Process of Problem Solving in Physics in the Context of Projectile Motion

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WHEN SOLVING the problems in Physics, multiple ideas come to the mind of the learners (Gandhi, Varma, 2004) . Their cognitive thinking may follow these sequences –

- They try to fit the problem in their existing cognitive schemes.
- They try to correlate the problem with their earlier experiences.
- They describe the problem by identifying the given quantities and the quantity/quantities to be found out.
- They prepare suitable hypothesis for solving the problem.
- They plan for action by identifying scientific principles and formula to be applied in the given situation.
- They analyse and/ or synthesise the relationship between the components of the problem and form a mental model of the relationship and concept.
- They apply the principles and formula with reasoning to arrive at the solution.
- They verify the result by going back to the problem to confirm that solution is correct.

As teaching of problem solving skills is one of the basic aims of Physics Instruction (Huffman, 1997), learners should be empowered to reflect on the problems independently. It becomes all the more important in the light of the fact that solving different types of problems requires attacking the problems using different strategies and different steps. Teachers' role is to guide the learners to decide

- which strategy is to be chosen;
- how it should be applied;
- why that particular strategy is being used; and
- when that strategy is to be applied (Gandhi, Varma, 2004).

It facilitates the learners in self-exploration and recognition of a suitable strategy. Becoming aware of their own strategies, they learn to orient their cognitive thinking to solve the problem by organising their thought in logical sequence and solve the problem independently.

Teacher has to make the process of problem solving transparent by exposing her own thinking patterns and sequences in dealing with the problem. She should discuss her own thinking process clearly to attack the problem. It would serve as a model to the learners. Simultaneously she should encourage the learners to give their ideas followed by the reasons and explanations for suggesting those ideas. By weaving thinking patterns for different steps of the solution of the problem with the help of learners, problem solving performance

and hence conceptual networks pertaining to principles of Physics can be strengthened. It develops cognitive schema of the learners facilitating constructive learning. Also learners become able to describe the problem first qualitatively, then quantitatively, which is a sound technique of problem solving in Physics (Duncan, 1997). In this process, they evaluate their strengths and weaknesses related to problem solving skills. Thus the highest level of learning of creative self-direction takes place and learners can solve the problems at their own initiative.

In this paper, an attempt is made to look for a simplistic approach to problem solving process in the context of projectile motion. It is suggested to work out the sequential steps for problem solving in teaching learning process as given below.

Let us now project the process of problem solving in projectile motion.

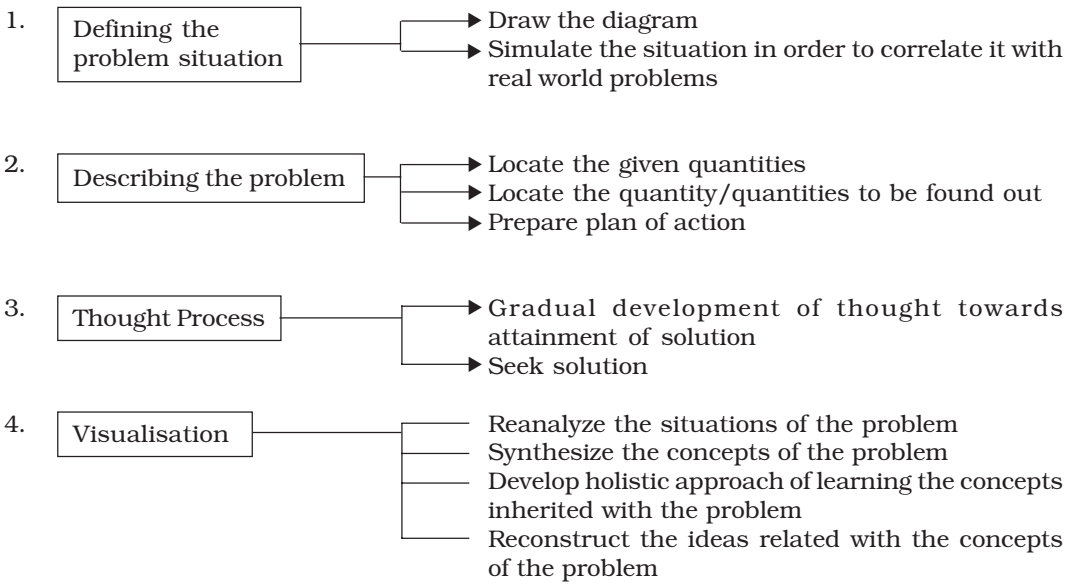
Exemplar Problem – 1

A person aims at a target on the ground from a horizontal distance of 100 m. If the gun can impart a velocity of 500 ms^{-1} to the bullet, at what height above the ground must he aim his gun to hit the target?

Solution

A. Defining Problem Situation

Draw a diagram of the situation and simulate the situation in the classroom in order to make the learner visualise the nature the problem.



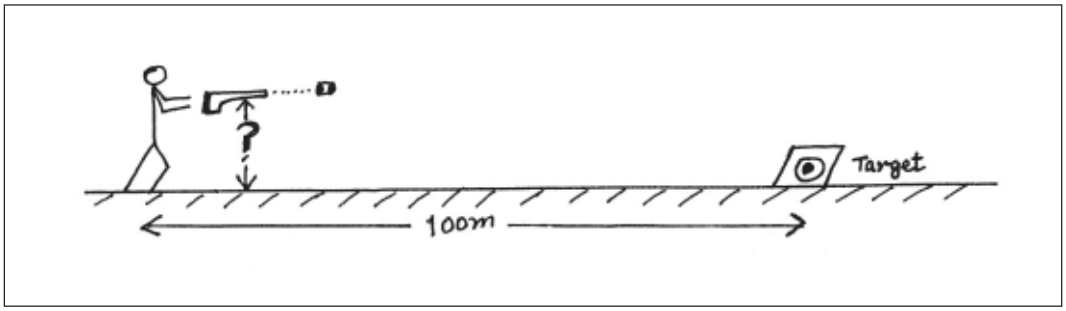


Fig. 1

B. Describing of Problem

Given quantities	*Quantity to be found out*
• Distance between the man and the target on the ground = 100 m • Velocity of the bullet = 500 ms^{-1}	• Height of the gun above the ground to hit the target?

C. Thought Process

- Vertical distance of the projectile from the ground can be determined by the expression

  $y = (u \sin \theta) t - (\frac{1}{2}) gt^2$
- But t is not given.
- t can be calculated by using the given data as

  t = distance/velocity = 100 m / 500 ms^{-1} = 0.2 s
- Substituting the value of t in this equation for y, we get

  $y = (0 \times 0.2) + (\frac{1}{2}) \times 10 \times (0.2)^2$

  = 0.2 m

  = 20 cm.
- Here initial velocity is zero and acceleration due to gravity is taken as 10 ms^{-1}.

D. Visualisation of the Problem

- Now let us write the calculated value of height in the language form for clarifying the situation of the problem as—

The person should aim his gun at a height 20 cm from the ground to hit the target.

Exemplar

Problem–2

It is possible to project a particle with a given velocity in two possible ways so as to make it pass through a point at a distance r from the point of projection. Determine how the product of the time taken in both ways to reach the point is related with r.

Solution

A. Defining the Problem

Simulate the situation in the classroom by taking an object and specifying x and y coordinates with respect to it.

Draw the diagram representing the situation.

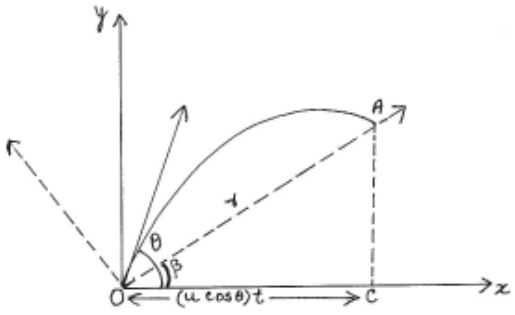


Fig. 2

B. Describing the Problem

As given in the box below.

C. Thought Process

- First determine the value of initial velocity, then that of r.
- Let the time taken by the particle at point A in two different cases be t_1 and t_2 respectively.
- Initial velocity can be determined by the equation of vertical displacement of the particle.

  $y = u (\sin\theta)\, t - (\frac{1}{2})\, gt^2$ .....(1)

- In the given situation u needs to be resolved into two rectangular components as –

  Component along OA = $u \cos(\theta - \beta)$

  Component along OB = $u \sin(\theta - \beta)$
- Components of acceleration due to gravity

  along OA = $- g \sin B$

  along OB = $- g \cos B$

Given quantities	*Quantities to be found out*
• A particle can be projected from point O in two different ways but with same velocity so as to reach at a point A. (OA = r)	• Relation between $(t_1 \times t_2)$ and r
• The particle reaches at A in two different times.	• For this the value of r is to be determined
• Since initial velocity of the particle remains same in two different cases, it is being thrown at two different angles	• In order to determine r, which is measurement of distance OA, we need to know the value of initial velocity. Hence we have to first find velocity of the particle.

Here, the problem demands that we need to develop the solution backwards.

- Now displacement of the particle along the direction perpendicular to OA is zero. Therefore substituting these values in equation (1), we get

  $0 = u \sin(q - b)\, t - (½)(g \cos b)\, t^2$ .....(2)

  or, $t = 2u \sin(q - b) / g \cos b$ .....(3)

  and $u = gt \cos b / 2 \sin(q - b)$ .....(4)

- To find OA = r

  From the right angled triangle OCA

  $OA = OC/\cos b = (u \cos q)\ t / \cos b$

  Putting the value of u from equation (4).

  $OA = r = (t \cos q / \cos b)\ [gt \cos b / 2 \sin(q - b)]$

  or $r = (g \cos q)t^2 / 2 \sin(q - b)$ .....(5)

- Now, since the particle is projected with the same initial velocity in the second case, its angle of projection and time taken to reach upto point A would be different.
- Let it be t_1 for angle of projection q_1 and t_2 for angle of projection q_2.
- Now $r = (g \cos Q_1)\, t_1^2 / 2 \sin(Q_1 - \beta)$

  also $r = (g \cos q_2)\, t_2^2 / 2 \sin(Q_2 - \beta)$
- $t_1^2\ t_2^2\ \alpha\ r^2$

D. Visualisation of the Problem

Hence the product of the time taken by the projectile with same initial velocity but thrown with different angle of projection is directly proportion to its distance r from the point of projection.

Above exemplar problems are suggestive and not prescriptive, as the thought processes vary from person to person depending upon his experiential knowledge, interest and aptitude. Also, one person may go through different thought processes at different time. Hence a problem may be tackled by a number of different approaches.

For the gradual development and growth of the solution, reasoning pattern of the thinking need to be strengthened. But it is worth mentioning that no matter how strong is the reasoning and how well woven the thinking patterns of the learner are, they must have clear concepts of the underlying principles of Physics.

It is said that a problem is a problem because there is no set steps for arriving at the solution. Hence it is imperative for the teacher to inculcate in the learner the values of self-awareness about their thought processes thereby leading to self-exploration, self-instruction and self-evaluation.

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