Question 18 **(15 marks)**

In an experiment, two neutrally-charged subatomic particles, A and B, each of mass m, are fired directly toward each other. Both have a speed of 0.600 c, as seen by the observer O shown in Figure 1. The particles collide and become one particle, C, which O observes to be stationary. No energy is lost due to interactions with the environment and no other particles, e.g. photons, are emitted.

Figure 1: Two particles of equal mass and opposite velocities collide

(a) Using conservation of relativistic energy, calculate the mass of the combined particle m_C. Give your answer in terms of m, the mass of each of the original particles. (4 marks)

Answer _____ m

(b) Explain why the velocity of the combined particle has to be 0 m s^{-1}. (2 marks)

For parts (c) and (d) consider the same collision viewed by an observer X, who is moving with a velocity of −0.600 c (i.e. the same velocity that Particle B had before the collision). X maintains this velocity after the collision.

Figure 2: Observer X is now shown.

(c) Using the formulas for relativistic velocity addition and relativistic momentum, determine the momentum of the system before the collision, as determined by X. Express your answer in terms of m and c, the speed of light. (5 marks)

Answer _____ mc

(d) With the use of a calculation, show that your answer in part (c) is the same as the momentum of the system after the collision, as determined by X. (4 marks)