Relativity Problem Set Solutions

**Solutions**

**1.** (a) the length of an object as measured by an observer who is at rest
relative to the object; 1

(b) (i) γ =  = 1.5; 1

(ii) *L* =  = 160 m; 1

(iii) *L*0 = γ*L* = 1.5 × 200 = 300 m; 1

(iv) the spaceship is never completely inside the tunnel;
because (according to observer B) the spaceship is longer
than the tunnel; 2
*Apply ECF in all parts of question* (*b).*

(c) observer B will not see the two flashes simultaneously;
according to B, light 2 is moving to the left/towards observer B;
since the speed of light is the same for both sources;
the flash from light 2 reaches B before the flash from light 1;

 ***or***

 according to B, the two flashes arrive at A simultaneously;
according to B, A is moving to the left/away from light 2;
since light from both sources moves with the same speed;
for the flashes to be received by A at the same time, the flash from
light 2 must be emitted first; 4
*Accept any equivalent discussion.*

[10]

**2.** (a) (i) proper length is measured by observer at rest relative to
object / Carrie is at rest relative to spaceship; 1

(ii) γ = 1.1;
evidence of algebraic manipulation *e.g.*  = 1 –  to give
*v* = 0.42 c;
≈ 0.4 c 2

(b) travel time measured by Peter = (10 × γ =) 11 years;
4.6 ly ***or*** 4.4 ly *(if 0.4 c used)*; 2

(c) moves away at 0.42 c so is 4.2 ly away when signal emitted; (*allow
ECF from* (*a)*(*ii))*signal travel time *t* where *ct* =4.2 + 0.42*ct*;
7.2 y ***or*** 7 y(*if 0.4 c used)*; 3

[8]

**3.** (a) a co-ordinate system (in which measurements of distance and
time can be made);
which is not accelerating/in which Newton’s laws are valid; 2

(b) (i) Time =  = 11 years; 1

(ii) Ann;
according to Ann, the two events of leaving Earth and
arriving at Sirius occur at the same point in space;
*Award* ***[0]*** *for bald correct answer or incorrect explanation.* 2

(iii) *γ* =  ≈ 1.7;
Time for Ann  6.6 years; 2

(iv) let *t* be the time signal takes to reach Earth according to Ann.
In this time, Ann would move further away from the Earth
by the distance *vt,* where *v* = 0.80c;
starship and Earth originally separated by 5.28light-years,
according to Ann;
so 5.28 = *ct* – *vt*  = 26 years; 3

[10]

**4.** (a) *proper length:*is the length of an object in the object’s rest frame / the length of the
object as measured by an observer at rest relative to the object;

 *proper time interval:*is the time interval between two events taking place at the same
point in space / the shortest time interval between two events; 2

(b) (i) realization that 6.00 s is the proper time;
so that time interval = *γ* × 6.00= 7.50s; 2

(ii) realization that 5.00 m is the proper length;
so that length = 4.00 m; 2
*Do not apply SD deduction here.*

(c) (i) laser B was fired first; 1

(ii) during the delay time *T,* space station moved backward a distance
*vT* =6.25 – 4.00 =2.25 m;
and so *T* = 1.25 × 10–8 s; 2

[9]