Relativity Q2 answer

We will always need the Lorentz factor. The speed is 0.9c so $\gamma=(1-0.9^2)^{-1/2} = 2.29$

(a) Proper length of pole is L_0=20m. This is what is seen at rest ie in the runners frame. Set this to be S' and its moving with u=0.9c with respect to S which is the barn frame. So in the rest frame of barn we transform the length so $L=L'/\gamma$ = 20/2.29=8.73m. So the 8.73m pole easily fits into the barn [1 mark]

(b) Proper length of the barn is B0=10m. This is what is seen in the barn frame. But we want to look at what is seen in the runners frame. So the easier way is to swap reference frames and put the barn in S' in which it is at rest, but moving with u=-0.9c with respect to the runner. But $\gamma(u)=\gamma(-u)$, so in the rest frame of the runner we transform length $B=B'/\gamma$ = 10/2.29=4.36m. So the 20m pole cannot fit into the barn! [1 mark]

(c) T0=0 when front of pole just enters barn. In the barn frame the speed of the runner is 0.9c and length of pole is 8.73m so the back of the pole enters the barn at T1=8.73/0.9c=3.23×10^{-8}s = 32.3ns

Then front of pole leaves barn T2=10/0.9c=37ns

Then the back of the pole leaves the barn at T3=T2+T1=69.3ns [2 marks]

(d) In the runner frame, the pole is stationary at 20m and the barn is 4.73m, moving at -0.9c towards the runner. So the back of the pole enters the barn at T1'=20/0.9c=74.1ns. The front of the pole exits the barn at T2'=4.73/0.9c=16.2ns and the back of the pole exits at T3'=T1'+T2'=90.3ns. - the order is reversed and the runner sees the front of the pole exit the barn before the back of the pole enters the barn [2 marks]

(e) In the barn frame, the front and back doors slam shut at 33.3ns and open again at 36ns so they never intersect the pole. We now want to find out what happens in the runner frame, but using the transformations $t'=\gamma(t-xu/c^2)$ and $x'=\gamma(x-ut)$

T1 (back enters barn) (t,x)=(32.3ns,0) – (t', x') = 74ns,-20m

T2 (front leaves barn) (t,x)=(37.0ns,10) - (t' x') = 16ns, 0

T3 (back leaves barn) (t,x)=(69.3ns,10) – (t' x') = 90ns, -20

FS (front door shuts) is at (t,x)=(33.3ns,0) – (t', x') = 76.2ns, -20.6m

BS (back door shuts) is at (t,x)=(33.3ns,10) – (t', x') =7.6ns, 2.31m

FO (front door opens) is at (t,x)=(36ns,0) – (t', x')= 82.4ns, -22.2m

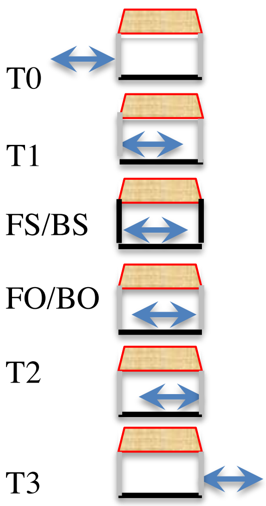
BO (back door opens) is at (t,x)=(36ns,10) – (t', x')=13.7ns, 0.64m [2 marks]

In the barn frame, the doors both shut with the pole inside, and both open allowing it out so there is no collision

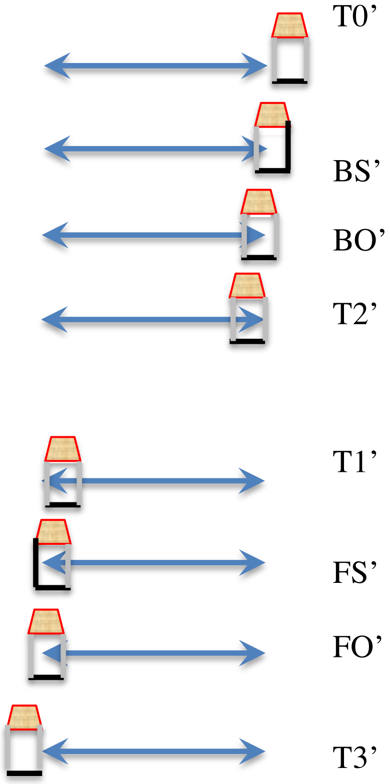
In the runner frame, the back door shuts and opens before the pole gets to it, and the front door shuts and opens after the barn has gone past so there is no collision.

So there is no collision in either frame, the physics is the same in both. But the order of events seen which occur at different places in space is different.

Barn frame: runner u=0.9c



Runner frame, barn=-0.9c



[2 marks]