Unit Overview: Advanced Mechanical Systems

Introduction

Newton's laws of motion relate the concepts of acceleration, mass, and force. If a system is easily described in terms of just those three components, Newton's laws predict its behavior by direct application. For example, when a brick slides down a ramp, the forces—both gravity and friction—are (nearly) constant and depend only on mass, so its analysis is straight-forward.

However, many systems of interest are not easily described in terms of just these three quantities. In particular, many can only be naturally described in terms of velocity or quantities related to it (e.g., momentum, kinetic energy) because the forces involved vary over time. Examples include collisions, the kinematics of devices powered by an internal power source, and objects subject to air resistance.

The *Advanced Mechanical Systems* Unit shows students how Newton's laws relate to these more complicated systems through the concepts of power and impulse. It is assumed students are already familiar with the basic components the unit weaves together: Newton's laws, kinetic energy, momentum, and work.

Time Estimate

The *Advanced Mechanical Systems* unit should take about a week.

Learning goals

After completing this unit, students will be able to …

- Relate Newton's laws of motion to collisions and the conservation of momentum.
- Describe the parallels between momentum and mass with respect to Newton's 2nd law.
- Calculate the impulse in a collision.
- Explain why the motion of powered systems (e.g., cars, electric motors, human runners) differs from the motion of freely falling bodies.
- Calculate the power generated in a system.
- Compute and graph the velocity curve for systems using a constant power source.
- Explain the effects of air resistance on moving bodies. (Extension)
- Create and interpret acceleration curves for real-life mechanical systems. (Extension)

Vocabulary: air resistance, efficiency, impulse, power

Lesson sequence

The *Advanced Mechanical Systems* Unit contains one Gizmo™ activity, one 3-part guided learning activity, one extension activity, and one vocabulary sheet. Each piece is available as a Word document (which you can edit) and a PDF. In addition, there are several Gizmos that complement this unit. We suggest organizing this unit in the following sequence:

I. Review: Newton's Laws, Energy, Momentum, Work

Before beginning the unit, students may need to review the basic concepts it synthesizes. The *Fan Carts Physics* Gizmo can be used to review Newton's laws. The *2-D Collisions* Gizmo can be used to review momentum. The *Inclined Plane–Simple Machines* Gizmo can be used to reacquaint students with the concepts of work and kinetic energy; its final activity describes the work-energy theorem, which is used in one question in the lesson on power.

II. Gizmo Activity: Impulse [ImpulseGA.doc]
This Gizmo activity uses the *2-D Collisions* Gizmo to introduce impulse as the connection between Newton's laws and the conservation of momentum.

III. Post Gizmo-Activity Discussion
After students have worked through the Gizmo Activity, use the final portion of class time to show why the results in question 3 would be the same regardless of the amount of time the pucks were assumed to be in contact with one another. Alternatively, this can be assigned as a homework exercise.

IV. Guided Learning: Power and Motion (Part 1) [PowerMotionGLp1.doc]
This activity, which can be assigned as a bell ringer, begins an investigation into the kinematics of systems run by internal power sources.

V. Guided Learning: Power and Motion (Part 2) [PowerMotionGLp2.doc]
This activity introduces the concept of power and provides students a comprehensive set of questions applying it in different contexts. Note that this sheet doubles as a comprehensive and challenging assessment of students' fluency with Newtonian mechanics.

VI. Optional Guided Learning: Power and Motion (Part 3) [PowerMotionGLp3.doc]
This enrichment activity describes an analogy that casts in more concrete terms why the acceleration curve for internally-powered machines is so steep. If time permits, we suggest making it the topic of a classroom discussion as it provides a useful visual representation of the quantities involved.

IV. Extension Activity: Air Resistance [AirResistanceEA.doc]
In this activity, students complete their investigation of the model problem used throughout the Power guided learning activity. Note that this activity is quite challenging. It is written as an individual lesson and can be assigned to strong students, but it is perfectly reasonable to assign it to groups of students to work on together or to work through the sheet as a class.

Related Gizmos
The following Gizmos are relevant to this unit:

Newton's Laws:
Fan Cart Physics: http://www.explorelearning.com/gizmo/id?403
Atwood Machine: http://www.explorelearning.com/gizmo/id?523
2-D Collisions: http://www.explorelearning.com/gizmo/id?361

Kinetic Energy and Work:
Inclined Plane–Sliding Objects: http://www.explorelearning.com/gizmo/id?27
Inclined Plane–Simple Machines: http://www.explorelearning.com/gizmo/id?604