Electric Potential

Basic Problems

1. How much work has to be done on a point charge 0.5 nC to move it from a first point in an electric field to a second point if the potential difference between the two points is 120 V?
2. A proton is lifted to a height of 1 m. What is the electric potential difference between initial and final position if the work to lift the proton in the gravitational field equals the work done by the electric field? Comment on the result.
3. What is a *gravitational potential difference*? Derive a formal expression for a homogeneous gravitational field.
4. The distance between two parallel plates is reduced by 10 % without changing the potential difference between the plates. How does the magnitude of the electric field between the plates change?
5. The acceleration voltage in a cathode ray tube is increased from 5 kV to 6 kV. How does the speed of the electrons accelerated in the tube change?
6. How does the acceleration voltage change if the accelerated particles gain a 20 % greater speed?
7. Express your mass in terms of the unit $\mathrm{eV/c^2}$.
8. A proton is accelerated to a kinetic energy of 20 MeV. Calculate its velocity.
9. An *equipotential surface* includes all points with the same potential. Explain why equipotential surfaces are always perpendicular to the electric field lines.
10. Sketch some equipotential lines for a system of two positive point charges.

Supplementary Problems

11. Prove that the work done on a point charge moving in a homogeneous field is independent of the path. Extend your reasoning to the field of a point charge.
    Hint: Approximate the path by piecewise straight lines parallel and perpendicular to the field lines.
12. An α-particle (nucleus of a Helium atom) is accelerated to 5 % of the speed of light. Calculate the acceleration voltage.
13. Electrons enter the electric field between two deflection plates perpendicularly to the field lines at a speed of $c/10$. The deflection plates are 5 cm long and have a distance of 1 cm. What is the magnitude of the potential difference across the plates required to deflect the electrons by 10°?

The potential of a point charge q can be written as

$$\varphi(r) = k \cdot \frac{q}{r},$$

where the reference point ($\varphi = 0$) is infinitely far away from the point charge. Use this formula to solve the following two problems.

14. A proton approaches the nucleus of a gold atom at a speed of 1 % of the speed of light. It slows down in the field of the nucleus. How far from the nucleus is the turning point?
15. The distance between two positive point charges of 5 nC each is 10 cm. Calculate the electric potential at the centre of the line connecting the point charges. What is the final velocity of a proton starting from this point and escaping to "infinity"?

Solutions of basic problems: 1. 60 nJ; 2. 0.1 µV; 3. $\Delta V = g\,h$; 4. + 11 %; 5. + 10 %; 6. + 44 %; 7. ?? · 10^{37} $\mathrm{eV/c^2}$; 8. $c/5$