Module 5: Advanced Mechanics

Content

Projectile Motion

Inquiry question: How can models that are used to explain projectile motion be used to analyse and make predictions?

Students:

- analyse the motion of projectiles by resolving the motion into horizontal and vertical components, making the following assumptions:
  - a constant vertical acceleration due to gravity
  - zero air resistance
    - apply the modelling of projectile motion to quantitatively derive the relationships between the following variables:
  - initial velocity
  - launch angle
  - maximum height
  - time of flight
  - final velocity
  - launch height
  - horizontal range of the projectile
- conduct a practical investigation to collect primary data in order to validate the relationships derived above.
- solve problems, create models and make quantitative predictions by applying the equations of motion relationships for uniformly accelerated and constant rectilinear motion

Circular Motion

Inquiry question: Why do objects move in circles?

Students:

- conduct investigations to explain and evaluate, for objects executing uniform circular motion, the relationships that exist between:
  - centripetal force
  - mass
  - speed
  - **radius**
- analyse the forces acting on an object executing uniform circular motion in a variety of situations, for example:
  - cars moving around horizontal circular bends
  - a mass on a string
  - objects on banked tracks
- solve problems, model and make quantitative predictions about objects executing uniform circular motion in a variety of situations, using the following relationships:
  - $a_c = \frac{v^2}{r}$
  - $v = \frac{2\pi r}{T}$
  - $F_c = \frac{mv^2}{r}$
  - $\omega = \frac{\Delta\theta}{t}$
- investigate the relationship between the total energy and work done on an object executing uniform circular motion
- investigate the relationship between the rotation of mechanical systems and the applied torque
  - $\tau = r_\perp F = rF \sin\theta$

Motion in Gravitational Fields

Inquiry question: How does the force of gravity determine the motion of planets and satellites?

Students:

- apply qualitatively and quantitatively Newton's Law of Universal Gravitation to:
  - determine the force of gravity between two objects $F = \frac{GMm}{r^2}$
  - investigate the factors that affect the gravitational field strength $g = \frac{GM}{r^2}$
  - predict the gravitational field strength at any point in a gravitational field, including at the surface of a planet
- investigate the orbital motion of planets and artificial satellites when applying the relationships between the following quantities:
  - gravitational force
  - centripetal force
  - centripetal acceleration
  - mass
  - orbital radius
  - orbital velocity
  - orbital period
- predict quantitatively the orbital properties of planets and satellites in a variety of situations, including near the Earth and geostationary orbits, and relate these to their uses
- investigate the relationship of Kepler's Laws of Planetary Motion to the forces acting on, and the total energy of, planets in circular and non-circular orbits using:
  - $v = \frac{2\pi r}{T}$
  - $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$
- derive quantitatively and apply the concepts of gravitational force and gravitational potential energy in radial gravitational fields to a variety of situations, including but not limited to:
  - the concept of escape velocity $v_{\text{esc}} = \sqrt{\frac{2GM}{r}}$
  - total potential energy of a planet or satellite in its orbit $\mathrm{U} = -\frac{GMm}{r}$
  - total energy of a planet or satellite in its orbit $\mathrm{U} + \mathrm{K} = -\frac{GMm}{2r}$
  - energy changes that occur when satellites move between orbits
  - Kepler's Laws of Planetary Motion