

Modern Physics: MP-QZ01

3__ 1 歷史上哪一位科學家最先提出相對性原理的概念？

(A)牛頓 (B)克卜勒 (C)伽利略 (D)愛因斯坦 (E)馬克斯威爾

4__ 2 下列何者為狹義相對論的基本假設之一？

(A)時間膨脹 (B)長度收縮 (C)質能互換 (D)光速恆定 (E)動量守恆

1__ 3 在地球上觀察飛行中的太空船，發現太空船裡的時鐘從下午2點到下午3點，經過一個小時的時間，但是在地球上卻經過了3601秒。利用相對論你可以計算出，這個太空船與地球之間的相對速度=_____ m/s?

(A) 2.8×10^6 (B) 4.3×10^6 (C) 7.1×10^6 (D) 9.8×10^7 (E) 2.1×10^8

1__ 4 The proper time between two events is measured by clocks at rest in a reference frame in which the two events:

(A) occur at the same coordinates (B) occur at the same time (C) are separated by the distance a light signal can travel during the time interval (D) occur within 1 s (E) satisfy none of the above

4__ 5 An observer notices that a moving clock runs slow by a factor of exactly 5. The speed of the clock is:

(A) $0.900c$ (B) $0.9500c$ (C) $0.990c$ (D) $0.980c$ (E) $0.995c$

4__ 6 π mesons at rest have a half-life of T . If a beam of π mesons is traveling at a speed of $v = \beta c$, the distance in which the intensity of the beam is halved is:

(A) $(1-\beta^2)^{1/2}vT$ (B) $c\beta T[(1+\beta)(1-\beta)]^{-1/2}$ (C) βvT (D) $c\beta T(1-\beta^2)^{-1/2}$ (E) none of the above

2__ 7 在狹義相對論中質點運動的動能可以表示為下列哪一個公式？

(A) $K = 1/2mv^2$ (B) $K = (\gamma - 1)m_0c^2$ (C) $K = \frac{p^2}{2m}$ (D) $K = pc$ (E) $K = mv^2 + pc$

1__ 8 If the kinetic energy of a free particle is much greater than its rest energy then its kinetic energy is proportional to:

(A) the magnitude of its velocity (B) the magnitude of its momentum (C) the square of the magnitude of its velocity (D) the square root of the magnitude of its momentum (E) the reciprocal of the magnitude of its momentum (F) none of the above

3__ 9 光的靜止質量為？

(A) $m_e c^2$ (B) $h\nu$ (C) 0 (D) $\frac{hc}{\lambda}$ (E) E/c^2

2_ 10 光的能量與動量之間的關係為下列何者？

(A) $E = pc^2/v$ (B) $E = pc$ (C) $E = \frac{p^2}{2m}$ (D) $E = \int p dv$ (E) $p = \frac{dE}{dx}$

2_ 11 The magnitude of the momentum of a particle can never exceed:

A) mc , where m is its mass B) E/c , where E is its energy C) K/c , where K is its kinetic energy D) none of the above, but there is an upper limit E) none of the above; there is no upper limit

The Burning Star

Problem 12

Suppose the rate at which a star is losing mass is 5×10^9 kg, given that the mean radius R of planet's orbit is 1.0×10^8 km. Calculate (a) the total radiation power of the star and (b) the intensity of star radiation at planet. The distance between the star and the planet is 1.0×10^{11} m.
(03小題)

答案空格編號:12 (a) the total power radiated by the Sun = _____ J/s

Ans:=4.5E26

答案空格編號:13 (b) the intensity of star radiation at planet = _____ Watt/m²

Ans:=3.58E3

答案空格編號:14 (c) What is the intensity of the star radiation at the half distance from the star to the planet? Intensity = _____ Watt/m²

1. The conversion of mass into energy, a consequence of conservation of energy in relativity, is implied by Equation 2-10. With $u = 0$ that equation becomes

$$E = mc^2$$

2. Assuming that the Sun radiates uniformly over a sphere of radius R , the total power radiated by the Sun is given by

$$\begin{aligned} P &= (\text{area of the sphere})(\text{solar constant}) \\ &= (4\pi R^2)(1.36 \times 10^3 \text{ W/m}^2) \\ &= 4\pi(1.50 \times 10^{11} \text{ m})^2(1.36 \times 10^3 \text{ W/m}^2) \\ &= 3.85 \times 10^{26} \text{ J/s} \end{aligned}$$

3. Thus, every second the Sun emits $3.85 \times 10^{26} \text{ J}$, which, from Equation 2-10, is the result of converting an amount of mass given by

$$\begin{aligned} m &= E/c^2 \\ &= \frac{3.85 \times 10^{26} \text{ J}}{(3.00 \times 10^8 \text{ m/s})^2} \\ &= 4.3 \times 10^9 \text{ kg} \end{aligned}$$

Remarks: Thus, the Sun is losing $4.3 \times 10^9 \text{ kg}$ of mass (about 4 million metric tons) every second! If this rate of mass loss remains constant (which it will for the next few billion years) and with a fusion mass-to-energy conversion efficiency of about 1 percent, the Sun's present mass of about $2.0 \times 10^{30} \text{ kg}$ will "only" last for about 10^{11} more years!

Ans:=14.32E3

Problem 13

Two clocks A and B are at rest and 100 m apart in frame S. Clock A', at rest in frame S', moves with velocity $0.6c$ along the line joining A to B. How long does it take to get from A to B according to observers in S and S'? (02小題)

答案空格編號:15 (a)the time measured in S=_____ s

Ans:=5.55E-7

答案空格編號:16 (b)the time measured in S'=_____ s

EXAMPLE 39.1: Two clocks A and B are at rest and 100 m apart in frame S. Clock A', at rest in frame S', moves with velocity $0.6c$ along the line joining A to B. How long does it take to get from A to B according to observers in S and S'?

Solution: For convenience we assume that clocks A and A' register zero when they coincide, as shown in Fig. 39.14a. In frame S the time taken for A' to coincide with B (Fig. 39.14b) is

$$T = \Delta t = \frac{100 \text{ m}}{1.8 \times 10^8 \text{ m/s}} = 5.55 \times 10^{-7} \text{ s}$$

Clock A' records the proper time for the journey. (Why?) From Eq. 39.8,

$$\begin{aligned} T_0 &= \left(\frac{1}{\gamma}\right) T \\ &= \left(\frac{4}{5}\right) (5.55 \times 10^{-7} \text{ s}) \\ &= 4.44 \times 10^{-7} \text{ s} \end{aligned}$$

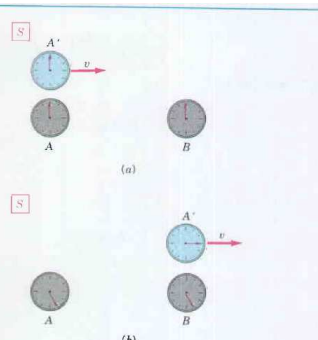


FIGURE 39.14 (a) Clocks A and A' are synchronized when they coincide. (b) When clock A' coincides with clock B, their readings do not agree. Clock B registers a later time.

Ans:=4.44E-7

Problem 14

A platform has a proper length of 200 m. An engine takes $0.5 \mu\text{s}$ to travel from one end of the platform to the other, as measured by the train driver. What is the relative speed? (01小題)

答案空格編號:17 $v = \underline{\hspace{2cm}}$ m/s

Ans:=2.4E8

Problem 15

An electron has a kinetic energy of 2 MeV. Find (a) its total energy, (b) its linear momentum, and (c) its speed. (03小題)

答案空格編號:18 (a) $E = \underline{\hspace{2cm}}$ MeV

Ans:=2.51

答案空格編號:19 (b) $p = \underline{\hspace{2cm}}$ kg.m/s

Ans:=1.31E-21

答案空格編號:20 (c) $v = \underline{\hspace{2cm}}$ c

EXAMPLE 39.7: An electron has a kinetic energy of 2 MeV. Find (a) its total energy, (b) its linear momentum, and (c) its speed.

Solution: (a) The rest energy of the electron is

$$E_0 = m_0 c^2 = (9.11 \times 10^{-31} \text{ kg})(3 \times 10^8 \text{ m/s})^2 = 8.20 \times 10^{-14} \text{ J} = 0.511 \text{ MeV}$$

The total energy is

$$E = K + m_0 c^2 = 2.51 \text{ MeV} = 4.02 \times 10^{-13} \text{ J}$$

(b) The linear momentum is given by Eq. 39.27:

$$p^2 c^2 = E^2 - m_0^2 c^4 = (16.1 \times 10^{-26} \text{ J})^2 - (6.72 \times 10^{-27} \text{ J})^2 = 15.4 \times 10^{-26} \text{ J}^2$$

Thus $p = 1.31 \times 10^{-21} \text{ kg} \cdot \text{m/s}$.

(c) On comparing $E = \gamma m_0 c^2 = 2.51 \text{ MeV}$ with $m_0 c^2 = 0.511 \text{ MeV}$ we see that $\gamma = 4.91$. We rewrite $1/\gamma^2 = 1 - v^2/c^2$ in the form

$$\frac{v^2}{c^2} = 1 - \frac{1}{\gamma^2}$$

to find $v/c = 0.98$, or $v = 0.98c$.

Ans:=0.98

elephant in space trip

Problem 16

Elephants have a gestation period(懷孕期) of 21 months. Suppose that a freshly impregnated elephant is placed on a spaceship and sent toward a distant space jungle at $v = 0.75c$. If we monitor radio transmissions from the spaceship, how long after launch might we expect to hear the first squealing(發出長而尖的叫聲) trumpet from the newborn calf? (02小題)

答案空格編號:21 (a)What is the time on Earth that the calf is born?
_____ months

Ans:=31.7

答案空格編號:22 (b) What is the time on Earth to receive the radio transmission of the squealing trupet from the spaceship? the time=_____ months

- | | |
|---|---|
| 1. In S' , the rest frame of the elephant, the time interval from launch to birth, is $\tau = 21$ months. In the Earth frame S the time interval is Δt_1 , given by Equation 1-26: | $\Delta t_1 = \gamma \tau = \frac{1}{\sqrt{1 - \beta^2}} \tau$ $= \frac{1}{\sqrt{1 - (0.75)^2}} (21 \text{ months})$ $= 31.7 \text{ months}$ |
| 2. At that time the radio signal announcing the happy event starts toward Earth at speed c , but from where? Using the result of Example 1-7, since launch the spaceship has moved Δx in S , given by | $\Delta x = \gamma v \tau = \gamma \beta c \tau$ $= (1.51)(0.75)(21 \text{ } c \cdot \text{months})$ $= 23.8 \text{ } c \cdot \text{months}$ <p>where $c \cdot \text{month}$ is the distance light travels in one month.</p> |
| 3. Notice that there is no need to convert Δx into meters since our interest is in how long it will take the radio signal to travel this distance in S . That time is Δt_2 , given by | $\Delta t_2 = \Delta x / c$ $= 23.8 \text{ } c \cdot \text{months} / c$ $= 23.8 \text{ months}$ |
| 4. Thus, the good news will arrive at Earth at time Δt after launch where | $\Delta t = \Delta t_1 + \Delta t_2$ $= 31.7 + 23.8$ $= 55.5 \text{ months}$ |

Ans:=55.5

Muon Decay

Problem 17

Muons decay according to the statistical law of radioactivity:

$$N(t) = N_0 e^{-t/\tau}$$

where N_0 is the original number of muons at time $t = 0$, $N(t)$ is the number remaining at time t , and τ is the mean lifetime (a proper time interval), which is about $2.5 \mu\text{s}$ for muons. Suppose that we observe 10^8 muons at an altitude of 6000 m in some time interval with a muon detector. The muons fly toward the earth in a speed of $0.998c$. How many would we expect to observe at sea level in the same time interval? (03小題)

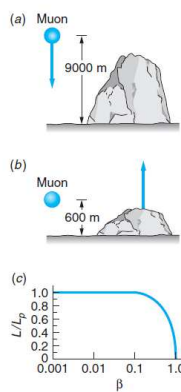
答案空格編號:23 (a)What is the mean life time of the moving muon when measured on Earth? $\tau' = \underline{\hspace{2cm}} \mu\text{s}$

Ans:=39.55

答案空格編號:24 (b)What is the distance for Earth to travel in the rest frame of muon? $x' = \underline{\hspace{2cm}} \text{ m}$

Ans:=479.27

答案空格編號:25 (c) How many would we expect to observe at sea level in the same time interval? $N = \underline{\hspace{2cm}}$



Muon Decay

An interesting example of both time dilation and length contraction is afforded by the appearance of muons as secondary radiation from cosmic rays. Muons decay according to the statistical law of radioactivity:

$$N(t) = N_0 e^{(-t/\tau)}$$

1-29

where N_0 is the original number of muons at time $t = 0$, $N(t)$ is the number remaining at time t , and τ is the mean lifetime (a proper time interval), which is about $2 \mu\text{s}$ for muons. Since muons are created (from the decay of pions) high in the atmosphere, usually several thousand meters above sea level, few muons should reach sea level. A typical muon moving with speed $0.998c$ would travel only about 600 m in $2 \mu\text{s}$. However, the lifetime of the muon measured in Earth's reference frame is increased according to time dilation (Equation 1-26) by the factor $1/(1 - v^2/c^2)^{1/2}$, which is 15 for this particular speed. The mean lifetime measured in Earth's reference frame is therefore $30 \mu\text{s}$, and a muon with speed $0.998c$ travels about 9000 m in this time. From the muon's point of view, it lives only $2 \mu\text{s}$, but the atmosphere is rushing past it with a speed of $0.998c$. The distance of 9000 m in Earth's frame is thus contracted to only 600 m in the muon's frame, as indicated in Figure 1-31.

It is easy to distinguish experimentally between the classical and relativistic predictions of the observations of muons at sea level. Suppose that we observe 10^8 muons at an altitude of 9000 m in some time interval with a muon detector. How many would we expect to observe at sea level in the same time interval? According to the nonrelativistic prediction, the time it takes for these muons to travel 9000 m is $(9000 \text{ m})/(0.998c) \approx 30 \mu\text{s}$, which is 15 lifetimes. Substituting $N_0 = 10^8$ and $t = 15\tau$ into Equation 1-29, we obtain

$$N = 10^8 e^{-15} = 30.6$$

We would thus expect all but about 31 of the original 100 million muons to decay before reaching sea level.

According to the relativistic prediction, Earth must travel only the contracted distance of 600 m in the rest frame of the muon. This takes only $2 \mu\text{s} = 1\tau$. Therefore, the number of muons expected at sea level is

$$N = 10^8 e^{-1} = 3.68 \times 10^7$$

Thus relativity predicts that we would observe 36.8 million muons in the same time interval. Experiments of this type have confirmed the relativistic predictions.

Ans:=6.029E7

Problem 18

What is the minimum energy that is required to break a nucleus of ^{12}C (of mass 11.99671 u) into three nuclei of ^4He (of mass 4.00151 u each)? (01小題)

答案空格編號:26 minimum energy=_____ MeV

Ans:=7.28