Mechanics 2017 – Handout 1

Tim Horbury, 9 October 2017

Introduction

Welcome to mechanics! This subject is central to every aspect of modern physics – which is why it is one of the first courses of your degree – and what you learn this term will help you throughout the rest of your time studying physics. Mechanics also played a crucial role in the development of our overall understanding of physics, with Galileo, Newton, Kepler and many others making vital contributions.

We all have intuition about mechanics, because we interact with the world all the time, but many aspects of this intuition are wrong: for example, it wasn't until the 16^{th} century that it was widely realised that objects did not naturally come to rest when nothing was pushing them, or that the planets in our solar system and a tennis ball's flight are described by the same laws of motion. During this course, we will derive some results that follow our intuition closely, but some that can be surprising. It pays to be careful, therefore, and you should not assume that the answer to a problem will be what you expect.

Course aims

To describe the basic laws concerning the motion of bodies under forces and the techniques to apply these laws to a range of problems including collisions and orbital motion.

Objectives

On completion of the course, you should

- understand the concepts of force, acceleration and momentum
- be able to state and apply Newton's laws of motion
- understand kinetic and potential energy, the conservation of energy and related concepts such as work and power
- solve problems of linear motion under various forces
- understand the concept of conservative forces, potentials and stability
- derive the simple harmonic motion of bodies
- apply Newton's laws to two body interactions including use of the centre of mass frame and reduced mass
- derive and use the basic rocket equations
- understand rotational motion including angular momentum and torque
- be able to derive basic types of orbital motion under central forces such as gravity
- have knowledge of Kepler's laws of orbital mechanics
- understand non-inertial frames and inertial forces
- have knowledge of rotating frames and Coriolis forces

Lecture plan

This plan might change a little bit but is close to the order in which we'll cover the material.

1. Introduction;
2. Newton's laws; frames;
3. Using Newton's laws; forces; energy
4. One-dimensional motion
5. Velocity-dependent forces; position-dependent forces
6. Potential energy and conservative forces
7. Potential functions and equilibrium
8. Two body dynamics; centre of mass; reduced mass
9. Collisions in 1D; elastic and inelastic
10. Collisions in 3D; equal masses; unequal masses
11. Centre of mass frame for collisions
12. Examples of collisions
13. Rockets
14. Mechanics in 3D: central forces
15. Angular momentum and torque; application to central forces
16. Planetary orbits; virial theorem
17. Orbits 2: circular, elliptical, parabolic, hyperbolic
18. Kepler's laws
19. Non-inertial frames; rotating frames
20. Earth as a rotating frame; Coriolis; Foucault
21. Rigid body dynamics
22. Gyroscopes

Lecture notes and other course materials

BlackBoard is the place to look for all course materials.

I'm not planning to distribute lecture notes. Instead, you should write down what I write on the board and this will give you a full set of notes. It will help you to remember the material if you re-write them neatly within one or two days of each lecture.

I'll be using **PowerPoint** occasionally in lectures and these will go up on BlackBoard as PDFs.

All the **lectures are recorded** on Panopto and again, you will find links on BlackBoard within a day or so.

I will give out **problem sheets** at the end of each week. You should work through the problems and these will be discussed in your tutorials, where you should also ask for help if you have any questions about the course.

Textbooks

There might well be things that you don't understand about the course as it goes along. Looking at a book, which gives a different – and, perish the thought, perhaps even a clearer – explanation can often be helpful. Here are some textbooks that you might find useful:

Classical Mechanics, Second Edition, by Martin McCall (who is a member of this Department), Wiley. A good, clear and concise textbook which covers the material in a similar style to the course. Lots of copies in the library. If you want to buy a copy, you can use the code FCH4 to get a 20% discount at this link.

University Physics, Young and Friedman, Addison Wesley. Covers most things in this course and lots more besides, in a clear way, but uses a lot of words to do it. Again, available in the library.

Newtonian Mechanics for Undergraduates, by Vijay Tymms (also a member of this Department), World Scientific. Rather simpler than McCall, doesn't cover everything in this course, but a good introduction.

Feynman Lectures on Physics, Richard Feynman, Addison Wesley - now also available online at this link. A fascinating read, with lots of good insight, but they can be confusing: try the other textbooks first if you don't understand a particular topic.

Office hours

While the course is running, office hours are *usually* Monday 5-6 pm and Friday 12-1 pm, but some weeks they will be different, so please check on BlackBoard for the times each week. Office hours are held in my office, Huxley 6M72, on floor 6M of the Huxley building. The easiest way to find it is to take the lifts between Blackett and Huxley to floor 6M. My office is just opposite when you leave the lifts. Please come along: office hours are a great chance to talk through bits of the course that aren't clear.

There will also be office hours in the weeks running up to the exam; look at Blackboard for more information nearer the time.

Contact details

I'm Tim Horbury and I'm a member of the Space and Atmospheric Physics Group. My research focuses on space plasma physics, particularly turbulence, shocks and the interaction of the solar wind with the Earth. I also lead the team that's building a magnetic field instrument for the Solar Orbiter mission, due to fly in 2019.

My email address is t.horbury@imperial.ac.uk