NILE UNIVERSITY of NIGERIA

FACULTY OF ENGINEERING

GET 101 2021. 2nd Intake. Introduction to Engineering. Presentation 6 - PROBLEM SOLVING TECHNIQUES

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1. INTRODUCTION

2. DEFINING SOLVEM

Introduction to SOLVEM

- The acronym **SOLVEM:**
    - **S**ketch
      Observations or **O**bjectives
      List of **V**ariables and
      Equations
      Manipulation
- Note that this approach is equally useful for problems involving estimation and more precise calculations.
- Each step is described below.

2. DEFINING SOLVEM

Sketch

- In sketching a problem, you are subconsciously thinking about it.
- Be sure to draw the diagram large enough so that everything is clear, and label the things that you know about the problem in the diagram.
- For some problems, a before-and-after set of diagrams may be helpful.
- In very complex problems, you can use intermediate diagrams or subdiagrams as well.
- Fig. 6-1 below illustrates how a drawing can help you visualise a problem.

2. DEFINING SOLVEM

Sketch

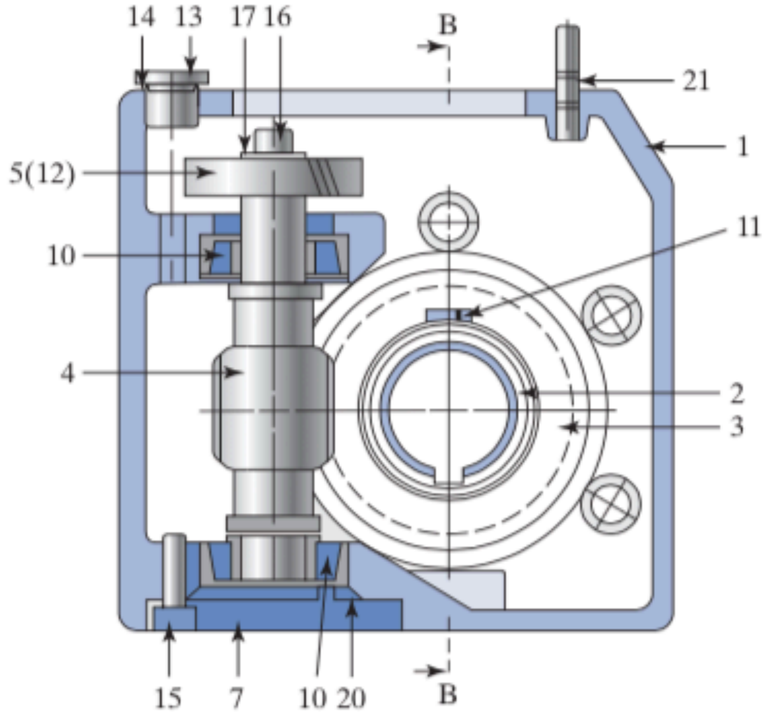

Fig. 6.1(a). Sketch of a Problem

2. DEFINING SOLVEM

Sketch

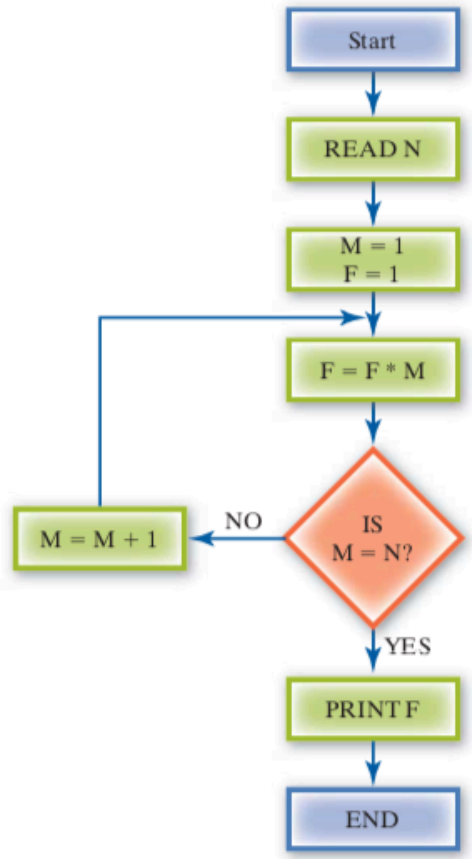

Fig. 6.1(b). Sketch of a Problem

2. DEFINING SOLVEM

Sketch

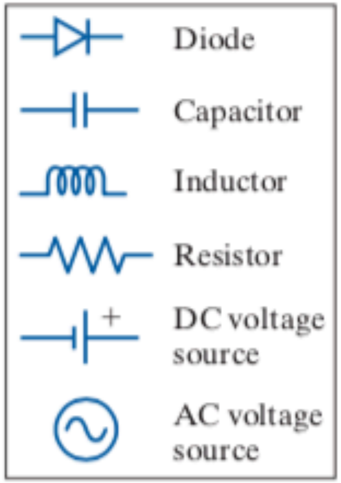

Fig. 6.1(c). Sketch of a Problem

2. DEFINING SOLVEM

Sketch

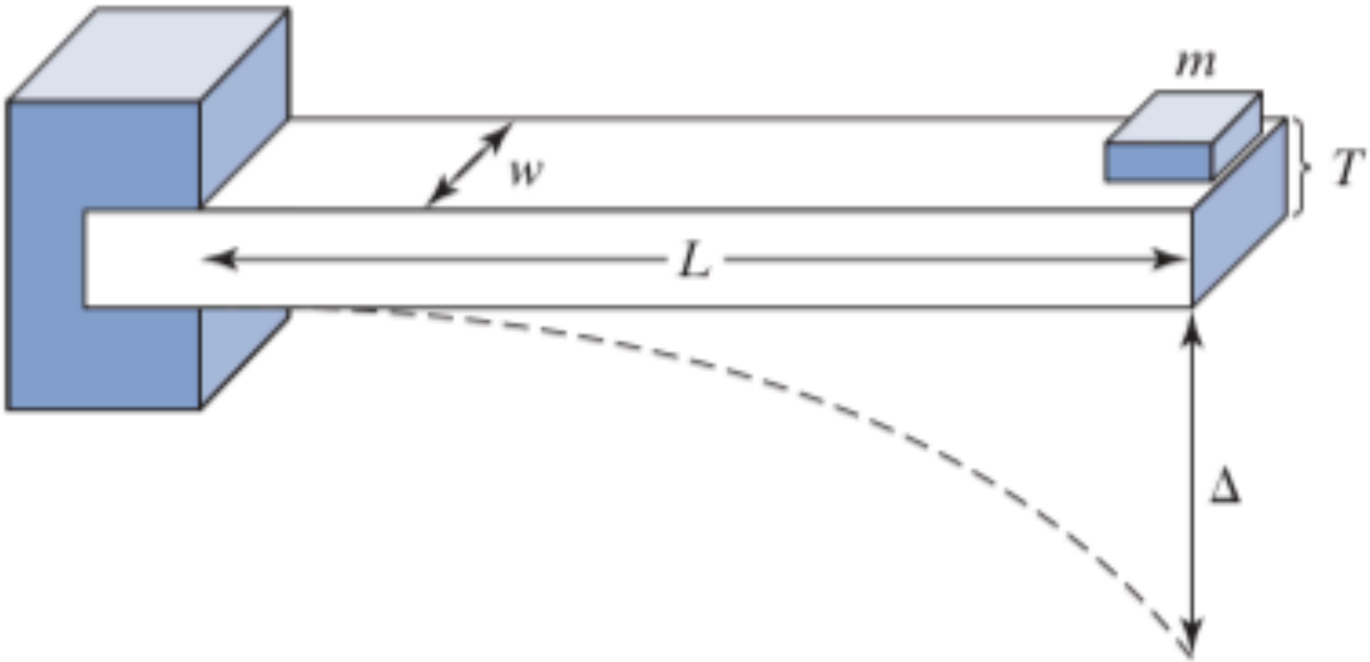

Fig. 6.1(d). Sketch of a Problem

2. DEFINING SOLVEM

Sketch

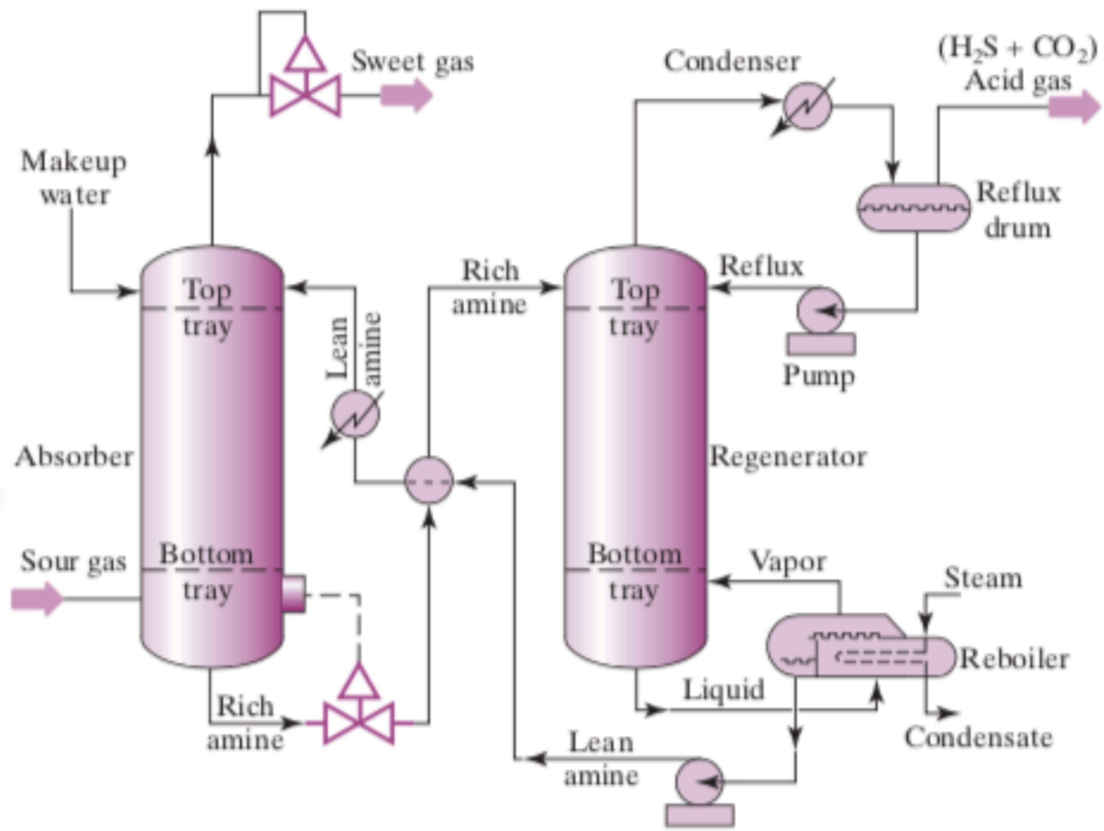

Fig. 6.1(e). Sketch of a Problem

2. DEFINING SOLVEM

Sketch

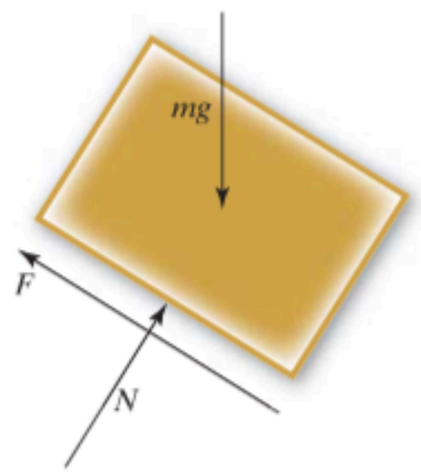

Fig. 6.1(e). Sketch of a Problem

2. DEFINING SOLVEM

Sketch

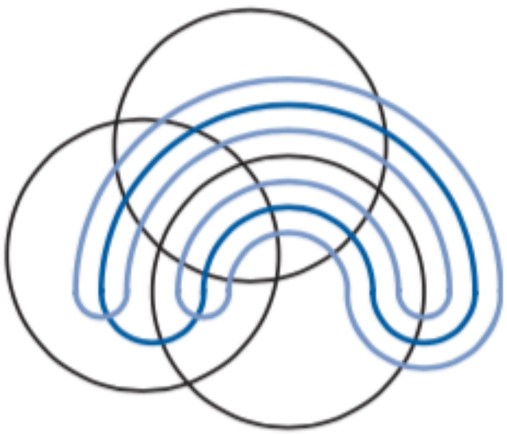

Fig. 6.1(g). Sketch of a Problem

2. DEFINING SOLVEM

Example 6.1 - Sketch

Create a sketch for the following problem.

- Calculate the mass in kilograms of gravel stored in a rectangular bin 18.5 feet by 25.0 feet. The depth of the gravel in the bin is 15 feet, and the density of the gravel is 97 pound-mass per cubic foot.

2. DEFINING SOLVEM

Observations, Objectives

- These can be in the form of
    - simple statements,
    - questions, or
    - anything else that might acquaint you with the problem at hand.

2. DEFINING SOLVEM

Observations, Objectives

- Divide your observations and objectives into several categories:
    - Objective to be achieved
    - Observations about the problem geometry (size, shape, etc.)
    - Observations about materials and material properties (density, hardness, etc.)
    - Observations about parameters not easily sketched (temperature, velocity, etc.)
    - Other miscellaneous observations that might be pertinent

2. DEFINING SOLVEM

Observations, Objectives

- An essential part of stating observations is to state the objectives.
- When making observations, do not forget that you have five senses.
- Here are some typical examples of *Objectives*
    - Find the velocity, force, flow rate, time, pressure, etc., for a given situation.
    - Profitably market the device for less than $25.
    - Fit the device into a 12-cubic-inch box.

2. DEFINING SOLVEM

Observations, Objectives

Observations - Problem Geometry

- The liquid has a free surface.
- The submerged plate is rectangular.
- The support is vertical.
- The tank is cylindrical
- The cross-sectional area is octagonal
- The orbit is elliptical.

2. DEFINING SOLVEM

Observations, Objectives

Observations - MATERIALS AND MATERIAL PROPERTIES

- The gate is steel.
- The coefficient of static friction is 0.6.
- The specific gravity is 0.65.
- Ice will float in water.
- The alloy superconducts at 97 kelvin.
- The alloy melts at 543 degrees Fahrenheit.

2. DEFINING SOLVEM

Observations, Objectives

Observations - OTHER PARAMETERS

- If depth increases, pressure increases.
- If temperature increases, resistance increases.
- The flow is steady.
- The fluid is a gas and is compressible.
- The pulley is frictionless.
- The magnetic field is decreasing
- Temperature may not fall below 34 degrees Fahrenheit.

2. DEFINING SOLVEM

Observations, Objectives

Observations - MISCELLANEOUS

- The force will act to the right.
- Gravity causes the ball to accelerate.
- The sphere is buoyant.
- Drag increases as the speed increases.

2. DEFINING SOLVEM

Observations, Objectives

Observations - THE ZERO VALUE

- Quantities whose value is zero contain valuable information
- Remember to include those quantities whose value is zero!
- Often such quantities are hidden with terms such as:
    - Constant 1implies derivative = 0
    - Initially 1at time = 0
    - At rest (no motion)
    - Dropped (no initial velocity)
    - At the origin (at zero position)
    - Melts or Evaporates (changes phase, temperature is constant)

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

State the objective and any relevant observations for the following problem.

- Calculate the mass in kilograms of gravel stored in a rectangular bin 18.5 feet by 25.0 feet.
- The depth of the gravel bin is 15 feet, and the density of the gravel is 97 pound-mass per cubic foot.

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

One of the most important reasons to make *many* observations is that you often will observe the “wrong” thing.

- For example, write down things as you read this:

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

- For example, write down things as you read this:

    - A bus contains 13 passengers.

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

One of the most important reasons to make *many* observations is that you often will observe the “wrong” thing.

- For example, write down things as you read this:

    - At the first stop, four get off and two get on.

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

One of the most important reasons to make *many* observations is that you often will observe the “wrong” thing.

- For example, write down things as you read this:

    - At the next stop, six get off and one gets on.

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

One of the most important reasons to make *many* observations is that you often will observe the “wrong” thing.

- For example, write down things as you read this:

    - At the next stop, nobody gets off and five get on.

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

One of the most important reasons to make *many* observations is that you often will observe the “wrong” thing.

- For example, write down things as you read this:

    - At the next stop, nobody gets off and five get on.

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

One of the most important reasons to make *many* observations is that you often will observe the “wrong” thing.

- For example, write down things as you read this: \

    - At the next stop, eight get off and three get on.

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

One of the most important reasons to make *many* observations is that you often will observe the “wrong” thing.

- For example, write down things as you read this:

    - At the next stop, one gets off.

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

One of the most important reasons to make *many* observations is that you often will observe the “wrong” thing.

- For example, write down things as you read this:

    - At the last stop, four get off and four get on.

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

One of the most important reasons to make *many* observations is that you often will observe the "wrong" thing.

- For example, write down things as you read this:
  - A bus contains 13 passengers.
  - At the first stop, four get off and two get on.
  - At the next stop, six get off and one gets on.
  - At the next stop, nobody gets off and five get on.
  - At the next stop, eight get off and three get on.
  - At the next stop, one gets off.
  - At the last stop, four get off and four get on.

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

- After putting your pencil down and without looking again at the list, answer the question given below

2. DEFINING SOLVEM

Example 6.2 - Observations, Objectives

- **QUESTION:** For the bus problem, how many stops did the bus make?
- The lesson here is that often we may be observing the wrong thing.

2. DEFINING SOLVEM

List of Variables and Constants

- Go over the observations previously determined and list the variables that are important.
- It may help to divide the list into several broad categories
    - those related to the geometry of the problem,
    - those related to the materials, and
    - a properties category

2. DEFINING SOLVEM

List of Variables and Constants

- Include in your list
  - the written name of the variable,
  - the symbol used to represent the quantity
  - list the numeric value, including units.
- If a value is a constant you had to look up,
  - record where you found the information.

2. DEFINING SOLVEM

List of Variables and Constants

- INITIAL AND FINAL CONDITIONS
  - Initial temperature $T_0 = 60^0F$
  - Initial radius $r_i = 5$ cm
  - Mass of the object $m = 23$ kg
- CONSTANT
  - Acceleration of gravity $g = 32.2$ ft/s^2
  - Ideal gas constant $R = 8{,}314$ [(Pa L)/(mol K)]

2. DEFINING SOLVEM

List of Variables and Constants

- GEOMETRY
  - Length of beam
  - Cross-sectional area of a pipe
  - Volume of a reactor vessel
- MATERIALS
  - Steel
  - Polyvinyl chloride (PVC)
  - Plasma
  - Gallium arsenide
  - Medium-density balsa wood

2. DEFINING SOLVEM

List of Variables and Constants

- PROPERTIES
  - Dynamic viscosity of honey μ 2,500 cP
  - Density of PVC ρ 1,380 kg/m^3
  - Spring constant k 0.05 N/m
  - Specific gravity SG 1.34

2. DEFINING SOLVEM

Example 6.3 - List of Variables and Constants

Create a list of variables and constants for the following problem.

- Calculate the mass in kilograms of gravel stored in a rectangular bin 18.5 feet by 25.0 feet.
- The depth of the gravel bin is 15 feet, and the density of the gravel is 97 pound-mass per cubic foot.

2. DEFINING SOLVEM

Equations

- After completing the steps above (S-O-L-V)
    - then think about the equations that might govern the problem.
- Make a list of the pertinent equations in a broad sense before listing specific expressions.
- For example:
    - Conservation of energy
    - Conservation of mass
    - Conservation of momentum
    - Frequency equations
    - Ideal gas law

2. DEFINING SOLVEM

Equations

- For example:
  - Newton's laws of motion
  - Stress–strain relations
  - Surface areas of geometric solids
  - Volumes of geometric solids
  - Work, energy relations

2. DEFINING SOLVEM

Equations

- You may need “sub-equations” such as:
  - Distance = (velocity) * (time)
  - Energy = (power) * (time)
  - Force = (pressure) * (area)
  - Mass = (density) * (volume)
  - Voltage = (current) * (resistance)
  - Weight = (mass) * (gravity)

2. DEFINING SOLVEM

Equations

- For an equation,
  - list the broad category of the equation (Hooke's law) and
  - then the actual expression ($F = kx$)
  - to help with problem recognition.
- Do not substitute numerical values of the parameters into the equation right away.
  - Instead, manipulate the equation algebraically to the desired form

2. DEFINING SOLVEM

Example 6.4 - Equations

Create a list of equations for the following problem.

- Calculate the mass in kilograms of gravel stored in a rectangular bin 18.5 feet by 25.0 feet.
- The depth of the gravel bin is 15 feet, and the density of the gravel is 97 pound-mass per cubic foot.

2. DEFINING SOLVEM

Manipulation

- You need to manipulate pertinent equations before you can obtain a final solution.
- *Do not substitute numerical values of the parameters into the equation right away*.
- Instead, manipulate the equation algebraically to the desired form.
- Often you will discover terms that will cancel, giving you a simpler expression to deal with.

2. DEFINING SOLVEM

Manipulation

- By doing this, you will:
  - Obtain general expressions useful for solving other problems of this type
  - Be less likely to make math errors
  - Be able to judge whether your final equation is dimensionally consistent
  - Better understand the final result

2. DEFINING SOLVEM

Manipulation

- The SOLVEM acronym does not contain a word or step for "numerical solution."
- In fact, this process helps you analyse the problem and obtain an expression or procedure so that you can find a numerical answer.
- Engineers need training to be able to analyse and solve problems.
- If you can do everything except "substitute numbers" you are essentially finished - as an engineer,
- you will "be paid the big bucks" for analysis, not for punching a calculator!


ZUCCHERO
Coffee Break

3. REPRESENTING FINAL RESULTS

Manipulation

- Recognise where and when to apply "reasonableness" within SOLVEM
- Do not plug values into the equation until the final step.
- When you have completed all the steps to SOLVEM, plug in values for the variables and constants and solve for a final answer.
- Be sure to use reasonableness.
- The final answer should include both a numeric value and its unit.
- Write a sentence describing how the answer meets the objectives.
- Box your final answer for easy identification.

3. REPRESENTING FINAL RESULTS

Manipulation

- Repeated use of SOLVEM can
    - help you develop a better "gut-level understanding" about the analysis of problems
    - by forcing you to talk and think about the generalities of the problem
    - before jumping in and searching for an equation
    - into which you can immediately substitute numbers.

3. REPRESENTING FINAL RESULTS

Example 6.4 - Manipulation

Manipulate and solve for the following problem, using the information from Examples 1 - 4.

- Calculate the mass in kilograms of gravel stored in a rectangular bin 18.5 feet by 25.0 feet.
- The depth of the gravel bin is 15 feet, and the density of the gravel is 97 pound-mass per cubic foot.


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Coffee Break

4. AVOIDING COMMON MISTAKES

Basic Concepts

Erroneous or argumentative thinking can lead to problem-solving errors.

For example,

1. I can probably find a good equation in the next few pages.
2. I hate algebra, or I cannot do algebra, or I have got the numbers, so let us substitute the values right in.
3. It is a simple problem, so why do I need a sketch?
4. I do not have time to think about the problem, I need to get this stuff finished.

4. AVOIDING COMMON MISTAKES

Basic Concepts

1. **I can probably find a good equation in the next few pages.**

    - Perhaps you read a problem and rifle through the chapter to find the proper equation so that you can start substituting numbers.
    - You find one that looks good.
    - You do not worry about whether the equation is the right one or whether the assumptions you made in committing to the equation apply to the present problem.
    - You whip out your calculator and produce an answer.
    - *Do NOT do this!*

4. AVOIDING COMMON MISTAKES

Basic Concepts

2. **I hate algebra, or I cannot do algebra, or I have got the numbers, so let us substitute the values right in.**

- Many problems become much simpler
    - if you are willing to do a little algebra before trying to find a numerical solution.
- Also, by doing some manipulation first,
    - you often obtain a general expression that is easy to apply to another problem when a variable is given a new value.
- By doing a little algebra,
    - you can also often circumvent problems with different sets of units.
- *Do some algebra!*

4. AVOIDING COMMON MISTAKES

Basic Concepts

1. **It is a simple problem, so why do I need a sketch?**

    - Even if you have a photographic memory,
        - you will need to communicate with people who do not.
    - It is usually much simpler to sort out the various parts of a problem if a picture is staring you right in the face.
    - *Draw pictures!*

4. AVOIDING COMMON MISTAKES

Basic Concepts

1. **I do not have time to think about the problem, I need to get this stuff finished.**
    - Well, most often, if you take a deep breath and jot down several important aspects of the problem,
    - you will find the problem much easier to solve and will solve it correctly.
    - *Take your time!*


ZUCCHERO
Coffee Break

5. EXAMPLES OF SOLVEM

Example 6.5

Estimate how many miles of wire stock are needed to make 1 million standard paper clips.

5. EXAMPLES OF SOLVEM

Example 6.5

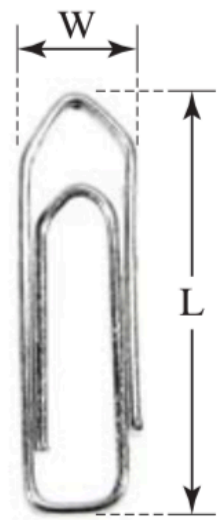
Solution

- Sketch
- Objectives
- Observation
- List of variables and constants
- Estimations and assumptions
- Equations
- Manipulation

5. EXAMPLES OF SOLVEM

Example 6.5

Sketch



5. EXAMPLES OF SOLVEM

Example 6.5

Objective:

Determine the amount of wire needed to manufacture a million paper clips.

Observations:

- *Paper clips come in a variety of sizes*
- *There are four straight segments and three semicircular sections in one clip*
- *The three semicircular sections have slightly different diameters*
- *The four straight sections have slightly different lengths*

5. EXAMPLES OF SOLVEM

Example 6.5

List of Variables and Constants:

- L — *Overall length of clip*
- W — *Overall width of clip*
- L_1, L_2, L_3, L_4 — *Lengths of four straight sections*
- D_1, D_2, D_3 — *Diameters of three semicircular sections*
- P_1, P_2, P_3 — *Lengths of three semicircular sections*
- A — *Total amount (length) of wire per clip*

5. EXAMPLES OF SOLVEM

Example 6.5

Estimations and Assumptions:

- *Length of clip:* $L = 1.5$ in
- *Width of clip:* $W = 3/8$ in
- *Diameters from largest to smallest*
  - $D_1 = W = 3/8$ in
  - $D_2 = 5/6$ in
  - $D_3 = 1/4$ in
- *Lengths from left to right in sketch*
  - L_1 = To be calculated
  - $L_2 = 0.8$ in
  - $L_3 \approx L4 = 1$ in

5. EXAMPLES OF SOLVEM

Example 6.5

Equations:

- *Perimeter of semicircle:* $P = \pi D/2$ *(half of circumference of circle)*
- $L_1 = L - D_1/2 - D_2/2$
- *Total length of wire in clip:* $A = L_1 + L_2 + L_3 + L_4 + P_1 + P_2 + P_3$

5. EXAMPLES OF SOLVEM

Example 6.5

Manipulation:

In this case, none of the equations need to be manipulated into another form.

Length of longest straight side:	$L_1 = 1.5 - {}^{3}/_{16} - {}^{5}/_{32} \approx 1.2$ in
Lengths of semicircular sections:	$P_1 = \pi\,{}^{3}/_{16} \approx 0.6$ in $P_2 = \pi\,{}^{5}/_{32} \approx 0.5$ in $P_3 = \pi\,{}^{1}/_{8} \approx 0.4$ in
Overall length for one clip:	$A = 1.2 + 0.8 + 1 + 1 + 0.6 + 0.5 + 0.4 = 5.5$ in/clip
Length of wire for 1 million clips:	$(5.5 \text{ in/clip})\,(1 \times 10^6 \text{clips}) = 5.5 \times 10^6$ in
Convert from inches to miles:	$(5.5 \times 10^6 \text{ in})\,(1 \text{ ft}/12 \text{ in})\,(1 \text{ mile}/5{,}280 \text{ ft}) \approx 86.8$ miles

One million, 1.5-inch paper clips require about 87 miles of wire stock.

5. EXAMPLES OF SOLVEM

Example 6.6

- A spherical balloon has an initial radius of 5 inches.
- Air is pumped in at a rate of 10 cubic inches per second, and the balloon expands.
- Assuming that the pressure and temperature of the air in the balloon remain constant,
    - how long will it take for the surface area to reach 1,000 square inches?

5. EXAMPLES OF SOLVEM

Example 6.6

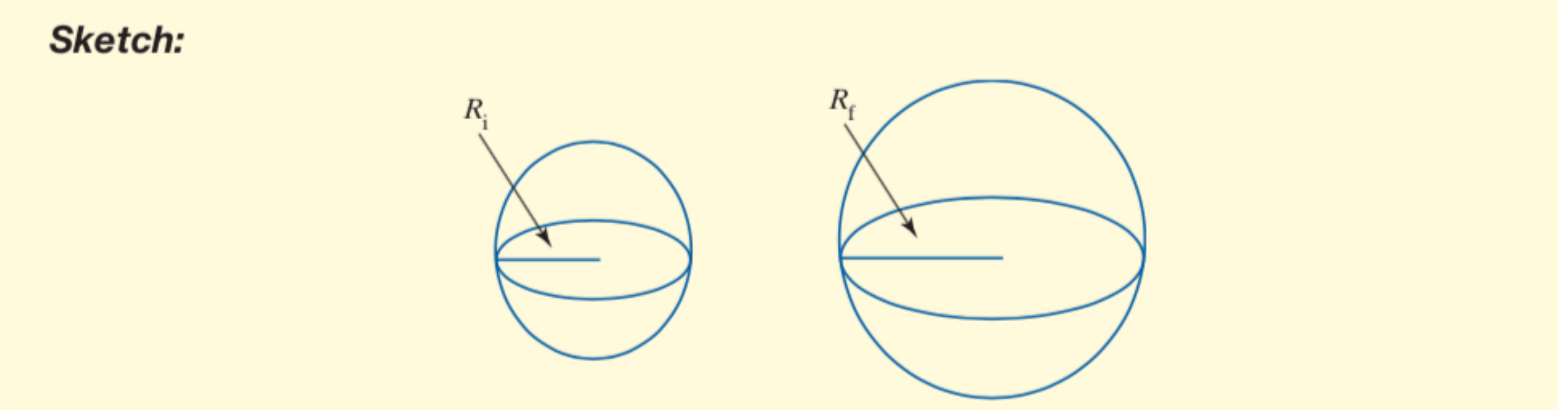
Solution

- Sketch
- Objectives
- Observation
- List of variables and constants
- Equations
- Manipulation

5. EXAMPLES OF SOLVEM

Example 6.6

- Sketch



5. EXAMPLES OF SOLVEM

Example 6.6

- Objective

Objective:

Determine how long it will take for the surface area of the balloon to reach 1,000 in^2

5. EXAMPLES OF SOLVEM

Example 6.6

Observations:

- *The balloon is spherical*
- *The balloon, thus its volume and surface area, gets larger as more air is pumped in*
- *The faster air is pumped in, the more rapidly the balloon expands*

5. EXAMPLES OF SOLVEM

Example 6.6

List of Variables and Constants:

- *Initial radius:* $R_i = 5$ [in]
- *Final radius:* R_f [in]
- *Initial surface area:* A_i [in^2]
- *Final surface area:* A_f [in^2]
- *Change in volume:* ΔV [in^3]
- *Initial volume:* V_i [in^3]
- *Final volume:* V_f [in^3]
- *Fill rate:* $Q = 10$ [in^3/s]
- *Time since initial size:* t [s]

5. EXAMPLES OF SOLVEM

Example 6.6

Equations:

- *Surface area of sphere:* $A = 4\pi R^2$
- *Volume of sphere:* $V = 4/3\ \pi R^3$
- *Change in volume:* $\Delta V = Qt$

5. EXAMPLES OF SOLVEM

Example 6.6

Manipulation:

There are a few different ways to proceed. The plan used here is to determine how much the balloon volume changes as air is blown into the balloon and to equate this to an expression for the volume change in terms of the balloon geometry (actually the radius of the balloon).

Radius of balloon in terms of surface area:	$R = \left(\frac{A}{4\pi}\right)^{1/2}$
Final balloon radius in terms of surface area:	$R_f = \left(\frac{A_f}{4\pi}\right)^{1/2}$
Final volume of balloon in terms of surface area:	$V_f = \left(\frac{4\pi}{3}\right)\left(\frac{A_f}{4\pi}\right)^{3/2}$
Volume change in terms of air blown in:	$\Delta V = V_f - V_i = Qt$
Volume change in terms of geometry:	$V_f - V_i = \left(\frac{4\pi}{3}\right)\left(\frac{A_f}{4\pi}\right)^{3/2} - \left(\frac{4\pi}{3}\right)R_i^3$
Solve for time to blow up balloon:	$t = \left(\frac{4\pi}{3Q}\right)\left(\frac{A_f}{4\pi}\right)^{3/2} - \left(\frac{4\pi}{3Q}\right)R_i^3$
And simplifying:	$t = \left(\frac{4\pi}{3Q}\right)\left\{\left(\frac{A_f}{4\pi}\right)^{3/2} - R_i^3\right\}$

It takes just over 4 minutes to increase the volume to 1,000 cubic inches.

5. EXAMPLES OF SOLVEM

Example 6.5 - Important Notes

- Whenever you obtain a result in equation form,
    - check to see if the dimensions match in each term.
- Recall that you should manipulate the equations *before* inserting known values.
- Note that the final expression for elapsed time is given in terms of initial radius (R_i), flow rate (Q), and final surface area (A_f).
- You now have a general equation that can be solved for any values of these three parameters.
- If you had begun substituting numbers into equations at the beginning and then wanted to obtain the same result for different starting values, you would have to resolve the entire problem.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ANY QUESTION?


Thank You!

NEXT TOPIC

IS

Fundamental Dimensions
and
Base Units