and systems
- carry out procedures, controlling the major variables *(e.g., ensure that materials to be tested are of the same size and are tested under identical conditions)*
- organize data, using a format that is appropriate to the task or experiment
- use tools and apparatus safely

Analyzing and Interpreting

Students will:

Analyze qualitative and quantitative data, and develop and assess possible explanations

- identify and correct practical problems in the way a prototype or constructed device functions
- evaluate designs and prototypes in terms of function, reliability, safety, efficiency, use of materials and impact on the environment *(e.g., test and evaluate the efficiency and reliability of a prototype device to lift a given mass from the floor to a tabletop)*
- identify and evaluate potential applications of findings *(e.g., identify possible applications of a simple machine or mechanical system they have studied)*

Communication and Teamwork

Students will:

Work collaboratively on problems; and use appropriate language and formats to communicate ideas, procedures and results

- use specific language that is scientifically and technologically appropriate *(e.g., use such terms as "system," "subsystem," "component" and "function" in describing a mechanical system)*
- communicate practical problems, plans and results in a variety of ways, using written and oral language, data tables, graphs, drawings and other means *(e.g., describe, using pictures and words, the transmission of a force through a mechanical system)*
- work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise

Attitude Outcomes

Interest in Science

Students will be encouraged to:

Show interest in science-related questions and issues, and pursue personal interests and career possibilities within science-related fields *(e.g., investigate examples of mechanical devices in their home and community; ask questions about techniques and materials used; show an interest in related careers and hobbies)*

Mutual Respect

Students will be encouraged to:

Appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds *(e.g., recognize that varied solutions to similar problems have been developed by different cultures throughout history; appreciate that different approaches to problems lead to different solutions, and that each may have merits for particular applications)*

Scientific Inquiry

Students will be encouraged to:

Seek and apply evidence when evaluating alternative approaches to investigations, problems and issues *(e.g., report the limitations of their designs; continue working on a problem or research project until the best possible solutions or answers are uncovered)*

Collaboration

Students will be encouraged to:

Work collaboratively in carrying out investigations and in generating and evaluating ideas *(e.g., accept various roles within a group, including that of leadership; understand that they can disagree with others but still work in a collaborative manner; share the responsibility for difficulties encountered during an activity)*

Stewardship

Students will be encouraged to:

Demonstrate sensitivity and responsibility in pursuing a balance between the needs of humans and a sustainable environment *(e.g., consider the impacts of their designs on society and the environment; participate in discussions on the appropriateness of a given technology)*

Safety

Students will be encouraged to:

Show concern for safety in planning, carrying out and reviewing activities *(e.g., readily alter a procedure to ensure the safety of members of the group; carefully manipulate materials, using skills learned in class or elsewhere; listen attentively to safety procedures given by the teacher)*