

## 11. THE RELATIVISTIC UNIVERSE

### Answers to conceptual exercises

2. Figure 11.4 says that, at a speed of  $0.6c$ , a meter stick is observed to be  $0.8$  m long. So Velma will observe the pool's length to be  $0.8 \times 20 \text{ m} = 16 \text{ m}$ , and its width to be  $10 \text{ m}$ .
14. Galileo's relativity predicts  $0.75c$ . Using Table 11.1, Einstein's prediction is  $0.667c$ . Einstein is correct.
16. Using Figure 11.4, Mort measures the mass to be  $1.6 \times 10,000 \text{ kg} = 16,000 \text{ kg}$ , and the length to be  $0.6 \times 100 \text{ m} = 60 \text{ m}$ .
30. No. If you were standing in the laboratory, you would notice that the electron's mass and energy had both increased.
32. It would fall toward the rear with an acceleration of  $2g$ , or about  $20 \text{ m/s}^2$ . It would fall toward the rear with an acceleration of  $0.5g$ , or about  $5 \text{ m/s}^2$ . It would remain suspended where you released it.

### Answers to Problems

4. About  $1\%$ , or  $0.01 \text{ kg}$ , is transformed. The energy transformed is  $mc^2 = (0.01 \text{ kg}) \times (9 \times 10^{16} \text{ m}^2/\text{s}^2) = 9 \times 10^{14} \text{ J}$ . To raise  $1 \text{ gm}$  of water from freezing to boiling requires  $400 \text{ J}$  of energy. So, to raise  $1 \text{ kg}$  requires  $400 \times 10^3 \text{ J}$ , or  $4 \times 10^5 \text{ J}$ . So the number of kilograms of water that could be raised from freezing to boiling by  $9 \times 10^{14} \text{ J}$  of energy is  $(9 \times 10^{14} \text{ J}) / (4 \times 10^5 \text{ J}) =$  about  $2 \times 10^9 \text{ kg}$  (2 billion kg). This is  $2 \times 10^6$  tonnes (2 million tonnes). At  $30$  tonnes per truck, the number of trucks needed to carry all this water is  $2 \times 10^6 / 30 =$  about  $70,000$  trucks!

## 12. ARE WE ALONE? *The Search for Extraterrestrial Intelligence*

### Answers to conceptual exercises

8. Divide 400 billion by 100 million:  $400 \times 10^9 / 100 \times 10^6 = 4000$ . We would have to survey 4000 stars in order to have a good chance of finding one with technology.
10. There is a rough consensus that there is on the order of a billion "good" places for life in our galaxy, and probably emerged on many of these, perhaps on millions of these. There is no consensus on the remaining questions.
12. No. There are always other frequencies to try, as well as other directions and more sensitive receivers. And other kinds of signals could be arriving, such as gravitational waves, that we cannot receive. And other civilizations might not be sending out any signals.
26. If an effect cannot be checked scientifically, then it lies outside the realm of science. So, if ESP cannot be observed by any conceivable scientific observation, then from the scientific point of view ESP does not exist.