Resources for excellence in IIT JEE, Olympiads & NTSE

CHALLENGES IN GENERAL PHYSICS - 1

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Foreword

Physics is one of the basic sciences - indeed it is one of the oldest sciences. At its base, Physics is nothing but a systematic study of the world around us. Hence, this subject is fundamental to all students - indeed it is taught in school all the way from primary to high school.

It goes without saying that Physics is a very important subject for all students aspiring to get into Engineering or Science streams of under-graduate and graduate study. Whilst learning and understanding the concepts and definitions are important, one can build up expertise in Physics only by solving problems. To this end, we have selected challenging problems in Physics and presented them, along with their solutions here. These problems show the beauty of the subject, and help the student to internalize the concepts and principles of Physics in a systematic manner.

We sincerely hope that the student is able to get a good grasp of the subject and the techniques after working with the content of this book. If the experience of going through this work is joyful for the student and works as a tool for building his / her understanding, we would be satisfied that we have met the primary objective of this effort.

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Preface

This book is the first in a series of book dealing with challenging problems in Physics. This volume starts the ball rolling, with problems from Mechanics. The student is expected to have a good knowledge of physics concepts at the pre-University level. In our experience, this is a necessary and sufficient condition to solve all the problems presented here.

The best way to use this book is for the student to attempt each problem on his/her own. In doing so, the depth of understanding in the subject improves. Physics is not a spectator sport. It requires patience, perseverance and practice. The level of expertise in the subject in some sense is directly proprotional to the number of problems solved by the student. The term "solved" is used to imply accuracy of thought, stringing together intermediate steps and accuracy of the final result. In a way, this term refers to the quality of the means and the quality of the end goal for each problem.

There may be situations where the student is stuck and requires a gentle push to make progress. When the student faces such a deadlock, the helping hand comes in the form of the detailed solution.

This work is a comprehensive self study guide for the students who desire to improve their understanding, appearing for Physics related competitive examinations and tests.

I believe that Astrarka has been blessed to have had the opportunity to work with some of the best and brightest Any work of this magnitude is always a product of teamwork. R Balasubramanian, and Juanita John have contributed a great deal to this effort. A big thanks goes to the family members of our team. They have been a great source of inspiration during this entire effort. They have made a personal sacrifice to ensure that Astrarka succeeds. Without the unflinching commitment and single minded dedication of my team and the members of their family, this book would have been an exercise in futility.

Chandramouli Mahadevan

Introduction

To say that Physics is useful, therefore, we must learn it, is an understatement. This book focuses on problem solving strategies. We have organized the material into problems, the solution of each problem immediately after the statement. Familiarity with high school mathematics is assumed, especially basic vector mathematics, calculus and some trigonometry.

This book must not be read like a work of fiction. Instead, the student is advised to spend quality time in ensuring conceptual understanding. Solving problems in order to verify our conceptual understanding is extremely important. Most of us believe arriving at the final answer is the ultimate goal. We have come across several books on the subject, where the authors have skipped several steps and simply used the phrase "it follows from the fundamental principles ..." and made a conclusion. We disagree with this approach. The purpose of the problem solving is build the path to the solution using first principles or well-known formulas - and build an airtight reasoning on how the problem solving process moves towards the final answer. This serves as a demonstration of our understanding of the subject - basics, formulas and methods of manipulation.

Good Habits

There are five fundamental principles, or say good habits that we would like to emphasize before we commence our discussion on Physics.

1. Neatness is conducive to accuracy. Refrain from the temptation to write down something quickly and then scratch the same to make the necessary corrections.
2. One of the weaknesses we find in students while solving word problems is the usage of = sign. This sign has a specific meaning in the world of mathematics. It cannot be used as a way to begin every new line or step in the problem solving process. Use appropriate mathematical signs and symbols. Never use them to mean something vague. = Sign is never a good space filler.
3. Spend a second or two to explain how you arrived at a certain step. Several books and references use a statement, such as ``it follows from the above statement". We have oftentimes wondered how the expression or equation below follows from the one above. A good explanation is an excellent demonstration of your understanding of the underlying principles.
4. When you are faced with several conclusions during a problem solving process, it is a good idea to number the statements or equations. In subsequent steps, you can refer to these conclusions by using the label or the assigned equation number.
5. The easiest of problems attracts the silliest of mistakes. If the problem is easy, motivate yourself to get it right. Do not let overconfidence or carelessness take control of the situation.

Chapter 1 - Statics

Problem 1: A motorboat going downstream overcame a raft at a point A ; τ = 60 min later it turned back and after some time passed the raft at a distance l = 6.0 km from the point A. Find the flow velocity assuming the duty of the engine to be constant.

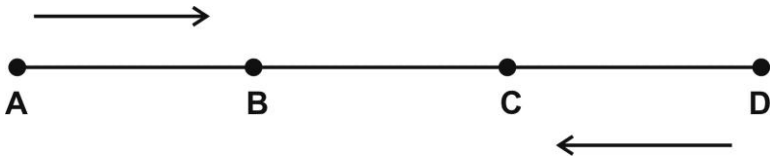

Diagram 1: The positions of the boat at different points

At time $t = 0$, the motor-boat and raft are at position A.

At time $t = \tau = 60$ minutes, the motor-boat is at position D and the raft is at position B. The boat turns back here.

At time $t = T$, the motor-boat and raft are both at position C, where $AC = l = 6$ km

From the perspective of an observer on the raft, the time taken by the boat to travel upstream and travel downstream are the same.

In other words, total time taken:

$$T = 2 \times \tau = 2\tau$$

Now, assume the river flow velocity is v_{flow}

The raft has travelled total distance of l in time T, which is 2τ

$$l = v_{flow} \times 2\tau$$

$$v_{flow} = \frac{l}{2\tau} = 3 \text{ km/hr}$$

Problem 2: A point traversed half the distance with a velocity v_0. The remaining part of the distance was covered with velocity v_1 for half the time, and with velocity v_2 for the other half of the time. Find the mean velocity of the point averaged over the whole time of motion.

Let the total time taken for the entire journey:

$$t = t_o + t_1 + t_2 \text{, for each of the three parts.}$$

From the problem description:

$$t_1 = t_2$$

Let d be the total distance covered.

The first half of the distance is covered with velocity v_0

Hence the time taken:

$$t_0 = \frac{d}{2v_0}$$

The remaining half was covered with velocity v_1 for time t_1 and velocity v_2 for time t_2

Hence distance:

$$\frac{d}{2} = v_1 t_1 + v_2 t_2$$

Since $t_1 = t_2$, we have:

$$\frac{d}{2} = v_1 t_1 + v_2 t_1 = (v_1 + v_2)\, t_1 = (v_1 + v_2)\left(\frac{t_1 + t_2}{2}\right)$$

So, time taken for the second and third parts:

$$t_1 + t_2 = \frac{d}{v_1 + v_2}$$

Total time taken::

$$t = t_0 + t_1 + t_2 = \frac{d}{2v_0} + \frac{d}{v_1 + v_2}$$

Mean or average velocity:

End of Preview.

Rest of the book can be read @
http://kinige.com/kbook.php?id=852

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