Chapter 2

Relativity

2.1 Overview of physics

2.1.1 Map of physics

See Figure 2.1.1.

Newtonian mechanics Everyday physics.

Electrostatics Non-relativistic electric interactions.

Newtonian gravity Everyday gravity.

Special relativity Unifies space and time.

Electrodynamics Unifies electric and magnetic interactions into a relativistic theory of a dynamical electric field.

General relativity Theory of dynamical spacetime with spacetime curvature $\equiv$ gravity.

Quantum mechanics Quantum theory of particles.

Quantum field theory Unifies particles and fields.

Standard Model The particular realization of quantum field theory in our neighbourhood of the universe. Composed of strong (nuclear), electroweak, quark, lepton (electron, etc) and Higgs quantum fields.

String theory The presumed theory of everything, unifying quantum field theory and general relativity. Started as a quantum theory of strings but has grown into something more general but not yet fundamentally understood.

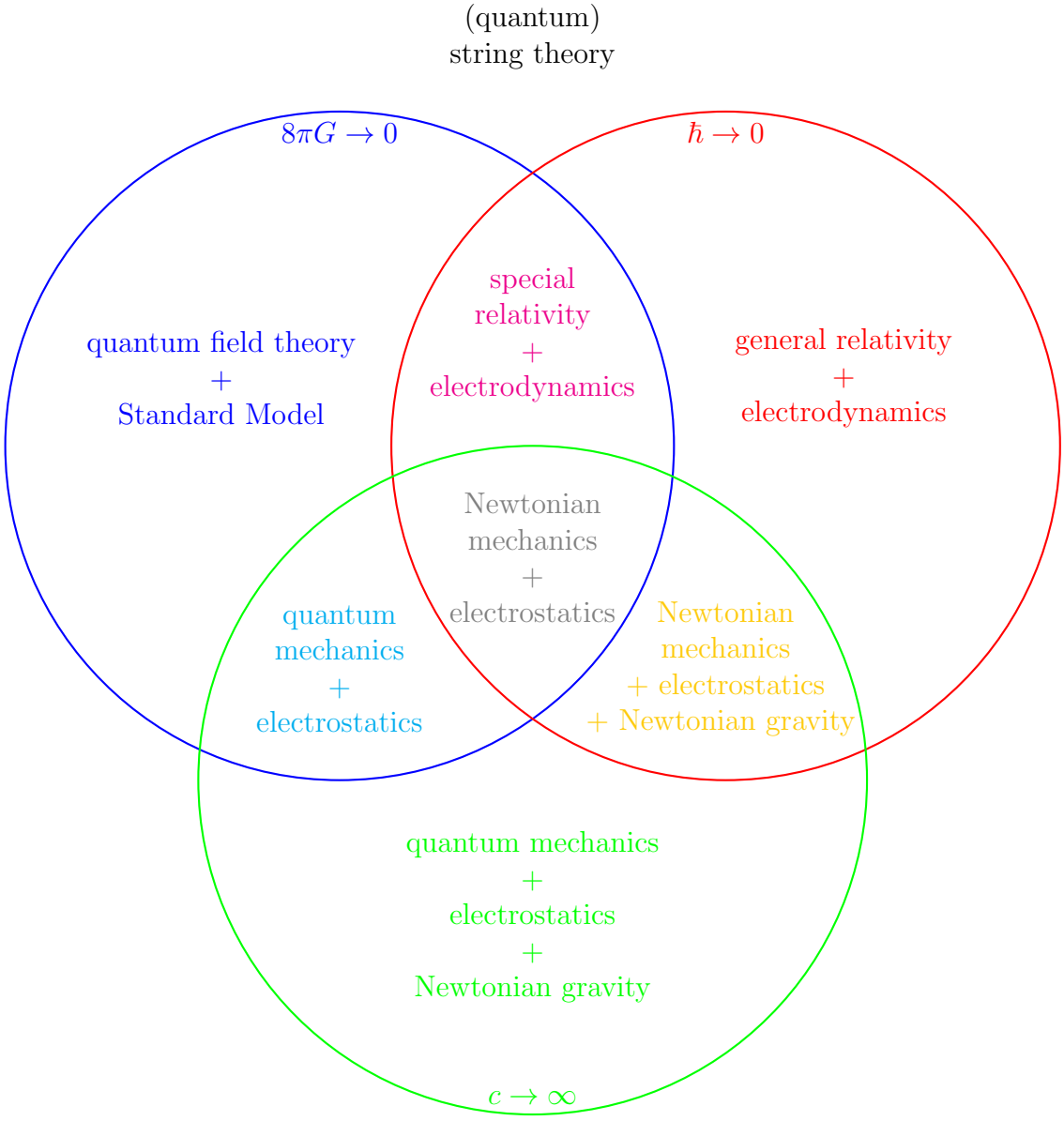

Figure 2.1.1: Physics as a function of the fundamental physical scales: Planck's constant $\hbar \simeq 1 \times 10^{-34}\,\mathrm{kg\,m^2\,s^{-1}}$, speed of light $c \simeq 3 \times 10^{8}\,\mathrm{m\,s^{-1}}$, gravitational constant $8\pi G \simeq 2 \times 10^{-9}\,\mathrm{kg^{-1}\,m^3\,s^{-2}} \simeq 20\,M_\oplus^{-1}\,A_\oplus\,\mathrm{m\,s^{-2}}$, where $M_\oplus$ and $A_\oplus$ are the mass and surface area of the Earth respectively.

2.1.2 Newtonian mechanics

A particle moving in space as a function of time has action

$$-S[x(t)] = \int \left[V(x,t) - \frac{1}{2} m g_{\mathbf{ab}} \dot{x}^{\mathbf{a}} \dot{x}^{\mathbf{b}} + \dots \right] dt \tag{2.1.1}$$

where the higher order (relativistic) terms can be neglected if the velocities are small. For this approximation to be consistent we also require spatial and temporal gradients to be small, hence we can neglect the space and time dependence of the coefficient m of the second term.