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Developing a Useful Instrument to Assess Student Problem Solving

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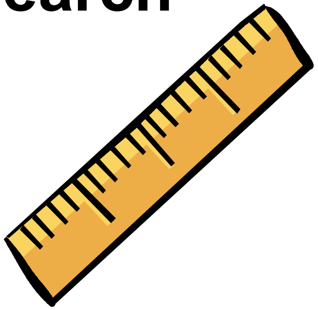
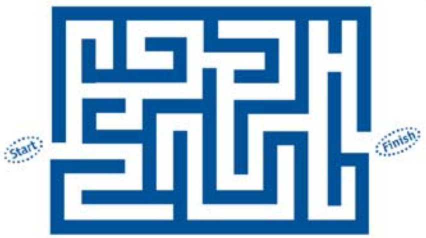
Problem Solving Measure

- Problem solving is one of the primary teaching goals, teaching tools, and evaluation techniques of physics courses.
- Issues:
  - There is no standard way to evaluate problem solving that is valid, reliable, and easy to use.
  - A single numerical score gives an inadequate description of a student’s skill at solving problems.
- A more detailed and meaningful measure of problem solving would be useful for both research and instruction.
- How do we measure a complex skill such as problem solving?



What is *problem solving*?

- "Problem solving is the process of moving toward a goal when the path to that goal is uncertain" (Martinez, 1998, p. 605)

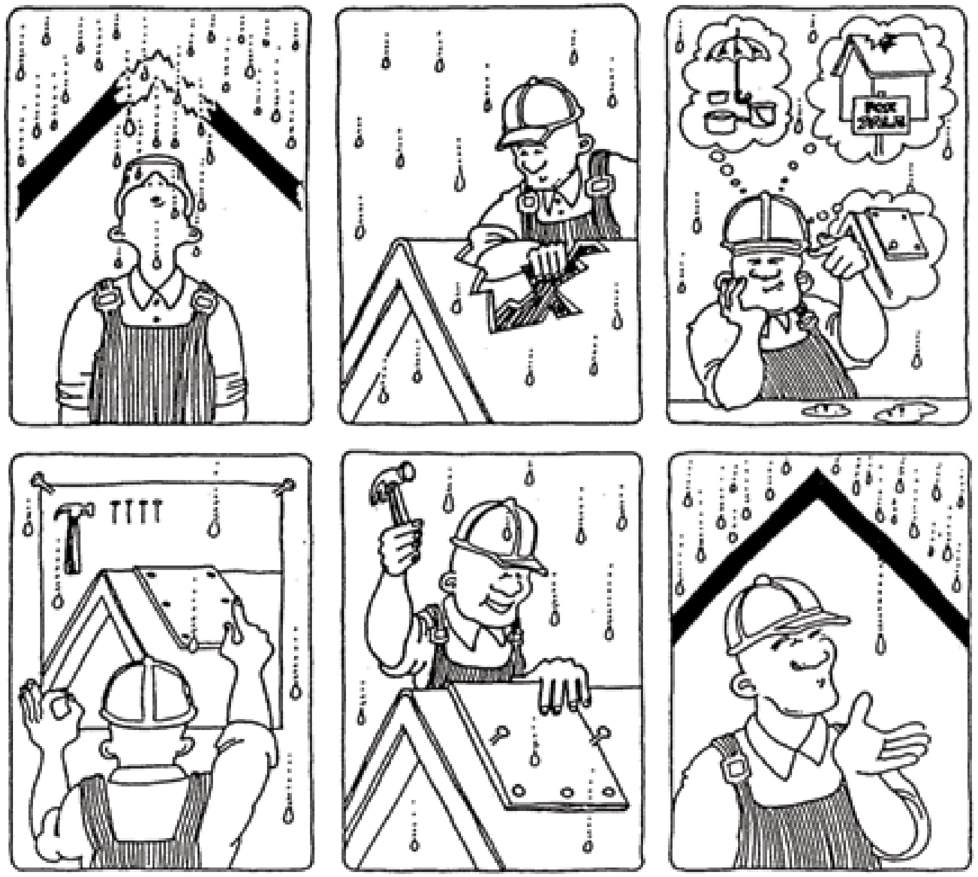


- What is a *problem* for one person might not be a problem for another person.
- Problem solving involves decision-making. If the steps to reach a solution are immediately known, this is an *exercise* for the solver.

Martinez, M. E. (1998). What is Problem Solving? *Phi Delta Kappan*, *79*, 605-609.

Problem Solving Process

1. **Identify & define the problem**
2. **Analyze the situation**
3. **Generate possible solutions/approaches**
4. **Select approach & devise a plan**
5. **Carry out the plan**
6. **Evaluate the solution**



http://www.hc-sc.gc.ca/fniah-spnia/images/fnihb-dgspni/pubs/services/toolbox-outils/78-eng.gif

Instrument at a glance (Rubric)

SCORE ←

CATEGORY:	5	4	3	2	1	0	NA(P)	NA(S)
Useful Description								
Physics Approach								
Specific Application								
Math Procedures								
Logical Progression								

Want

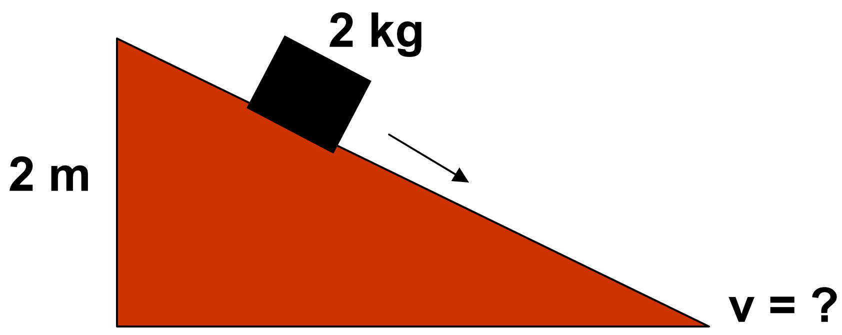
- ***Minimum*** ***number of categories that include relevant aspects of problem solving***
- ***Minimum*** ***number of scores that give enough information to improve instruction***
- ***Minimum*** ***training to use***

Rubric Scores (in general)

5	4	3	2
Complete & appropriate	Minor omissions or errors	Parts missing and/or contain errors	Most missing and/or contain errors

1	0	NA Prob	NA Solver
All inappro-priate	No evidence / missing	Not necessary for this problem	Not necessary for this solver

Example of NA (Problem)

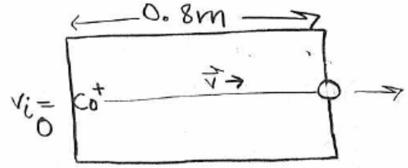


***Useful Description*:**
visual & symbolic representation given

A block of mass m = 2 kg slides down a frictionless ramp of height h = 2 m. Use conservation of energy to determine the speed of the block at the bottom of the ramp.

***Physics Approach*:**
physics concept or principle stated in problem

Range of detail in solutions



$s = 0.8$ m
$v_f = 8 \times 10^4$ m/s
$m_{co} = 28$ g/mol

Question: Calculate the direction and magnitude of the electric field needed so that Co^+ ions created at rest at one end will have a speed of 8×10^4 m/s when they exit the other side

Approach: Use conservation of energy

system: Co^+ particle

initial time: right as Co^+ enters the box

final time: right as Co^+ leaves the box

$E_i = 0$ $v_i = 0$

$E_f = \frac{1}{2}mv^2$ E_{in} = electric potential energy, $E_{out} = 0$

Electric potential energy $= \Delta V q = -q\int \vec{E} \cdot ds$

because the electric field is constant

$PE_e = -qE\int ds$

$PE_e = -qEs$ ← just want magnitude so can leave negative sign off

$E_f - E_i = E_{in} - E_{out}$ check units

$\frac{1}{2}mv^2 = qEs$ $\frac{1}{2}mv^2 \rightarrow$ energy units

$E = \frac{\frac{1}{2}mv^2}{qs}$ $\frac{E \cdot s}{V \cdot C}, q$ = energy units

units ok ✓

$|E| = \frac{\frac{1}{2}mv^2}{qs} =$ $J = n \cdot m$

$CO - e^- = CO^+$

$.028\text{ kg} - 9.11 \times 10^{-31}\text{ kg} = 0.028\text{ kg}$

$$|E| = \frac{\frac{1}{2}(0.028\text{ kg})(8 \times 10^4\text{ m/s})^2}{(1.602 \times 10^{-19}\text{ C})(0.8\text{ m})}$$

$$|E| = 6.99 \times 10^{26}\text{ N/C}$$

$+\xrightarrow{F_e}$ $qE = F_e = ma$

$E = \frac{ma}{q}$ $v_f^2 = v_i^2 + 2a\Delta x$ ($v_i = 0$)

$a = \frac{v_f^2}{2\Delta x}$

$E = \frac{mv_f^2}{q2\Delta x} = \frac{[kg] \cdot [m]^2}{[s]^2[C][m]} = \frac{N}{C}$ $\frac{V}{m} = \frac{N}{C}$ $N = \frac{kg\,m}{s^2}$

units ok ✓

$$E = 1162 \frac{N}{C}$$

***Useful Description*:** **unnecessary for this solver NA(S)**

Developing the Rubric

- **Draft instrument (based on lit. & past research)**
  - **Write draft → test out → revise…………x 8**
- **Preliminary testing**
  - **Distinguish between instructor & student solutions? YES!**
  - **Score agreement between two raters - good**
- **Pilot testing**
  - **Graduate students used rubric before & after brief training**
  - **Results:**
    - **confusion about NA, influenced by grading experience, multi-part problems difficult to score, score agreement improved slightly with training**
- **Revised pilot + Field testing**
  - **Revise training materials and re-pilot with graduate students and/or faculty**
  - **Collect & score exam copies for semester**

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Work in Progress!

Materials on the Web:

http://groups.physics.umn.edu/physed
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ADDITIONAL SLIDES

http://groups.physics.umn.edu/physed
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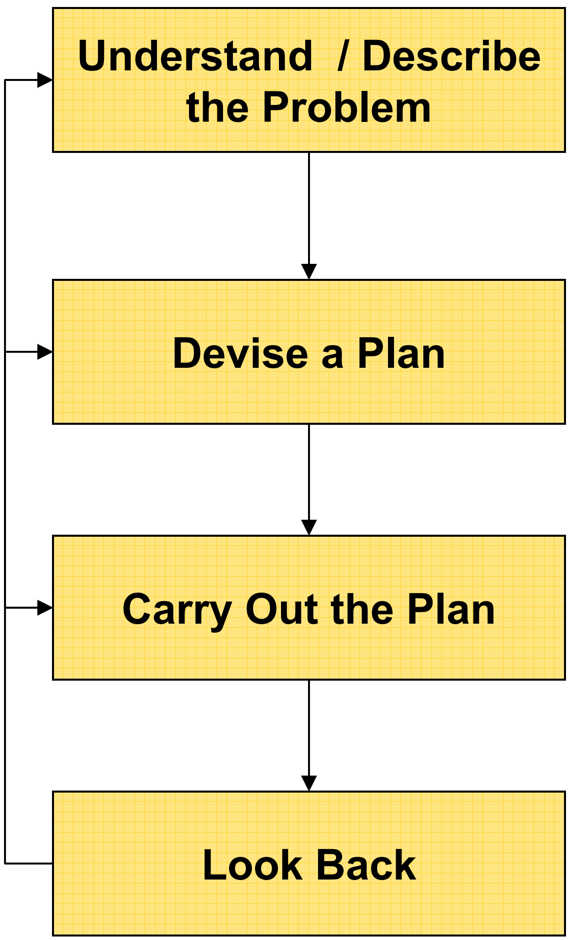
Rubric Categories (based on research literature)

- **Useful Description**
  - organize information from the problem statement symbolically, visually, and/or in writing.
- **Physics Approach**
  - select appropriate physics concepts and principles to use
- **Specific Application of Physics**
  - apply physics approach to the specific conditions in problem
- **Mathematical Procedures**
  - follow appropriate & correct math rules/procedures
- **Logical Progression**
  - (overall) solution progresses logically; it is coherent, focused toward a goal, and consistent

Note: 4 of the 5 categories are qualitative

Problem Solving Process (Physics)



- Redescribe information from the problem statement (pictures, words)
- Introduce symbolic notation & identify target quantity
- Identify key concepts

- Use your knowledge of concepts to relate target to known information

- Execute math procedures to isolate target quantity (symbols, then numbers)
- Monitor progress

- Check answer (units, reasonableness, limiting or extreme cases)

Pólya (1957); F. Reif & J. Heller (1982, 1984)

Expert-novice characteristics

Inexperienced or "novice" problem solvers:

- Little representation (jump to equations)
- Inefficient approaches (formula-seeking, solution pattern matching) based on objects in the problem
- Do not evaluate solution

Experienced or "expert" problem solvers:

- Low-detail overview of the problem before equations
  - *qualitative analysis*
- Principle-based approaches
- Evaluate their solution

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