S271 Discovering Physics
CMA 45 1996
Answers and comments

Q1 The correct responses are B and E

A is true; it is the basic message of Unit 12!

B is false; E_1 and E_2 may be linked by a light signal, in which case the distance is *equal* to ct.

C is true; for *all* speeds (less than c).

D is true; X–rays are like light, a type of electromagnetic radiation.

E is false; the special theory links inertial frames with a *constant* relative velocity.

F is true; the length is a constant for the inertial observer at rest in Concorde, but not for an observer in another frame in which Concorde is not at rest.

G is true; if c were infinite V^2/c^2 and xV/c would both be zero.

Q2 C is correct

$L = L_0\sqrt{1 - v^2/c^2}$ where L and L_0 are the lengths measured in the frames where respectively the rocket is moving and it is stationary, i.e. $L = 25$ m; $L_0 = d$

Hence $$d = \frac{25\text{ m}}{\sqrt{1 - \frac{(3c/5)^2}{c^2}}} = 25\text{ m} \times \frac{5}{4} = 31.25\text{ m}.$$

Q3 The correct response is B and E

Suppose the coordinates of the two events according to O are x_1,t and x_2,t.

Then the coordinates of the two events according to O′ are determined using the Lorentz transformation:

for E_1: $x_1' = (x_1 - Vt)\big/\sqrt{1 - V^2/c^2}$; $t_1' = \left(t - Vx_1/c^2\right)\big/\sqrt{1 - V^2/c^2}$

for E_2: $x_2' = (x_2 - Vt)\big/\sqrt{1 - V^2/c^2}$; $t_2' = \left(t - Vx_2/c^2\right)\big/\sqrt{1 - V^2/c^2}$.

Thus $t_1' - t_2' = V(x_2 - x_1)\big/c^2\sqrt{1 - V^2/c^2}$. Since $x_1 \neq x_2$, the two events cannot be simultaneous in O′.

Also, $x_1' - x_2' = (x_1 - x_2)\big/\sqrt{1 - V^2/c^2} = s\big/\sqrt{1 - V^2/c^2}$ which cannot be equal to 0 or to s.

Q4 The correct response is E

$$E = \frac{mc^2}{\sqrt{1 - v^2/c^2}} \quad \therefore E = 1.2 \times (3 \times 10^8)^2 \Bigg/ \sqrt{1 - \left(\frac{1000}{3 \times 10^8}\right)^2}\text{ J.}$$

The speed of 1000 m s^{-1} is negligible compared with c,

so $E \approx mc^2 = 1.2 \times (3 \times 10^8)^2\text{ J} = 1.08 \times 10^{17}\text{ J} = 1.1 \times 10^{17}$ J to 2 sig. figs.

Q5 The correct response is F

Einstein's photoelectric equation states that

$$hf - hf_t = \frac{1}{2}m_e v_{\max}^2 \quad (\phi = hf_t)$$

so $$f_t = f - E_{\text{kin,max}}/h$$

$$f = \frac{c}{\lambda} = \left(\frac{3 \times 10^8}{4 \times 10^{-7}}\right)\text{ Hz} = 7.5 \times 10^{14}\text{ Hz}$$

hence $$f_t = \left(7.5 \times 10^{14} - 3 \times 10^{-19}/6.63 \times 10^{-34}\right)\text{ Hz} = 3 \times 10^{14}\text{ Hz.}$$

Q6 The correct responses are B and F

A is false; the uniform sphere in Thomson's model is about the size of an atom, say 10^{-10} m in diameter.

B is correct; the spatial distribution of the electrons is *not* explained by the Rutherford model.