Resources for excellence in IIT JEE, Olympiads & NTSE

CHALLENGES IN GENERAL PHYSICS - 2

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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 undergraduate 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 is a sequel to the book titlled "Challenges in General Phsyics Part 1". The student is expected to have a good knowledge of physics concepts at the pre-University level. The Russians have always filled our bookshelves with some of the best textbooks. 200 odd gens from Physics Olympiads held between 1968-1985 is the source and inspiration of this work. These gems served me well when I was preparing for competitive examinations which essentially require an advanced problem solving skills.

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.

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. Ms Khushboo Varma has been a significant contributor to the overall quality of this output. We thank her for her contributions. 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

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1 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 - concepts, formulas and methods of manipulation.

2 Good Habits

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

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 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 over-confidence or carelessness take control of the situation.

3 Problems

For the problems of this chapter, the free-fall acceleration g (wherever required) should be taken equal to 10 m/s².

Q1. A body with zero initial velocity moves down an inclined plane from a height *h* and then ascends along the same plane with an initial velocity such that it stops at the same height *h*. In which case is the time of motion longer?

Q2. At a distance $L = 400m$ from the traffic light, brakes are applied to a loco motive moving at a velocity $v = 54km/h$. Determine the position of the locomotive relative to the traffic light 1 min after the application of brakes if its acceleration $a = -0 \cdot 3\frac{m}{s^2}$.

Q3. A helicopter takes off along the vertical with an acceleration $a = 3\frac{m}{s^2}$ and zero initial velocity. In a certain time t_1, the pilot switches off the engine. At the point of take-off, the sound dies away in a time $t_2 = 30$ s. Determine the velocity *v* of the helicopter at the moment when its engine is switched off, assuming that the velocity c of sound is 320 m/s.

Q4. A point mass starts moving in a straight line with a constant acceleration a. At a time t_1 after the beginning of motion, the acceleration changes sign, remaining the same in magnitude. Determine the time t from the beginning of motion in which the point mass returns to the initial position.

Q5. Two bodies move in a straight line towards each other at initial velocities v_1 and v_2 and with constant accelerations a_1 and a_2 directed against the corresponding velocities at the initial instant. What

must be the maximum initial separation l_{max} between the bodies for which they meet during the motion?

Q6. Two steel balls fall freely on an elastic slab. The first ball is dropped from a height $h_1 = 44$ cm and the second from a height $h_2 = h_2 = 11$ cm τ s after the first ball. After the passage of time τ, the velocities of the balls coincide in magnitude and direction. Determine the time t and the time interval during which the velocities of the two balls will be equal, assuming that the balls do not collide.

Q7. Small balls with zero initial velocity fall from a height $H = \frac{R}{8}$ near the vertical axis of symmetry on a concave spherical surface of radius *R*. Assuming that the impacts of the balls against the surface are perfectly elastic, prove that after the first impact each ball gets into the lowest point of the spherical surface (the balls do not collide).

Q8. A small ball thrown at an initial velocity v_0 at an angle a to the horizontal strikes a vertical wall moving towards it at a horizontal velocity v and is bounced to the point from which it was thrown. Determine the time t from the beginning of motion to the moment of impact, neglecting friction losses.

Q9. A small ball moves at a constant velocity *v* along a horizontal surface and at point *A* fall s into a vertical well of depth *H* and radius r. The velocity *v* of the ball forms an angle a with the diameter of the well drawn through point *A* (Fig. 1, top view). Determine the relation between *v, H, r,* and a for which the ball can "get out" of the well after elastic impacts with the walls. Friction losses should be neglected.

Q10. A cannon fires from under a shelter inclined at an angle *a* to the horizontal (Fig. 2). The cannon is at point *A* at a distance l

from the base of the shelter (point *B).* The initial velocity of the shell is v_0, and its trajectory lies in the plane of the figure. Determine the maximum range $L_{\max}$ of the shell.

Q11. The slopes of the windscreen of two motorcars are $\beta_1 = 30^\circ$ and $\beta_2 = 15^\circ$ respectively. At what ratio $\frac{v_1}{v_2}$ of the velocities of the cars will their drivers see the hailstones bounced by the windscreen of their cars in the vertical direction? Assume that hailstones fall vertically.

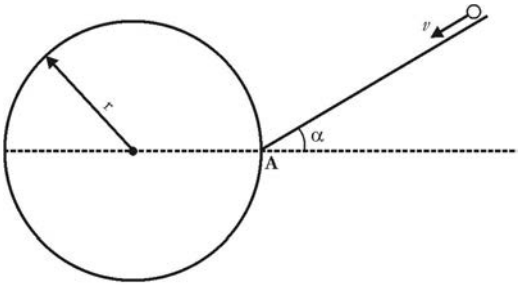

Fig.1

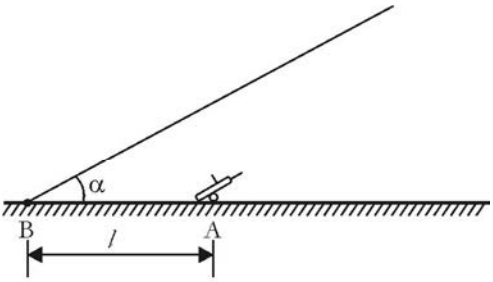

Fig. 2

End of Preview.

Rest of the book can be read @
http://kinige.com/kbook.php?id=863

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