Newtonian Mechanics
8.01

Problem Solving Strategies

Learning Objectives

- Create an engaging and technologically enabled active learning environment
- Move away from passive lecture/recitation format
- Incorporate hands-on experiments
- Enhance conceptual understanding and problem-solving ability

Problem Solving

- Measures understanding in technical and scientific courses

- Problem solving requires factual and procedural knowledge, knowledge of numerous schema, plus skill in overall problem solving.

- Schema is loosely defined as a “specific type of problem” such as principal, rate, and interest problems, one-dimensional kinematic problems with constant acceleration, etc..

Models

- Models represent some features of some thing
- Physical Models represent pattern(s) found in physical reality
  - Pattern includes structure, relationships, properties.
  - Pattern is a simplified/approximate of reality
  - More useful if pattern occurs often in reality.
- Solution to physics problem is a model
  - Solution may combine several standard models.

Structure of Models

- System – separate part of universe
- Description of System:
  - Objects
  - State variables
  - Interactions, agents:
- Multiple Representations
  - Ways to see it
  - How to relate them
- Law of Change, Interaction

Models for 8.01

1. One-Dimensional Motion: One-Dimensional Motion with constant acceleration; One-Dimensional Motion with constant velocity; One-Dimensional Motion with non-constant acceleration

2. Two-Dimensional Motion: Projectile motion (with and without drag; Circular motion

3. Momentum and Impulse: Dynamics

4. Energy Conservation: Work and Heat; Mechanical Energy; Work-Energy; Potential Energy

5. Simple Harmonic Motion: Springs and pendulums

6. Angular Momentum: motion in plane; three dimensional gyroscopic motion

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Four Stages of Attack

1. Understand the Problem and Models
2. Plan your Approach – Models and Schema
3. Execute your plan (does it work?)
4. Review - does answer make sense?
   - return to plan if necessary

Understand: Get it in Your Head

What concepts are involved?

Represent problem - Draw pictures, graphs, storylines…

Similarity to previous problems?

What known models/physical principles are involved?

e.g. motion with constant acceleartion; two bodies

Find special features, constraints

e.g. different acceleration before and after some instant in time

Plan your Approach

Model: Real life contains great complexity, so in physics you actually solve a model problem that contains the essential elements of the real problem.

Build on familiar models

Lessons from previous similar problems

Select your system,

Pick coordinates to your advantage

Are there constraints, given conditions?

Execute the Plan

From general model to specific equations

Examine equations of the models, constraints

Is all/enough understanding embodied in Eqs.?

count equations and unknowns

simplest way through the algebra

Solve analytically (numbers later)

Keep notation simple (substitute later)

Keep track of where you are in your plan

Check that intermediate results make sense

Stuck?

Represent the Problem in New Way

- Graphical
- Pictures with descriptions
- Pure verbal
- Equations

Could You Solve it if…

- the problem were simplified?
- you knew some other fact/relationship?
- You could solve any part of problem, even a simple one?

Review

a. Does the solution make sense?

   Check units, special cases, scaling. Is your answer reasonably close to a simple estimation?

b. If it seems wrong, review the whole process.

c. If it seems right,

   review the pattern and models used,

   note the approximations,

   tricky/helpful math steps.

Estimation Problems

Quantitative estimation of phenomena

Order of magnitude estimations

Estimations Strategies

Identify a set of quantities that can be estimated or calculated.

What type of quantity is being estimated?

How is that quantity related to other quantities, which can be estimated more accurately?

Establish an approximate or exact relationship between these quantities and the quantity to be estimated in the problem

Concept Question: Estimation Volume of Earth's Atmosphere

What is your best estimate for the volume of the earth's

1. between 10^1 and 10^5 cubic meters
2. between 10^5 and 10^{10} cubic meters
3. between 10^{10} and 10^{15} cubic meters
4. between 10^{15} and 10^{20} cubic meters
5. between 10^{20} and 10^{25} cubic meters
6. between 10^{25} and 10^{30} cubic meters

Example Estimation: Number of Molecules in Atmosphere

Estimation quantity is a scalar: N number of molecules and is related to volume of atmosphere. Estimate thickness of atmosphere as 10 km.

Volume of atmosphere: $Vol = 4\pi R_e^{\,2} t \quad (4\pi)(6\times 10^{6}\text{ m})^2(1\times 10^{4}\text{ m}){=}4\times 10^{18}\text{ m}^3$

Number of molecules = (number of molecules in a mole)(number of moles in atmosphere)

Number of moles in atmosphere = (volume of atmosphere)/(volume of mole)

Number of molecules in a mole N_A = 6 x 10^{23} molecules/mole.

Number of molecules in atmosphere: at STP (Standard Temperature and Pressure): one mole of an ideal gas occupies 22.4 L = 22.4 x 10^{-3} m^3.

$$N = (6\times 10^{23}\text{ molecules/mole})(4\times 10^{18}\text{ m}^3)\,/\,(22.4\times 10^{-3}\text{ m}^3\,/\,\text{mole})$$

$$= 1\times 10^{44}\text{ molecules}$$

Number of Molecules in Atmosphere: Using Pressure

Estimation quantity is a scalar: N number of molecules and is related to the mass of the atmosphere. Determine mass per square meter from atmospheric pressure. Use atmospheric pressure at the surface of the earth is weight of a column of air per area: $P_{atm} = 1 \text{ x } 10^5 \text{ N m}^{-2}$; and mass per mole: $30 \text{ x } 10^{-3}$ kg-mole^{-1}.

$$mass / area \quad (Pressure / g) = (1 \times 10^5 \,\mathrm{N\,m^{-2}}) / (10 \,\mathrm{m\,s^{-2}}) = 10^4 \,\mathrm{kg\,m^{-2}}$$

Total mass equals surface area of earth times mass per square meter.

$$mass = (mass / area)(4\pi R_{earth}^2) \quad (10^4 \,\mathrm{kg\,m^{-2}})(4\pi)(6 \times 10^6 \,\mathrm{m})^2 = (4 \times 10^{18} \,\mathrm{kg})$$

Number of moles in atmosphere = (mass of atmosphere)/(mass per mole)

$$\# moles \quad (4 \times 10^{18} \,\mathrm{kg})/(30 \times 10^{-3} \,\mathrm{kg\,mole^{-1}}) \quad 1.3 \times 10^{20} \text{ mole}$$

Number of molecules = (number of molecules in a mole)(number of moles in atmosphere). Number of molecules in a mole $N_A = 6 \text{ x } 10^{23}$ molecules/mole.

$$N = (6 \times 10^{23} \text{ molecules/mole})(1.3 \times 10^{20} \text{ mole}) = 1 \times 10^{44} \text{ molecules}$$