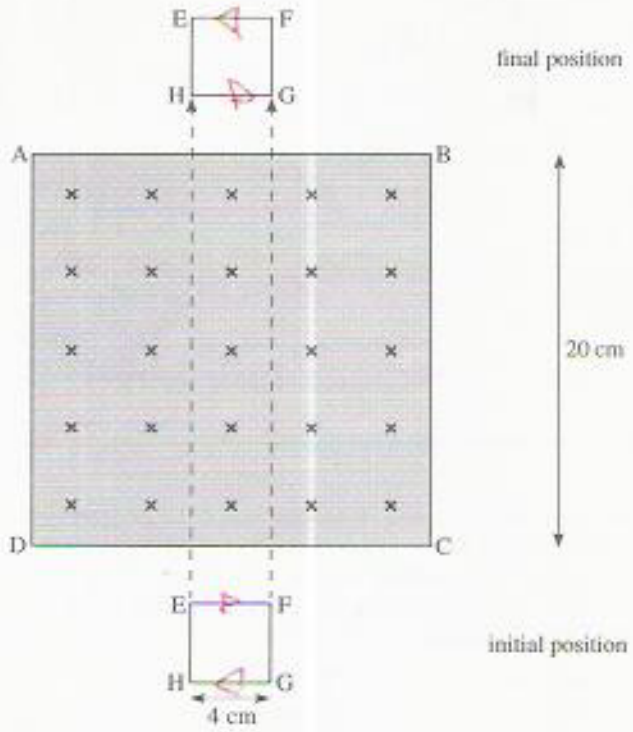

FIGURE 1

(d) Use your answer to part (c) to calculate the total energy dissipated in the process of moving EFGH from outside ABCD, to inside, and outside again. *(4 marks)*

(e) Where has the dissipated energy come from? You can gain full marks for this part with a qualitative answer expressed in a single sentence. You may (optionally) give a more complete answer by considering the magnetic forces acting on the sides of EFGH during its passage into and out of the magnetic field. *(4 marks)*

Question 3

This question relates mainly to Unit 12 and carries 35% of the marks for this assignment.

Cheryl is sitting exactly in the middle of a railway carriage as it travels along a straight track. There are mirrors on the inside end walls of the carriage: mirror A is at the front of the carriage and mirror B at the back. Cheryl measures both mirrors to be a distance $d_0 = 15$ metres away from her, and the length of the carriage to be 30 metres.

A train spotter, Dan, who is standing by the side of the track, observes that the train is travelling extremely fast, at $v = c/2$, where c is the speed of light. He also notes that, at the very instant Cheryl passes him, she starts to light a match. This question refers to the first spark from this match. Both Cheryl and Dan have set their watches so that this event corresponds to time zero. Some light from the spark initially travels in the direction of the train's motion, is reflected from mirror A and returns to Cheryl; other light from the same spark initially travels in the opposite direction, is reflected from mirror B and also returns to Cheryl.

(a) Find the times, according to Cheryl, when light from the spark (i) reaches mirror A; (ii) reaches mirror B; (iii) returns to Cheryl from mirror A and (iv) returns to Cheryl from mirror B. *(4 marks)*

(b) Find the times, according to Dan, when the same four events take place. One way of answering this question is to start from Cheryl's space and time coordinates of the four events and then apply the Lorentz transformation equations. In applying these equations note that it is permissible to choose Cheryl's frame on the moving train as the *unprimed* frame and Dan's frame on the ground as the *primed* frame. (This choice has some advantages in simplifying the algebra, but you will need to take care in allocating signs to physical quantities.) *(12 marks)*

Use your answers to parts (a) and (b) to answer the following:

(c) Do Dan and Cheryl agree that light from the spark reaches mirror A at the same time as mirror B? Do they agree that the light returning from mirror A reaches Cheryl at the same time as the light returning from mirror B? Comment on your answers, drawing out general principles about the relativity of simultaneity in special relativity. *(7 marks)*

(d) Do Dan and Cheryl agree that the time taken for light to travel from the spark to mirror A is the same as the time taken for light to travel from mirror B to Cheryl? Give a simple argument explaining why such agreement or disagreement is reasonable. *(4 marks)*

(e) Use two of the times calculated in parts (a) and (b) to illustrate what is meant by time dilation in special relativity. *(6 marks)*