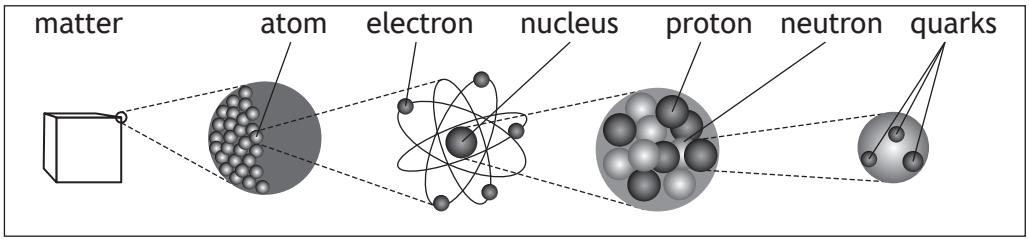
7. The following diagram gives information on the Standard Model of fundamental particles.



(a) Explain why the proton and the neutron are **not** fundamental particles. **1**

(b) An extract from a data book contains the following information about three types of sigma (Σ) particles. Sigma particles are made up of three quarks.

Particle	*Symbol*	*Quark Content*	*Charge*	*Mean lifetime* (s)
sigma plus	Σ^+	up up strange	$+1e$	$8{\cdot}0 \times 10^{-11}$
neutral sigma	Σ^0	up down strange	0	$7{\cdot}4 \times 10^{-20}$
sigma minus	Σ^-	down down strange	$-1e$	$1{\cdot}5 \times 10^{-10}$

(i) A student makes the following statement.

All baryons are hadrons, but not all hadrons are baryons.

Explain why this statement is correct. **2**

(ii) The charge on an up quark is $+\frac{2}{3}e$.

Determine the charge on a strange quark. **1**

Space for working and answer

7. (continued)

(c) (i) State the name of the force that holds the quarks together in the sigma (Σ) particle. **1**

(ii) State the name of the boson associated with this force. **1**

(d) Sigma minus (Σ^-) particles have a mean lifetime of $1{\cdot}5 \times 10^{-10}$ s in their frame of reference.

Σ^- are produced in a particle accelerator and travel at a speed of $0{\cdot}9c$ relative to a stationary observer.

Calculate the mean lifetime of the Σ^- particle as measured by this observer. **3**

Space for working and answer