Teaching ideas for Topic 2: *Mechanics*, AHL

Questions

A number of worksheets are provided for this Topic:

- support questions examine the very basic concepts of the syllabus
- extended questions delve deeper and are equivalent to exam level questions.

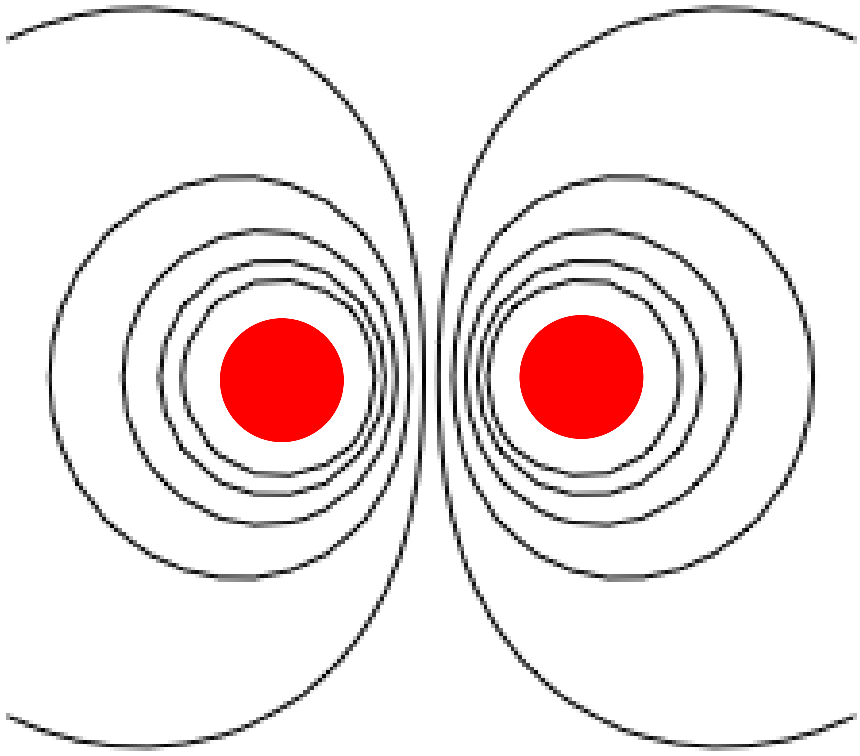
Teaching ideas

- It is crucial that students can derive the formula for the orbital speed $v^2 = \frac{GM}{r}$ by equating the gravitational force to the centripetal force.
- It is also important that they know how to derive the escape speed formula, $v^2 = \frac{2GM}{r}$. In this regard a very instructive exercise after deriving this is to ask about the distance from earth that a probe launched with a fraction of the escape speed would reach. For example, with $v = \frac{v_{esc}}{2}$ the probe would get to a height above the surface of only $h = \frac{R}{3}$, a result most students find hard to believe and impossible to predict before the calculation is actually finished.
- In this topic we can ask about similarities and differences between gravitation and electricity. An interesting question for discussion and further investigation is: 'Gravity is always attractive but electricity can be attractive or repulsive'. Notice, though, that attraction for gravity occurs for similar sign masses (positive, the only possibility) but for similar sign charges the electric force is repulsive. Why this asymmetry? Students can be asked to look for answers to this question that, ultimately, has to do with the exchange particles of the electric and gravitational force (the photon and the graviton, respectively) having different spins, the photon spin 1 and the graviton spin 2. This is for the physicists-to-be only though!
- The concept of potential (whether electric or gravitational) is often difficult for students. It might help to represent potential as a hill or a valley and imagine a ball moving around. Then we can explain increases or decreases in kinetic energy as the effect of potential on masses or charges.

Practical activities/ICT

- A topic that catches students' attention is the story of the binary pulsar PSR 1913+16 studied by Joseph Taylor and Russel Hulse (who shared the Nobel Prize in Physics in 1993). Information on this pulsar can be found at http://www.astro.cornell.edu/academics/courses/astro201/psr1913.htm/. Loss of energy by gravitational radiation decreases the orbital period of the binary. This can be studied in a simplified way through circular orbits.
  See page 151 and problem 27 on page 156 of the textbook.
  See also the October 1981 article in *Scientific American*.

- A useful classroom activity is to show the following diagram of equipotential surfaces:



Then ask: 'Can the sources can be charges or masses or both?' They can only be charges and of opposite sign. One explanation is that with this arrangement the field at the mid-point of the line joining the sources is not zero. It would have to be zero for equal masses.

Common problems

- Students often make the mistake of using *mgh* for gravitational potential energy and it must be stressed that this is not correct.
- Sometimes students do not realize that the motion we deal with in this topic is ballisitic motion and not the motion of objects *with engines*! Thus rockets do not have to be launched with the escape speed or anything near it to move very far away.

Theory of knowledge (TOK)

- The application of Newton's laws of mechanics and gravitation to the motion of the planets is the towering achievement of classical Newtonian physics. It is responsible for the 'clockwork universe' or deterministic interpretation of physics, according to which once we give the initial conditions for any system (whether it be the whole solar system or just a ball rolling down an inclined plane) the future evolution of the system is determined once and for all.

- Whereas chaos theory and quantum mechanics have changed this point of view, it is worth pointing out to students that the Newtonian theory failed to account for a very small and almost insignificant effect, namely the precession of the perihelion of the planet Mercury. The orbit of Mercury precesses (i.e. the red line shown below rotates) by the incredibly small amount of $43.11''$ per century! (One arc second is a very small part of one degree: $1'' = \frac{1}{3600}^{\circ}$.) Clearly we would not know anything about this precession if we didn't have *very accurate data* about the motion of Mercury that go back to 1765. This failure of Newtonian gravitation was corrected by a new theory, Einstein's general relativity. Einstein predicted that the perihelion of Mercury would precess by $43.03''$ per century!