18 In 1977 a fifth quark, named the bottom quark, was discovered by particle physicists.

The table shows the particles in the standard model known at that time.

Quarks		Leptons	
up	down	electron	electron neutrino
strange	charm	muon	muon neutrino
bottom		tau	

(a) (i) Explain why the existence of a sixth quark was predicted.

(3)

(ii) A short time after formation, most quarks combine to make particles known as hadrons. There are two categories of hadron.

Name the two categories of hadron.

(1)

(b) In 1995 the sixth quark, known as the top quark, was discovered using the Tevatron collider at Fermilab. A collision of a proton with an anti-proton produced a top quark and a top anti-quark.

Particle experiments may direct beams of particles at stationary targets or collide beams of particles travelling in opposite directions.

(i) Explain the advantage of colliding beams of particles.

(4)

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(ii) In the collider experiment, the protons and anti-protons each had total energy 900 GeV.

Calculate the maximum kinetic energy, in joules, of a top quark produced in this experiment.

rest energy of top quark = 173 GeV

(3)

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Maximum kinetic energy = ... J

(iii) Deduce whether a top quark with kinetic energy 1.2×10^{-7} J is travelling at a relativistic speed.

rest mass of top quark = 173 GeV/c^2

(3)

(c) Most types of quark form hadrons on a timescale of 10^{-23} s. The top quark does not form hadrons because its lifetime is only 10^{-25} s.

A student suggests that, if the top quarks travelled at relativistic speeds, it could be possible for them to form hadrons.

Assess this suggestion.

(2)

(Total for Question 18 = 16 marks)