Physics 25 Practice Problems Chapter 28

1. An ambulance driver and an emergency medical technician (EMT) place a car-accident victim in the ambulance and race off toward the hospital at a speed of 0.90 c relative to an observer left behind at the accident scene. The observer left behind can see the patient as he is being driven away. Twenty minutes after putting the patient into the ambulance, the EMT inside the ambulance says the patient died. (a) How long does the observer left behind say the patient lived after entering the ambulance? (b) Who is right?

2. Observer A, holding a burning candle, is moving relative to Observer B who says the candle takes 16 minutes to burn out, while the candle-holding Observer A says the candle took four minutes to burn out. What is the speed of Observer A relative to Observer B, as a multiple of c?

3. A spaceship travels at a constant speed from Earth to a distant galaxy. When the spacecraft arrives, 12 years have elapsed according to Earth-observers, and 9 years have elapsed according to observers on the spaceship. (a) How far away is the galaxy, according to observers on Earth? (b) How far away does the spaceship traveler say the galaxy is?

4. A stationary person on the ground watches a squirrel fall without harm to the ground. (a) What length of the fall path, travel time, and speed does the squirrel measure. (b) What length of the fall path, travel time, and speed does the person measure?

5. The proper length of a building is 40 yards. What is the contracted length as measured by an observer traveling at 0.70c relative to the building?

6. The length of a football field according to an observer at rest relative to the ground is 100 meters. A kicked football at the start of the game is caught on the goal line, and the player runs it in for a touchdown. (a) How fast would he say he was running if he says he only ran 20 meters? (b) How long does the runner say it took him to run 20 meters? (c) How long do the spectators say is the time it took the runner to run the length of the football field? (d) What do the spectators say is the runner's speed?

7. Recall $Q = mc\Delta T$, and that the specific heat capacity of water is 1.0 cal/g-C. Also recall that one calorie = 4.19 J. Suppose the temperature of 50 grams of water is changed from 40 ^{o}C to 10 ^{o}C. By how much does the mass of the water change?

8. The "fissioning" of uranium results in a mass "loss" of 2.2×10^{-28} kg, i.e., $\Delta m = -2.2 \times 10^{-28}$ kg. Calculate the energy (in MeV) released when this event occurs.

9. How much work (in joules) would be required to change the speed of a proton from $\beta_o = 0.40$ to $\beta = 0.75$?

10. Spaceship A is moving away from Earth at a velocity 0.70 c. Moving toward Spaceship A is Spaceship B, traveling at -0.50 c. What is the relative speed between the two spaceships?

Problem Solutions

1.	2.	3.
The EMT is present at the location of the event--the dying of the patient inside the ambulance, so she measures the proper time: $T_o = 20$ minutes. $\beta = 0.90$ The observer left behind is moving relative to the location of the event (the dying in the ambulance), so he measures the dilated time: $T = 20 / (1 - 0.90^2)^{1/2}$ $= 45.88$ minutes How long did the patient *really* take to die? Answer: It *really* took 20 minutes, but it also *really* took 45.88 minutes. One's reality depends on one's speed relative to the event or object one is observing. In this case, there are an infinity of true dying times corresponding to the infinity of possible moving observers of the event.	The candle-holding Observer A is at rest relative to the location of the event--the burning of the candle, so he measures the proper time interval: $T_o = 4$ minutes Observer B--is moving relative to the location of the event (the burning candle), so she measures the dilated time interval: $T = 16$ minutes. $16 = 4 /[1 - \beta^2]^{1/2}$ $v/c = 0.97$ The relative speed is 97% of the speed of light.	$12 = 9 /[1 - \beta^2]^{½}$ $\beta = 0.661$ $v = 0.661 (3.0 \times 10^8)$ $= 1.98 \times 10^8$ m/s (a) The Earth observer says the spaceship had been traveling at 1.98×10^8 m/s for twelve years: $T = 12 (365)(24)(3600)$ $= 3.78 \times 10^8$ s The length of the path traveled by the spaceship, as measured by the Earth observer, is the proper length, L_o, because she is stationary relative to that path: Distance = Speed x Time $L_o = (1.98 \times 10^8 \text{ m/s}) (3.78 \times 10^8 \text{ s})$ $= 7.48 \times 10^{16}$ m (b) The observer in the spacecraft says he was traveling at 1.98×10^8 m/s for nine years, $T_o = 9 (365)(24)(3600)$ $= 2.84 \times 10^8$ s Distance = Speed x Time Length $= 1.98 \times 10^8 (2.84 \times 10^8)$ $= 5.62 \times 10^{16}$ m The length above is measured by the observer in the spacecraft, which is moving relative to the path, so he measures the contracted length, L: $L = 5.62 \times 10^{16}$ m

4.

(a)
The squirrel is stationary relative to the location of the event--wherever the squirrel is. Thus, the squirrel measures the proper time, T_o--the shorter time. The squirrel is moving relative to the fall path, so it measures the contracted distance, L--the shorter distance.

Squirrel: Speed = Distance/Time
$= L/T_o$
$= [Lo \sqrt{(1 - (v/c)2}]/To$

(b)
The person observing the fall is stationary relative to the path connecting the tree and ground, so he measures the proper distance, L_o, --the greater distance. The person watching the squirrel fall is moving relative to the location of the event (wherever the squirrel is), so she measures the dilated time, T--the longer time.

Person: Speed = Distance/Time
$= L_o /T$
$= L_o /[T_o/\sqrt{(1 - (v/c)^2}]$
$= [Lo \sqrt{(1 - (v/c)2}]/To$

The speeds are the same.

5.

$L = 40 (1 - 0.70^2)^{1/2}$
$= 28.6$ yards

6. (a) $20 = 100 [1 - \beta^2]^{1/2}$ $\beta = 0.9798$ $v = 0.9798\ c$ $= 0.9798 (3.0 \times 10^8)$ $= 2.9394 \times 10^8$ m/s (b) Time = 20 m / (2.9394×10^8 m/s) $= 6.8041 \times 10^{-8}$ s The runner is always at the location of the event (wherever the runner is), so he is stationary relative to the event, and therefore measures the proper time: $T_o = 6.8041 \times 10^{-8}$ s	(c) The spectators, who are moving relative to the location of the event (wherever the runner is), measure the dilated time, T: $T = 6.8041 \times 10^{-8} / (1 - 0.9798^2)^{1/2}$ $= 3.4024 \times 10^{-7}$ s (d) Speed = Distance/Time v = (100 m) / (3.4024×10^{-7} s) $= 2.9391 \times 10^8$ m/s The spectators measure the same runner speed as is measured by the runner, except for a very small “round-off” error.

7.

$Q = mc\Delta T$
$= 50(1.0)(-30)$
$= -1500$ cal
$= -1500(4.19)$
$= -6285$ J
$\Delta E = -6285$ J

$\Delta m = \Delta E/c^2$
$= -6285 / (3.0 \times 10^8)^2$
$= -6.98 \times 10^{-14}$ kg
$= -6.98 \times 10^{-11}$ g

8.

$\Delta E = (\Delta m)\, c^2$
$= (-2.2 \times 10^{-28})\,(3.0 \times 10^8)^2$
$= -1.98 \times 10^{-11}$ J
$= -(1.98 \times 10^{-11}\text{ J}) / 1.6 \times 10^{-19}$ J/eV
$= -1.24 \times 10^8$ eV
$= -124 \times 10^6$ eV
$= -124$ MeV

124 MeV of mass-energy is lost, so 124 eV of energy is released (in the form of heat and electromagnetic radiation.

9. Use the Work - Kinetic Energy Theorem

$mc^2 = 1.67 \times 10^{-27}\,(3.0 \times 10^8)^2$
$= 1.50 \times 10^{-10}$ J

$\beta_o = 0.40 \qquad \beta = 0.75$

$K = mc^2/ (1 - \beta^2)^{1/2} - mc^2$
$= 1.50 \times 10^{-10} / (1 - \beta^2)^{1/2} - 1.50 \times 10^{-10}$
$= 7.68 \times 10^{-11}$ J

$K_o = 1.50 \times 10^{-10}/ (1 - \beta_o^2)^{1/2} - 1.50 \times 10^{-10}$
$= 1.37 \times 10^{-11}$ J

$W = K - K_o$
$= 6.31 \times 10^{-11}$ J

10.

$\beta_{AB} = (\beta_{AO} - \beta_{BO}) / (1 - \beta_{AO} \beta_{BO})$
$\beta_{AO} = 0.70$
$\beta_{BO} = -0.50$

$\beta_{AB} = (\beta_{AO} - \beta_{BO}) / (1 - \beta_{AO} \beta_{BO})$ (Equation 1)
$= (0.70 + 0.50) / [1 + (0.70)(0.50)]$
$= 0.89$