Topic 10: Fields

11 hours

Essential idea: Electric charges and masses each influence the space around them and that influence can be represented through the concept of fields.

10.1 – Describing fields

Nature of science:

Paradigm shift: The move from direct, observable actions being responsible for influence on an object to acceptance of a field's "action at a distance" required a paradigm shift in the world of science. (2.3)

Understandings:

- Gravitational fields
- Electrostatic fields
- Electric potential and gravitational potential
- Field lines
- Equipotential surfaces

Applications and skills:

- Representing sources of mass and charge, lines of electric and gravitational force, and field patterns using an appropriate symbolism
- Mapping fields using potential
- Describing the connection between equipotential surfaces and field lines

Theory of knowledge:

- Although gravitational and electrostatic forces decrease with the square of distance and will only become zero at infinite separation, from a practical standpoint they become negligible at much smaller distances. How do scientists decide when an effect is so small that it can be ignored?

Utilization:

- Knowledge of vector analysis is useful for this sub-topic (see *Physics* sub-topic *1.3*)

Aims:

- **Aim 9:** models developed for electric and gravitational fields using lines of forces allow predictions to be made but have limitations in terms of the finite width of a line

10.1 – Describing fields

Guidance:

- Electrostatic fields are restricted to the radial fields around point or spherical charges, the field between two point charges and the uniform fields between charged parallel plates
- Gravitational fields are restricted to the radial fields around point or spherical masses and the (assumed) uniform field close to the surface of massive celestial bodies and planetary bodies
- Students should recognize that no work is done in moving charge or mass on an equipotential surface

Data booklet reference:

- $W = q\Delta V_e$
- $W = m\Delta V_g$

Essential idea: Similar approaches can be taken in analysing electrical and gravitational potential problems.

10.2 – Fields at work

Nature of science:

Communication of scientific explanations: The ability to apply field theory to the unobservable (charges) and the massively scaled (motion of satellites) required scientists to develop new ways to investigate, analyse and report findings to a general public used to scientific discoveries based on tangible and discernible evidence. (5.1)

Understandings:

- Potential and potential energy
- Potential gradient
- Potential difference
- Escape speed
- Orbital motion, orbital speed and orbital energy
- Forces and inverse-square law behaviour

Applications and skills:

- Determining the potential energy of a point mass and the potential energy of a point charge
- Solving problems involving potential energy
- Determining the potential inside a charged sphere
- Solving problems involving the speed required for an object to go into orbit around a planet and for an object to escape the gravitational field of a planet
- Solving problems involving orbital energy of charged particles in circular orbital motion and masses in circular orbital motion
- Solving problems involving forces on charges and masses in radial and uniform fields

Utilization:

- The global positioning system depends on complete understanding of satellite motion
- Geostationary/polar satellites
- The acceleration of charged particles in particle accelerators and in many medical imaging devices depends on the presence of electric fields (see *Physics* option sub-topic *C.4*)

Aims:

- **Aim 2:** Newton's law of gravitation and Coulomb's law form part of the structure known as "classical physics". This body of knowledge has provided the methods and tools of analysis up to the advent of the theory of relativity and the quantum theory
- **Aim 4:** the theories of gravitation and electrostatic interactions allows for a great synthesis in the description of a large number of phenomena

10.2 – Fields at work	
Guidance: • Orbital motion of a satellite around a planet is restricted to a consideration of circular orbits (links to 6.1 and 6.2) • Both uniform and radial fields need to be considered • Students should recognize that lines of force can be two-dimensional representations of three-dimensional fields • Students should assume that the electric field everywhere between parallel plates is uniform with edge effects occurring beyond the limits of the plates. **Data booklet reference:**	

$V_g = -\frac{GM}{r}$	$V_e = \frac{kq}{r}$
$g = -\frac{\Delta V_g}{\Delta r}$	$E = -\frac{\Delta V_e}{\Delta r}$
$E_P = mV_g = -\frac{GMm}{r}$	$E_P = qV_e = \frac{kq_1q_2}{r}$
$F_G = G\frac{m_1m_2}{r^2}$	$F_E = k\frac{q_1q_2}{r^2}$

- $V_{esc} = \sqrt{\frac{2GM}{r}}$
- $V_{orbit} = \sqrt{\frac{GM}{r}}$