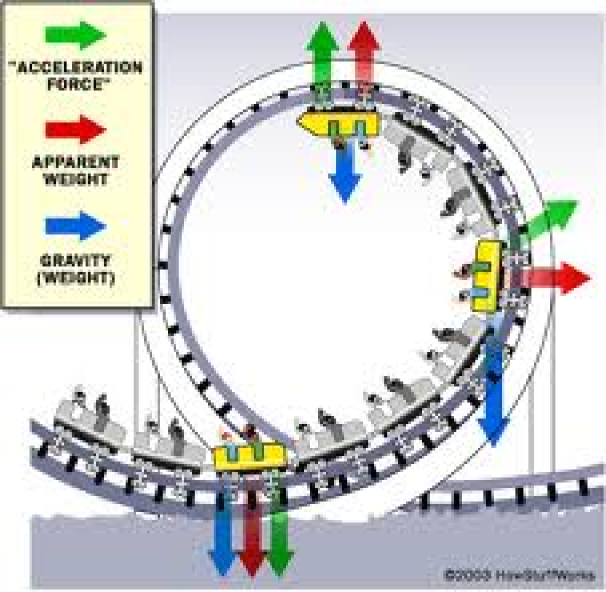
"ACCELERATION FORCE"
APPARENT WEIGHT
GRAVITY (WEIGHT)
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Lesson 1 : WORK

- **Work** is the amount of **energy TRANSFERRED** and is measured in **JOULES (J).**

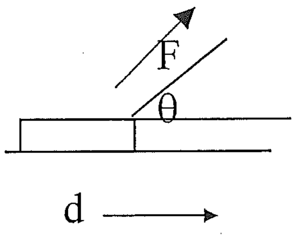
  1Joule = Nm = 1 kgm²/s²

- Work is done when an applied **force acts through some distance.**

- Work **Formulae**

  •**W = Fd** (**F** and **d** must be in the **SAME direction**)
  •**W = mad** (since **F = ma**)

  •**W = cos θ Fd** (for **pulling** or **pushing**)



Examples

Is work done by YOU here?

a) **lifting** anything. **YES** F↑ d↑

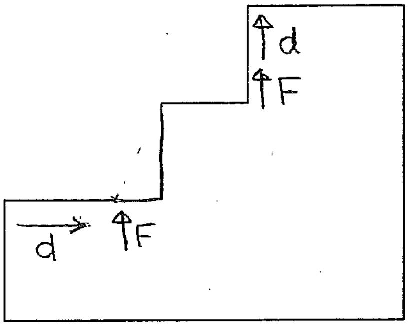
b) **carrying** anything across a room. **NO** F↑ d→

c) **pushing** or **pulling** a **stationary object**

NO F→ or ← but d = 0

Lesson 1

d) **carrying** an object **UP stairs. Yes as you move UP,** but not as you move horizontally



d↑

F↑ **work** is **done** as you move **vertically** as F and d are in the same direction

d → F↑ **no work** as you move **horizontally**.

e) **down stairs. NO** F↑ ↓d or →

- $1J = Nm = \frac{kg\,m}{s^2} \times m = \frac{kg\,m^2}{s^2}$

W = **Fd** or **m a d** or **1/2 mv^2**

Joules are a measure of work or energy

Lesson 1

Kinetic and Potential Energy (other forms of work)

Work is measured in Joules: $1\ J = 1\ Nm = 1\ kgm^2/s^2$

$W = Fd$ or mad or $1/2mv^2$

Kinetic Energy: the **energy** of **MOTION**

$$E_k = K.E. = 1/2\ mv^2$$

- note the **squared function**, if **v** is "**doubled**":

  $(2 \ x\ v)$ becomes $(2v)^2$ which is really $4v^2$

  thus **K.E.** is **increased by a factor** of **4**!

- KE is measured in Joules and is a form of work

When **solving for v**, rearrange the formula as follows:

$$* \ v = \sqrt{\frac{2KE}{m}}$$

Potential Energy: **energy** due to **position** or **condition**.

- **P.E. (Ep) depends** on:

  i) the **force** acting on the object.

  ii) the **displacement** (change in position or height)

$$\mathbf{E_p = P.E. = F_g d = ma_g d} \qquad (\text{or } F_g \ x \ h = ma_g h)$$

displacement/distance　　　　height

Lesson 1

Energy and Work

1. A 15.0 kg object is lifted at a constant velocity from the floor to a height of 1.50 m. Ho
object?

2. A 10.0 kg object is pulled horizontally 5.00 m across a level frictionless floor using a horizontal net force of 3.00 N. How much work is done on the object?

3. A 3.0 kg object is held 1.2 m above the floor for 15 s. How much work is done on the object?

4. A 50.0 kg box is pulled 11.0 m along a level frictionless surface by a rope. If the rope makes an angle with the surface of 35.0°, and the net force exerted through the rope is 90.0 N, how much work is done on the box?

5. A 1385 kg car travelling at 61 km/h is brought to a stop while skidding 42 m. What is the work done on the car by the frictional forces?

6. A 65.0 kg student runs up a flight of stairs at a constant velocity when late for a class. The vertical height of the stairs is 15.0 m. How much work is done by the student?

7. A 32.0 kg object is accelerated from rest through a distance of 5.5 m in 3.2 s across a level floor. If the force of friction between the object and the floor is 4.5 N, what is the work done in moving the object?

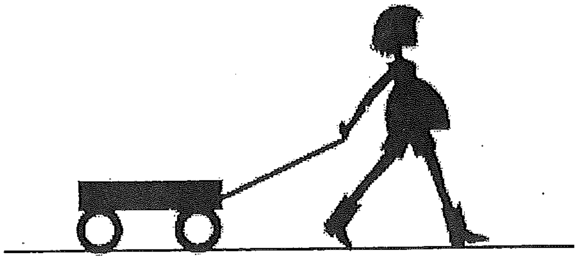
8. An 86.0 N box is pulled 7.50 m along a level frictionless surface by a rope. If the rope makes an angle of 39° with the surface and the force exerted through the rope is 67.0 N, how much work is done on the box?

9. A crate with a mass of 5.0 kg is pulled 16 m along a horizontal floor to the right by a constant force of 70 N. The coefficient of kinetic friction between the crate and the floor is 0.60.

a) Find the work done by each unbalanced force acting on the crate.

b) Find the net work done on the crate.

10 . A 25.0 kg wagon is pulled with a force of 130N through the handle as shown below. How much work is done on the wagon if it moves forward 8.0m? (the handle makes a 22.0° angle with the horizontal; assume no friction).



1.) 221 J 2.) 15 J 3.) 0 J 4.) 811 J 5.) 1.99×10^5 J 6. 9.56×10^3 J 7) 2.1×10^2 J 8) 391 J 9) $+1.1 \times 10^3$ J; -4.7×10^2 J 10) 964 J]

#5) $61 \frac{Km}{h} = 16.9(4) \frac{m}{s}$

MECHANICAL ENERGY

✓1. A 15.0 kg object is lifted from the floor to a vertical height of 2.50 m. What is the potential energy (gravitational) of the object with respect to the floor? (368 J)

✓2. An object with a mass of 5.7 kg is dropped from a height of 8.0 m. What is the kinetic energy of this object as it hits the ground? (4.5×10^2 J)

✓3. A 0.15 kg stone falls from the top of a building. An observer inside the building notices that the speed of the stone is 12 m/s at the top of the window and that the stone takes 0.25 s to travel past the window. The height at the top of the window is 38 m above the ground. [Ignore air resistance]

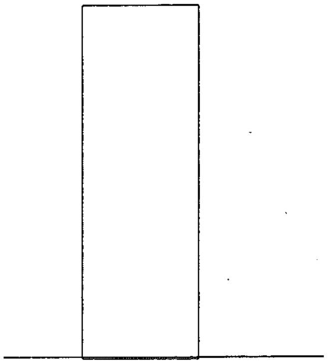
a) Find the kinetic energy, potential energy and total energy of the stone at the top of the window. (11J, 56J, 67J)

b) Find the kinetic energy, potential energy and total energy of the stone at the bottom of the window. (16J, 51J, 67J)

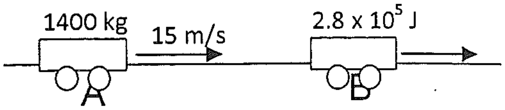
c) Find the work done by the gravitational force. (5J)

d) Find the change in kinetic energy, potential energy, and total energy between the top and the bottom of the window.

(5.0J, -5.0J, 0J)



✓4. A car of a mass of 1400 kg has an initial speed of 15 m/s at point A. Later, it has kinetic energy of 2.8×10^5 J at point B.

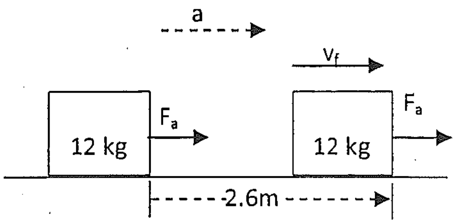


a) Find the kinetic energy of the car at point A. (1.6×10^5 J)

b) Find the speed of the car at point B. (20 m/s)

c) Find the net work done on the car as it moves from point A to point B. (1.2×10^5 J)

✓5. A woman pulls a 12 kg crate (initially at rest) along a horizontal surface as shown in the diagram. She does 96 J of work in the process and the crate moves 2.6 m. Ignore friction.



a) Find the final speed of the crate. (4.0 m/s)

b) Find the acceleration of the crate. (3.1 m/s^2)

c) Find the horizontal force exerted on the crate by the woman. (37 N)

6. A person pushes an 85 kg refrigerator (initially at rest) 16m along a horizontal floor with a constant horizontal force of 220N. The coefficient of friction between the refrigerator and the floor is 0.20.

a) Find the work done on the refrigerator by the person. (3.5×10^3 J)

b) Find the work done on the refrigerator by the friction. (-2.7×10^3 J)

c) Final the acceleration of the refrigerator. (0.63 m/s^2)

d) Find the final speed of the refrigerator. (4.5 m/s)

7. A 10 kg sled is moving at an initial speed of 2.7 m/s along a horizontal trail of snow. The coefficient of kinetic friction between the sled and the snow is 0.12.

a) How far does the sled move before it stops? (3.1m)

b) How much time does it take for the sled to come to a stop? (2.3s)

c) What is the work done on the sled by the frictional force? (-36J)

d) What is the kinetic energy of the sled before it begins to slow down? (36J)

8. A 56 kg student on a cliff holds a 32 m rope used as a swing. He starts from rest with the horizontal rope 34 m high. At the lowest point, the rope is released and he falls into the water. Ignore air resistance.

a) Find the student's kinetic and gravitational potential energy relative to the water level when the rope is horizontal. (0J, 1.9×10^4 J)

b) Find the student's gravitational potential energy relative to the water level when the rope makes a 60° angle with the vertical. (8.8×10^3 J)

c) Find the work done by the force of gravity when he moves from the top of the cliff to the lowest position. (1.8×10^4 J)

✓ 9. A skydiver falls freely to the ground at a height of 46 m. The work done on the skydiver by the force of gravity is 2.8×10^4J. Find the skydiver's mass. (62 kg)

Lesson 2

Law of Conservation of Mechanical Energy

Mechanical energy is the energy of an object due to its position (which is called potential energy, E_p or P.E) or motion (which is called kinetic energy, E_K or K.E.)

Mechanical energy can be either potential energy or kinetic energy (or both)

Kinetic energy can be converted to potential energy and vice versa $E_K \leftrightarrow E_P$
Mechanical energy (the sum of E_K and E_P) remains constant in a frictionless system
→law of conservation of mechanical energy
(assuming no energy is added and no energy is lost (as heat or due to friction, etc.)

If there is friction, some mechanical energy is converted into THERMAL (heat) energy.
Since mechanical energy remains constant in a frictionless system: i = initial f = final

$E_{K_i}+E_{P_i}= E_{K_f}+E_{P_f}$ or $\frac{1}{2}mv_i^2+mgh_i=\frac{1}{2}mv_f^2+mgh_f$

However WITH FRICTION:

$E_{K_i}+E_{P_i}=E_{K_f}+E_{P_f}+W_{fr}$ ← Work done due to friction i.e. the sum of the initial kinetic energy and initial potential energy is the same as the sum of the final kinetic energy and the final potential energy.

Initial	Final
$ma_gh_i+ \frac{1}{2}m(v_i)^2$	$ma_gh_f+\frac{1}{2}m(v_f)^2$

Example 1:

An english book is dropped from a height of 12.0m. What is its speed as it hits the ground?

Initial Energy: $ma_gh_i+ \frac{1}{2}m(v_i)^2$,

$v_i=0$ so Total energy = ma_gh_i

Final: $ma_gh_f+\frac{1}{2}m(v_f)^2$ but $h_f=0$ so the final energy is $\frac{1}{2}m(v_f)^2$: $\overset{0}{\cancel{\frac{1}{2}mv_i^2}} + ma_gh_i = \frac{1}{2}mv_f^2 + \overset{0}{\cancel{ma_gh_f}}$

So $ma_gh_i=\frac{1}{2}m(v_f)^2$

Masses cancel leaving

$a_gh_i=\frac{1}{2}(v_f)^2$

$$\therefore v_f = \sqrt{2a_gh_i} = \sqrt{2(9.80m/s^2)(-12.0m)}$$

so

$$v_f = 15.3m/s$$

Example 2: An annoying Care Bear is thrown vertically down from a 100m building at a speed of 10.0m/s. What is Flat Bear's speed as it hits the ground?

The final height is 0 and the initial velocity is 10.0m/s $\cancel{m}a_gh_i + \frac{1}{2}\cancel{m}v_i^2 = \cancel{ma_gh_f}^{\,0} + \frac{1}{2}\cancel{m}v_f^2$

$m a_g h_i + \frac{1}{2}m(v_i)^2 = \frac{1}{2}m(v_f)^2$ (all m's cancel)

$a_g h_i + \frac{1}{2}(v_i)^2 = \frac{1}{2}(v_f)^2$

$$\therefore v_f = \sqrt{2\left(a_g h_i + \frac{1}{2}v_i^2\right)} \quad \text{or } v_f = \sqrt{\frac{\left(a_g h_i + \frac{1}{2}v_i^2\right)}{\frac{1}{2}}}$$

$$= \sqrt{2\left(\left(-9.80m/s^2\right)\left(-100m\right) + \frac{1}{2}(-10.0m/s)^2\right)}$$

so $= 45.4\,m/s$

Example 3:

A 55 kg fat toddler slides down a slide 5.0m high. If his/her speed at the bottom is 2.9m/s how much heat was generated?

$$\frac{1}{2}m\underset{\overset{\uparrow}{0}}{v_i^2} + ma_gh_i = \frac{1}{2}mv_f^2 + ma_g\underset{\overset{\uparrow}{0}}{h_f} + \underset{\nwarrow \text{heat}}{W_{fr}}$$

$$\therefore ma_gh_i = \frac{1}{2}mv_f^2 + W_{fr}$$

$$(55kg)(-9.80\tfrac{m}{s^2})(-5.0m) = \frac{1}{2}(55kg)(2.9m/s)^2 + W_{fr}$$

$$2695J = 231.3J + W_{fr}$$

$$W_{fr} = 2463.7J = 2.5\times10^3J$$

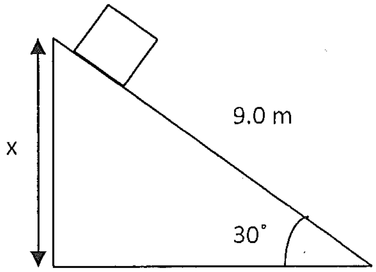
Lesson 2

Law of Conservation of Energy

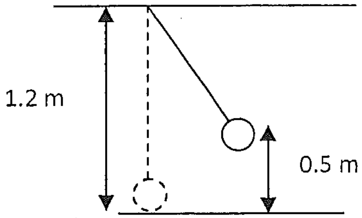
1. A heavy object is dropped from a vertical distance of 12.0 m above the ground. What is the speed of the object as it hits the ground? (15.3 m/s)

2. A heavy object is thrown vertically down from the top of a 1.00 x 10^2 m building at a velocity of 10.0 m/s. What is the speed as it reaches the ground? (45.4 m/s)

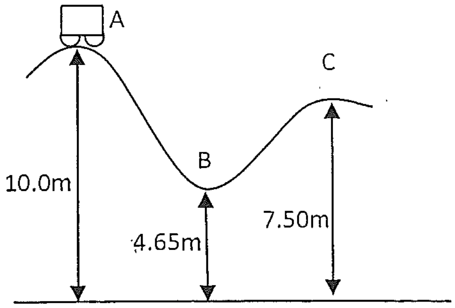
3. A heavy object slides down a frictionless surface. If the box starts from rest at the top of the incline, what is its speed at the bottom? (9.4 m/s)



4. A pendulum is dropped from the position shown in the diagram 0.75m above the equilibrium position. What is the speed of the pendulum bob as it passes through the equilibrium position? (3.1 m/s)



5. A roller coaster car starts from rest at point A. What is the speed of the car at point C if the track is frictionless? (7.0 m/s)



6. A basketball is dropped out of a window 7.4 m above the ground. The basketball hits the ground and rebounds to 5.2 m. Ignore air resistance.

a) Find the speed of the basketball just before it hits the ground. (12 m/s)

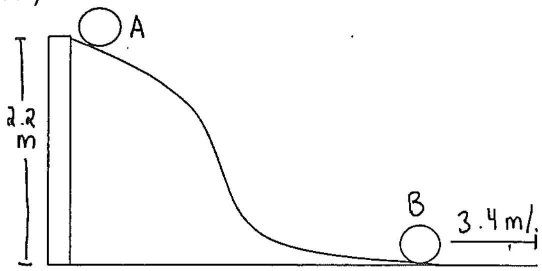
b) Find the speed of the basketball when it rebounds. (10 m/s)

c) If the mass of the basketball is 0.62 kg, find the change in mechanical energy of the basketball when it hits the ground and rebounds. (13 J lost)

7. A 0.050 kg ball starts from rest at point A and slides down a track of 2.2 m above the ground as shown in the diagram. The ball reaches a speed of 3.4 m/s at point B. The length of the track from point A to point B is 4.6 m.

a) Find and explain the change in mechanical energy of the ball from point A to point B. (-0.791J; lost to friction)

b) Find the average force of friction acting on the ball from point A to point B. (-0.17N)

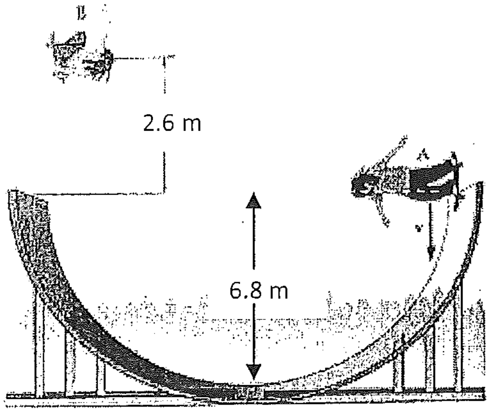


8. A student starts from rest at the top of a water slide. After leaving the horizontal bottom of the slide, she lands in the water 4.5 m from the edge of the slide in 0.36 s. Find the height of the slide from which she starts. Ignore friction and air resistance. (8.0 m)

9. A 46 kg skateboarder starts at one end of a semicircular track 6.8 m above the ground and rises to a height of 2.6 m above the other end of the track. Ignore air resistance.

a) If friction is ignored, what is the skateboarder's initial speed?

BONUS b) If an average frictional force of 5.6 N acts on the skateboarder as the skateboarder moves on the track, what is the skateboarder's initial speed?

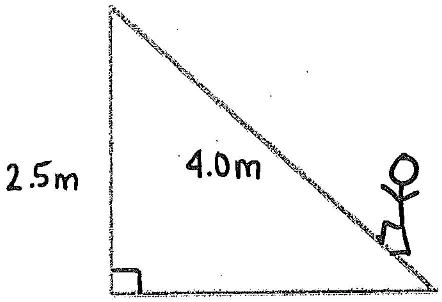


$P = \frac{W}{t} = \frac{F \times d}{t} = F \times v$

Lesson 3

Power and Efficiency

✓1. A 60.0 kg student runs at a constant velocity up the incline described in the diagram in 4.5s. Calculate the power output of the student.



✓2. A 1.00 x 10^3 kg car accelerates from rest to a velocity of 15.0 m/s in 4.00 s. Calculate the power output of the car in this 4.00 s. (assume no friction)

✓ 3. A 630 kg elevator is pulled at a constant velocity of 2.50 m/s by a 20.0 kW motor. Calculate the efficiency of the motor.

? 4. A 7.0 kg object is accelerated uniformly from rest to 7.5 m/s while moving 2.75 m across a level surface. If the force of friction is 3.5 N, calculate the power output.

✓ 5. If a 275 kW motor has an efficiency of 79%, how long will it take to lift a 45.0 kg object to a height of 12.0 m at a constant velocity?

6. A 62 kg runner starts from rest and reaches a speed of 7.2 m/s in 2.3 s (no air resistance). The runner then runs the remainder of the race at a constant speed of 7.2 m/s running against a constant air resistance of 28 N.

a) Find the average power needed to accelerate the runner.

b) Find the average power needed to sustain the constant speed of 7.2 m/s for the remainder of the race

7. A crane lifts a 2600 kg container under the influence of a constant frictional force of 3200N opposing its motion.

a) If the crane lifts the container 7.8 m vertically in 3.0 s at a constant speed, what is the average power delivered by the crane's motor?

b) If the crane accelerates the container from 2.6 m/s to 3.2 m/s up in 3.0 s, what is the average power delivered by the crane motor?

✓8. A crane 1800 W motor lifts a 260 kg crate through a vertical height of 24 m in 56 s at a constant speed.

a) Find the average power needed to lift the crate.

b) Find the efficiency of the crane motor.

1) 3.3×10^2 W 2) 2.8×10^4 W 3) 77.2% 4) 2.8×10^2 W 5) 0.024 s 6) 7.0×10^2 W; 2.0×10^2 W

7) 7.5×10^4 W; 8.5×10^4 W 8) 1.1×10^3 W; 61%

Lesson 4

Energy

Problems: Heat

Formula: $\Delta E_h = m \Delta t c$

Example Problems:

1. An insulated container (negligible specific heat capacity) contains 525 g of water at a temperature of 15.0°C. How much heat is needed to raise the temperature of this water to 75.0°C?

$\Delta E_h = m \Delta t c$
$= (0.525 \text{ kg})(75.0°\text{C} - 15.0°\text{C})(4.18 \times 10^3 \text{ J/kg}\cdot°\text{C})$
$= 1.32 \times 10^5 \text{ J}$

2. An insulated container (negligible specific heat capacity) contains 475 g of water at a temperature of 15°C. If 325 g of hot water at a temperature of 80.0°C is added, what is the temperature of the water in the container when it is completely mixed?

heat gained by cold water + heat lost by hot water = 0
or $\Delta E_{hC} + \Delta E_{hH} = 0$
$m_C \Delta t_C c_C + m_H \Delta t_H c_H = 0$
$(0.476 \text{ kg})(t_f - 15.0°\text{C})(4.18 \times 10^3 \text{ J/kg}\cdot°\text{C}) +$
$(0.325 \text{ kg})(t_f - 80.0°\text{C})(4.18 \times 10^3 \text{ J/kg}\cdot°\text{C}) = 0$
$(1.99 \times 10^3 \text{ J/°C})t_f - 2.98 \times 10^4 \text{ J} +$
$(1.36 \times 10^3 \text{ J/°C})t_f - 1.09 \times 10^5 \text{ J} = 0$

$(3.34 \times 10^3 \text{ J/°C})t_f = 1.38 \times 10^5 \text{ J}$

$t_f = 41.4°\text{C}$

3. When 0.300 kg of lead ($c = 1.30 \times 10^2$ J/kg•°C) at a temperature of 165°C is added to water at a temperature of 15.0°C, the temperature of the water raises to 25.0°C. What is the mass of the water? (Assume the water is in a container that has negligible heat capacity.)

heat gained by water + heat lost by lead = 0
or $\Delta E_{hW} + \Delta E_{hL} = 0$
$m_W \Delta t_W c_W + m_L \Delta t_L c_L = 0$
$m_W(25.0°\text{C} - 15.0°\text{C})(4.18 \times 10^3 \text{ J/kg}\cdot°\text{C}) +$
$(0.300 \text{ kg})(25.0°\text{C} - 165°\text{C})(1.30 \times 10^2 \text{ J/kg}\cdot°\text{C}) = 0$
$(4.18 \times 10^4 \text{ J/kg})m_W - 5.46\ \ 10^3 \text{ J} = 0$

$m_W = 0.131 \text{ kg}$

Practice Problems:

1. An insulated container (negligible specific heat capacity) contains 462 g of water at a temperature of 24.0°C. How much heat is needed to rise the temperature of the 462 g of water from 24.0°C to 80.0°C?

(1.08×10^5 J)

2. How much heat is needed to raise the temperature of 462 g of copper ($c = 1.30 \times 10^2$ J/kg•°C) from 24.0°C to 80.0°C?

(3.36×10^3 J)

3. What is the final temperature of 0.200 kg of a clear liquid ($c = 3.47 \times 10^3$ J/kg•°C) at an original temperature of 20.0°C when it gains 2.50×10^4 J of heat?

(56.0°C)

10

4. What mass of water can be heated from 25.0°C to 40.0°C using 2.10×10^4 J of heat?

(0.335 kg)

5. An insulated container (negligible specific heat capacity) contains 185 g of water at a temperature of 12.0°C. If 295 g of water at a temperature of 85.0°C is added, what is the final temperature of the mixture when it is completely mixed?

(56.9°C)

6. A 0.240 kg copper mass is heated to 215°C and quickly placed in an insulated container (negligible specific heat capacity) that contains 0.275 kg of water that has a temperature of 12.0°C. What is the final temperature of the water?

(27.3°C)

7. A student did an experiment to determine the specific heat capacity of an unknown metal. She heated 0.352 kg of the metal to 215°C and quickly placed it in an insulated container (negligible specific heat capacity) that contained 0.265 kg of water at a temperature of 26.0°C. If the final temperature of the water is 33.0°C, what is the specific heat capacity of the metal?

(1.21×10^2 J/kg•°C)

8. A rain drop (mass = 1.00 g) is travelling at a speed of 40 m/s when it hits the surface of 100 g of water contained in a drinking glass. What is the change in temperature of the water in the glass if we assume that i) all the kinetic energy of the raindrop is converted to energy that changes the water's temperature, and ii) the water in the glass and the raindrop were at the same original temperature?

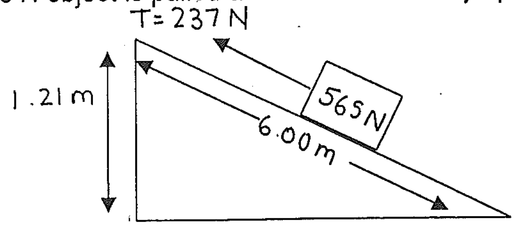
(0.191°C)

11

Lesson 5

Physics 11 – Energy Review

1. A 565 N object is pulled at a constant velocity up an incline with a force of 237 N as shown in the diagram.



Assume that the difference between the work output and the work input is the work required to overcome friction.

a) What is the force of friction along the incline? (-123 N)

b) What is the efficiency of the system? (48%)

2. You exert a force of 435 N in pulling 12.4 m of rope in using a pulley system to lift a 1.34×10^2 N object 4.50 m. What is the efficiency of this pulley system?

(11%)

✓3. 134 kg of a clear liquid (specific heat capacity = 5.45×10^2 J/kg•°C) at a temperature of 23.0°C gains 4.34×10^6 J of heat. What is the final temperature of the liquid?

(82.4°C)

✓4. A 346g sample of metal (specific heat capacity of 3.45×10^2 J/kg•°C) was heated 176°C and quickly placed into an insulated container with 750g of water at a temperature of 20.0°C. What is the final temperature of the water?

(25.4°C)

✓5. A 2.30×10^4 W electric motor is used to lift a 755 kg object vertically 17.0 m at a constant velocity in 35.0 s. What is the efficiency of the motor?

(15.6%)

✓6. A 2000 kg object is raised vertically at a constant velocity of 3.50 m/s by a crane. What is the power output of the crane?

(6.86×10^4 W)

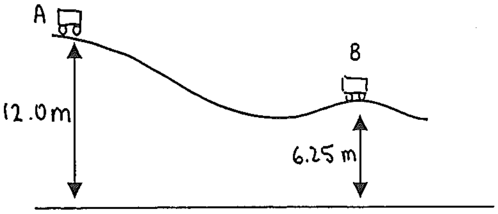
7. What is the average power of a 57.0 kg sprinter accelerating from rest to 1.75 m/s in 5.5 s? [assume no friction]

(15.9 W)

✓ 8. What force is required to accelerate a 25.0 kg object from rest to 4.00 m/s along a 4.25 m horizontal frictionless surface?

(47 N)

✓ 9. A roller coaster is travelling without friction as shown in the diagram. If the speed of the roller coaster at A is 2.5 m/s, what is the speed at B?



(10.9 m/s)

✓10. A heavy object was dropped from some distance above the ground. When it reached the ground, it had a speed of 7.65 m/s. From what height was the object dropped?

(2.98 m)

11. A 4.5 kg object travels vertically at a constant velocity of 2.3 m/s. What is the increase in gravitational potential energy after 4.3 s?

(4.4×10^2 J)

✓12. At what speed would a heavy object hit the floor if it was lifted vertically from the ground at a constant speed of 2.1 m/s for 1.7 s and then dropped?

(8.4 m/s)

✓13. Calculate the kinetic energy of a 1345 kg car travelling at a speed of 30.0 km/h.

(4.67×10^4 J)

✓14. What is the gravitational potential energy with respect to the ground of a 35.0 N object that is 3.0 m above the ground?

(1.1×10^2 J)

15. A 5.6 kg object is pulled 7.5 m at a constant velocity of 5.0 m/s along a horizontal surface by a force of 3.0 N. What is the work done on the object to overcome friction?

(-23 J)

✓16. How much work is done on a 5.7 kg object to accelerate it from 7.0 m/s to 14.0 m/s in 5.40 s?[assume no friction]

(4.2×10^2 J)

17. A crate with a mass of 15.0 kg is pulled 24 m along a horizontal floor to the right by a constant force of 240 N. The coefficient of kinetic friction between the crate and the floor is 0.33.

a) Find the work done by each unbalanced force acting on the crate. (5.7×10^3J; -1.2×10^3J)

b) Find the net work done on the crate.(4.6×10^3J)

18. A 55 kg runner starts from rest and reaches a speed of 2.3 m/s in 4.0 s with an air resistance of 13 N. Find the average power needed to accelerate the runner.

(52 W)

19. A crane lifts a 1500 kg container under the influence of a constant frictional force of 550N opposing its motion.

a) If the crane lifts the container 15 m vertically in 12.0 s at a constant speed, what is the average power delivered by the crane's motor? (1.9×10^4W)

b) If the crane accelerates the container from 1.2m/s to 4.0 m/s up in 6.0 s, what is the average power delivered by the crane motor? (4.1×10^4W)

20. A 2.3 kW electric motor is used to lift a crate (780 kg) to a height of 11.0 m in 43.0 s at a constant velocity. What is the efficiency of the motor? (85%)

21. A person pushes a 185 kg piano (initially at rest) 16m along a horizontal floor with a constant horizontal force of 1220N. The coefficient of friction between the refrigerator and the floor is 0.20.

a) Find the work done on the piano by the person.(2.0x10^4J)

b) Find the work done on the piano by the friction. (-5.8x10^3J)

c) Final the acceleration of the piano. (4.6m/s^2)

d) Find the final speed of the piano. (12.1m/s)

22. A tennis ball is dropped out of a window 4.4 m above the ground. The tennis ball hits the ground and rebounds to 2.1 m. Ignore air resistance.

a) Find the speed of the tennis ball just before it hits the ground. (9.3 m/s)

b) Find the speed of the tennis ball when it rebounds. (6.4 m/s)

c) If the mass of the tennis ball is 0.30 kg, find the change in mechanical energy of the basketball when it hits the ground and rebounds. (6.8 J transformed to other forms of energy).

Lesson 6 notes

Relativity - Physics 11

emal NucFusion 4 power point + open in Evernote!

MICHELSON AND MORLEY

What EMR

Maxwell's theory of EMR did away with the need for ether as a supporting medium for light waves. EMR is composed of vibrating electric and magnetic fields that generate each other. No medium is required. Maxwell's theory, however, introduces another question, "What is the speed of light (EMR) relative to?" In Maxwell's theory there is only provision for one speed (3.00 x 10^8 m/s). What is this speed relative to? Is there an absolute frame of reference in the universe? An absolute frame would be a frame that does not move. Scientists believed that the ether was this absolute frame of reference. The ether does not move, but the earth, etc., move through space (ether). It was therefore assumed that Maxwell's theory gives the speed of EMR (light) relative to ether. Maxwell's theory does away with the need for ether as the supporting medium, but introduces the need for ether as the special frame of reference.

Michelson and Morley were unable to detect the ether.

Michelson and Morley designed an experiment to measure the speed of light relative to ether. What they did was to compare the speeds of light travelling in two perpendicular directions relative to the earth's motion through the ether. They expected to find a difference in the measured speed of light depending upon how their apparatus was oriented with respect to the ether wind. To detect such a small difference in speed, Michelson and Morley used an interferometer that produced an interference pattern between two parts of a split beam of light moving in different directions with respect to the ether wind. Any small difference in the velocity of light along the two paths would be indicated by a change in the interference pattern as the apparatus is rotated. The great importance of this experiment was its failure to show what was expected -- there was no change in the interference pattern. The speed of light was the same whether it travelled parallel or perpendicular to the ether wind. This result is called the "null" result and was a great puzzle of the time (late 1800s).

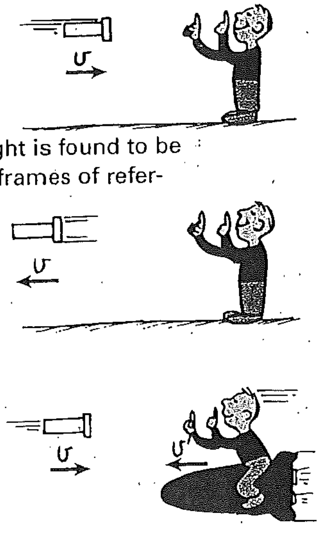
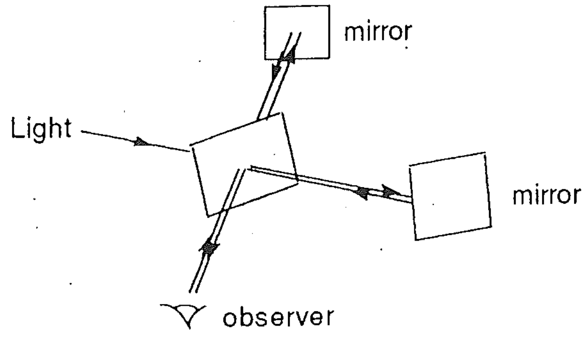


Figure 15.6 The speed of light is found to be the same in all frames of reference.

This is called the "null" result.



Interferometer.

(Ladner)

The idea is like a boat on a river. If the boat is moving with the water, it will travel at a different speed than it will when moving perpendicular to the water movement.

Many theories attempting to explain the speed of light were proposed by the scientists of the time, but the first person to account for it satisfactorily was Einstein. Einstein asked himself the question, "What would I see if I rode a light beam?" In thinking about this question, Einstein concluded that the speed of light could not be zero with respect to any observer -- because if it could not be zero, it could not be reduced for any observer. That is, the speed of light is the same for all observers (for all frames of reference). This may not make sense to us because we think in earthly terms. The speed of a car on the street depends on the frame of reference. The speed of the car is not the same if the reference point is a parked car, or a car moving in the same direction as the car, or in the opposite direction to the car. If the speed of light is the same for all observers (does not depend on the frame of reference), this does away completely with the need for ether.

Einstein: "What would I see if I rode a light beam?"

From the earth frame of reference, light takes 30 000 years to travel from the center of the Milky Way galaxy to our solar system. From the frame of reference of a high-speed spaceship, the trip takes less time. From the frame of reference of light itself, the trip takes no time. There is no time in a speed-of-light frame of reference.

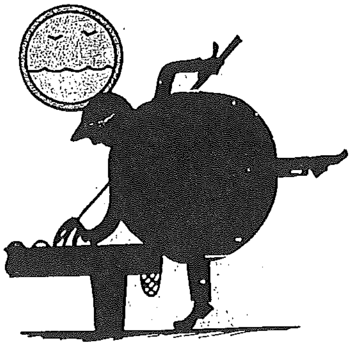


Figure 15.8 ▲
A person playing pool on a smooth and fast-moving ocean liner does not have to make adjustments to compensate for the speed of the ship. The laws of physics are the same for the ship whether it is moving uniformly or is at rest.

EINSTEIN'S SPECIAL THEORY OF RELATIVITY

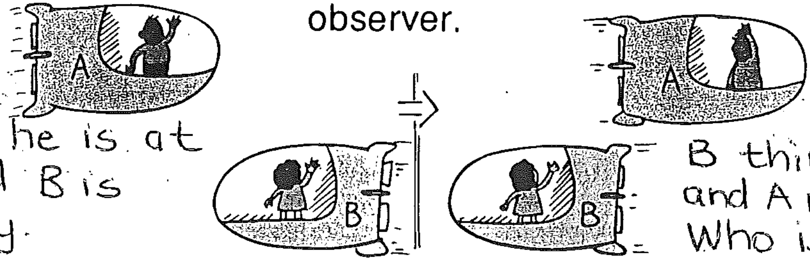
The special theory of relativity is based on two assumptions or postulates.

- The laws of physics in all uniformly moving frames of reference are the same.

A person playing pool on a smooth and fast moving ocean liner does not have to make adjustments to compensate for the speed of the ship. There is no experiment confined to the ship that can be done to determine whether or not there is uniform motion.

- The speed of light in space is the same for all observers, regardless of the motion of the source or observer.

Fig 15.7



A thinks he is at rest and B is flying by.

B thinks she is at rest and A is moving. Who is right?

Speed of light is the same for all observers. Time is not absolute but depends on the speed.

In order for the second postulate to be correct without breaking the first postulate, there are some interesting conclusions. If velocity is absolute, then distance and/or time cannot be. Velocity is equal to distance divided by time (v = d/t). If v does not change (is absolute), then distance and/or time must change. That is, distance and time depend on the frame of reference. To use time as an example: time is not the same in all frames of reference.

* m_o, t_o, L_o is rest value <u>OR</u> the value from the spaceship perspective

- m, t, L is the apparent / relativistic value as seen by the earthling (as the spaceship flies by).

This is illustrated by the story of the twins. One twin was to travel into space. From the twins' calculation, the trip would take fifty years. The twins were already twenty-five; therefore, when they returned to earth they would be seventy-five. Neither twin wanted to make the journey, but one had to. It should be noted that the space craft to be used could travel at a speed just under the speed of light. Fifty years passed. The twin that remained on earth was an old man, but when his twin stepped from the spacecraft, he still looked twenty-five. Time in the two frames of reference was not the same. Fifty years passed on earth; but only a few months passed on the space craft. Time, according to Einstein's special theory of relativity is not absolute.

Mass is not absolute but depends on the speed.

In the same way, mass depends on the frame of reference -- it is not absolute. As far as this course is concerned, it is mass that we must deal with. Mass, like time, depends on the speed it is travelling. Mass increases with speed according to the following relativity equations:

1) $$\bullet m = \frac{{}^{*}m_o}{\sqrt{1 - (v/c)^2}}$$

Time Dilation (see Figure 15.16)

2) $$\bullet t = \frac{{}^{*}t_o}{\sqrt{1-(v/c)^2}}$$

∴ the faster you travel the more massive you become & the slower time travels

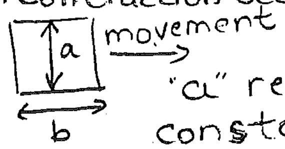
m = relativistic mass
v = relativistic speed
m_o = rest mass
c = speed of light

$$E_k = (m - m_o)c^2$$

E = energy
m_o = rest mass
m = relativistic mass
c = speed of light

3) $$\overset{\circ}{L} = {}^{*}L_o \times \sqrt{1-(v/c)^2}$$

(length contraction see fig 16.3)

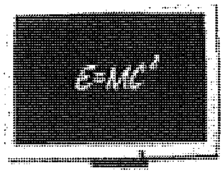


"a" remains constant BUT the faster the movement the smaller the dimension in the same direction of movement (the smaller "b" becomes

<u>Note</u>: When we are dealing with masses travelling at speeds that approach the speed of light, we first must calculate the relativistic mass using these formulas. A rough guide for using relativity is speeds greater than 7.5 x 10^7 m/s (25% of the speed of light.

Lesson 6

Physics 11 - Special Relativity Review



Name:

1. An astronaut is travelling at a constant speed of 6.25 x 10^7 m/s through space relative to earth. According to timing devices aboard the space vehicle the trip lasted 3.50 years. How long did the trip take if measured relative to earth?

(3.58 years)

2. A space vehicle is travelling at a constant speed of 0.870c parallel to a brick wall. If this wall appears to be 60.0 m long as observed by the astronaut on the space vehicle, how long is the wall to an observer standing along side of it?

(122 m)

3. A meter stick is moving parallel to the earth at a constant speed of 0.750c relative to earth. What is the apparent length of the meter stick to an observer standing on earth?

(0.66 m)

4. Calculate the rest mass of an object that has a relativistic mass of 6.75 x 10^{-18} kg at a speed 2.60 x 10^8 m/s.

(3.37 x 10^{-18} kg)

5. Calculate the energy produced if a 10.0 kg mass was 100% converted to heat.

(9.0 x 10^{17} J)

6. You are travelling through space and have aged 3 years. Your friend who remained on earth has aged 7.5 years. How fast was your space vehicle travelling through space relative to earth?

(2.75 x 10^8 m/s)

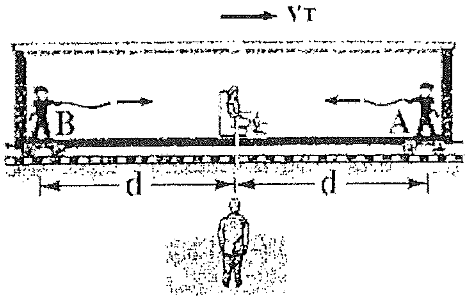
7. Calculate the relativistic mass of an electron that is travelling 0.92c. (hint: use your formula sheet for the rest mass of an electron)

(2.32 x 10^{-30} kg)

8. What mass would be required to produce 8.20 x 10^{14} J of heat if the mass was 100% converted to heat?

(0.009 kg)

Lesson6

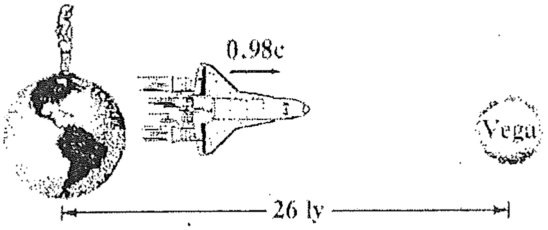


9. Two children with toy laser guns fire a laser beam at the ends A and B of a moving train as shown in the diagram. Two observers are midway between points A and B. The observer standing on the ground says the laser beam was fired at the same time.

a) What would the observer sitting on the train say concerning the two firings? Explain your answer.

b) What would the observer standing on the ground say concerning the two firings? Explain your answer.

c) What observer is correct concerning the two firings? Explain your answer.



10. Vega, the fifth brightest star in the night sky, is located 26 light years from the earth. An astronaut sets out on a journey to Vega at a speed of 0.98c relative to the earth, leaving her 32-year-old twin sister behind on the earth. Assume that the earth and Vega are stationary relative to each other. [light-year is a measure of length and time]

a) How long does the journey take according to the twin sister on earth? (26.5 years)

b) What are their ages as the astronaut reaches Vega? (37.1 years old, 58.5 years old)

c) What distance to Vega does the astronaut measure? (5.2 light years)

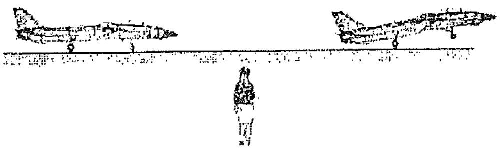
d) If the astronaut wants to age only 3.0 years during her journey to Vega, how fast must she travel? (2.98×10^8 m/s)

11. An astronaut on a spaceship moving at a speed of 0.62c relative to the earth measures her heartbeat rate to be 74 beats per minute. The signals generated by her heartbeat are transmitted to the earth.

a) Find the heartbeat rate as measured by an observer on the earth. (58 beats/min)

b) If the speed of the spaceship increased to 0.90c, what is the heartbeat rate as measured by an observer on the earth?

(32 beats/min)



12. A student is standing next to a runway when an airplane

Both the student and the passenger in the airplane are looking at the runway.

a) Which of them measures the proper length of the airplane? Explain the answer.

b) Which of them measures the proper length of the runway? Explain the answer.

13. A car of rest mass $m_o = 2100$ kg is traveling at a speed of 0.5c relative to the earth.

a) Find the mass of the car as measured by the person on the ground. (m=2425 kg)

b) Find the momentum of the car as measured by the person on the ground. (3.6×10^{11} kg•m/s)

The Twin Paradox
(Time dilation)

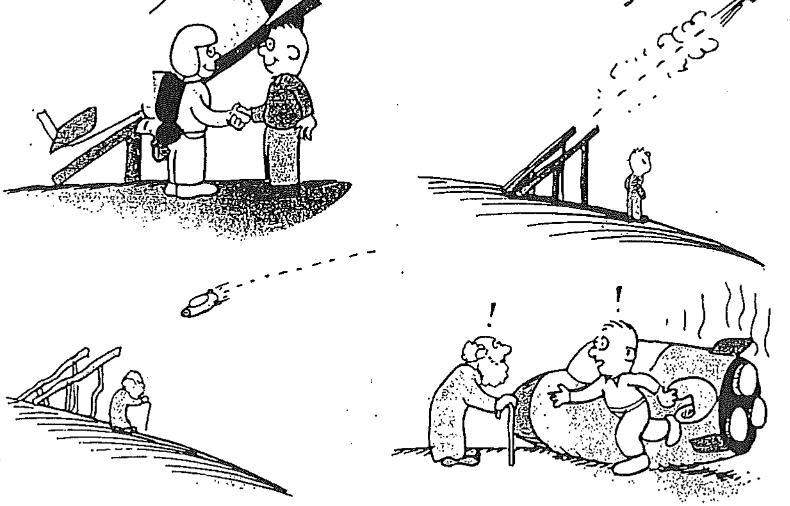


Figure 15.16
The traveling twin does not age as fast as the stay-at-home twin.

LINK TO TECHNOLOGY

Relativistic Clocks

In 1971 atomic clocks were carried around the earth in jet planes. Upon landing, the traveling clocks were a few billionths of a second "younger" than twin clocks that stayed behind. Atomic clocks now cruise overhead at even greater speeds in the satellites that are part of the global positioning system (GPS). In designing this system, which can pinpoint positions on Earth to within meters, scientists and engineers had to accommodate for relativistic time dilation. If they didn't, GPS could not precisely locate positions on Earth. So time dilation is a fact of everyday life to scientists and engineers—especially those who design equipment for global navigation work.

Review Questions

1. If we witness events in a frame of reference moving past us, time appears to be stretched out (dilated). How do the lengths of objects in that frame appear? (16.1)
2. How long would a meterstick appear if it were thrown like a spear at 99.5% the speed of light? (16.1)
3. How long would a meterstick appear if it were traveling at 99.5% the speed of light, but with its length perpendicular to its direction of motion? (Why are your answers to this and the last question different?) (16.1)
4. If you were traveling in a high-speed spaceship, would metersticks on board appear contracted to you? Defend your answer. (16.1)
5. What is meant by the equivalence of mass and energy? That is, what does the equation $E_0 = mc^2$ mean? (16.3)
6. Does the equation $E_0 = mc^2$ apply only to reactions that involve the atomic nucleus? (16.3)

LINK TO BIOLOGY

Muons and Mutations

When cosmic rays bombard atoms at the top of the atmosphere, new particles are made. Some are *muons,* radioactive particles that streak downward toward the earth's surface. A muon's average lifetime is only two millionths of a second, seemingly too brief to reach the ground below before decaying. But because muons move at nearly the speed of light, length contraction dramatically shortens their distance to the earth. You are hit by hundreds of muons every second! Muon impact, like that of all high-speed elementary particles, causes biological mutations. So we see a link between the effects of relativity and the evolution of living creatures on earth.

Length Contraction

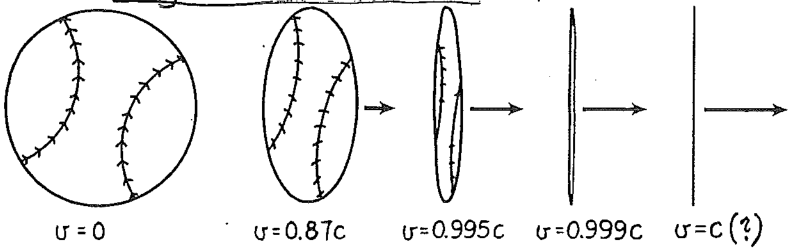
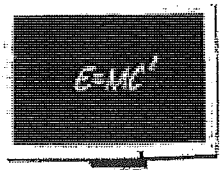


Figure 16.3 ▲
As relative speed increases, contraction in the direction of motion increases. Lengths in the perpendicular direction do not change.

Energy and
Modern Physics
key

Lesson 6 Key

Physics 11 - Special Relativity Review



Name:

omit #10

1. An astronaut is travelling at a constant speed of 6.25 x 10⁷ m/s through space relative to earth. According to timing devices aboard the space vehicle the trip lasted 3.50 years. How long did the trip take if measured relative to earth?

$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{3.50}{\sqrt{1-\frac{(6.25\times10^7)^2}{(3\times10^8)^2}}} = 3.58 \text{ years}$

(3.58 years)

2. A space vehicle is travelling at a constant speed of 0.870c parallel to a brick wall. If this wall appears to be 60.0 m long as observed by the astronaut on the space vehicle, how long is the wall to an observer standing along side of it?

$l = l_0\sqrt{1-\frac{v^2}{c^2}}$ $\quad 60 = l_0\sqrt{1-\frac{(0.87c)^2}{c^2}}$ $\quad l_0 = 122 m$

(122 m)

3. A meter stick is moving parallel to the earth at a constant speed of 0.750c relative to earth. What is the apparent length of the meter stick to an observer standing on earth?

$l = l_0\sqrt{1-\frac{v^2}{c^2}}$ $\quad l = 1.00 \times \sqrt{1-\frac{(0.75c)^2}{c^2}} = 0.66m$

(0.66 m)

4. Calculate the rest mass of an object that has a relativistic mass of 6.75 x 10⁻¹⁸ kg at a speed 2.60 x 10⁸ m/s.

$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$ $\quad 6.75\times10^{-18} = \frac{m_0}{\sqrt{1-\frac{(2.60\times10^8)^2}{(3.0\times10^8)^2}}} = 3.37\times10^{-18} kg$

(3.37 x 10⁻¹⁸ kg)

5. Calculate the energy produced if a 10.0 kg mass was 100% converted to heat.

$E = mc^2$ $\quad (10.0)(3.00\times10^8)^2 = 9.0\times10^{17} J$

(9.0 x 10¹⁷ J)

6. You are travelling through space and have aged 3 years. Your friend who remained on earth has aged 7.5 years. How fast was your space vehicle travelling through space relative to earth?

$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$ $\quad 7.5 = \frac{3}{\sqrt{1-\frac{v^2}{(3.00\times10^8)^2}}}$ $\quad V = 2.75\times10^8 m/s$

(2.75 x 10⁸ m/s)

7. Calculate the relativistic mass of an electron that is travelling 0.92c. (hint: use your formula sheet for the rest mass of an electron)

$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$ $\quad m = \frac{9.11\times10^{-31}}{\sqrt{1-\frac{(0.92c)^2}{c^2}}} = 2.32\times10^{-30} kg$

(2.32 x 10⁻³⁰ kg)

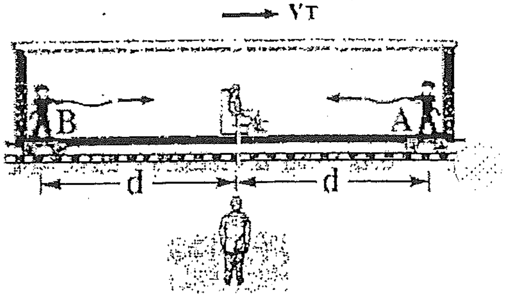
8. What mass would be required to produce 8.20 x 10¹⁴ J of heat if the mass was 100% converted to heat?

$E = mc^2$

$8.20\times10^4 = m(3.00\times10^8)^2$

$\boxed{m = 0.009 kg}$

(0.009 kg)

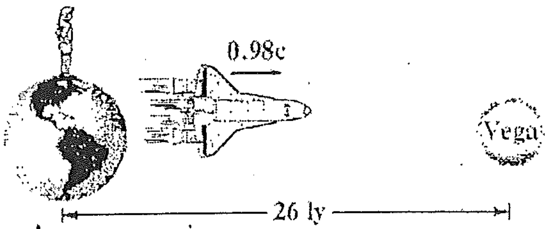


9. Two children with toy laser guns fire a laser beam at the ends A and B of a moving train as shown in the diagram. Two observers are midway between points A and B. The observer standing on the ground says the laser beam was fired at the same time.

a) What would the observer sitting on the train say concerning the two firings? Explain your answer.

b) What would the observer standing on the ground say concerning the two firings? Explain your answer.

c) What observer is correct concerning the two firings? Explain your answer.



10. Vega, the fifth brightest star in the night sky, is located 26 light years from the earth. An astronaut sets out on a journey to Vega at a speed of 0.98c relative to the earth, leaving her 32-year-old twin sister behind on the earth. Assume that the earth and Vega are stationary relative to each other. [light-year is a measure of length and time]

a) How long does the journey take according to the twin sister on earth? $t = \frac{d}{V}$ $\frac{26ly}{0.98c} = 26.5 years$ (26.5 years)

b) What are their ages as the astronaut reaches Vega? $t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$ $26 = \frac{t_0}{\sqrt{1-\frac{0.98^2}{c^2}}}$ $t_0 = 5.2$ (37.1 years old, 58.5 years old)

$32 + 26.5 = 58.5$ years old

$32 + 5.2 = 37.1$ years old

c) What distance to Vega does the astronaut measure? 5.2 light years (5.2 light years)

d) If the astronaut wants to age only 3.0 years during her journey to Vega, how fast must she travel? (2.98 x 10⁸ m/

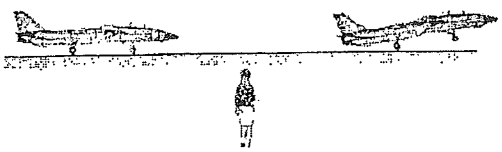
$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$ $26 = \frac{3}{\sqrt{1-\frac{v^2}{c^2}}}$ $\therefore V = 2.98 \times 10^8 m/s$

11. An astronaut on a spaceship moving at a speed of 0.62c relative to the earth measures her heartbeat rate to be 74 beats per minute. The signals generated by her heartbeat are transmitted to the earth.

a) Find the heartbeat rate as measured by an observer on the earth. $t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$ $74 = \frac{t_0}{\sqrt{1-\frac{0.62c^2}{c^2}}}$ $t_0 = 58$ beats/min (58 beats/min)

b) If the speed of the spaceship increased to 0.90c, what is the heartbeat rate as measured by an observer on the earth?

$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$ $74 = \frac{t_0}{\sqrt{1-\frac{(0.90c)^2}{c^2}}}$ $t_0 = 32$ beats/min (32 beats/min)



12. A student is standing next to a runway when an airplane
Both the student and the passenger in the airplane are looking at the runway.

a) Which of them measures the proper length of the airplane? Explain the answer.

b) Which of them measures the proper length of the runway? Explain the answer.

13. A car of rest mass m_o = 2100 kg is traveling at a speed of 0.5c relative to the earth.

a) Find the mass of the car as measured by the person on the ground. $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{2100}{\sqrt{1-\frac{(0.5c)^2}{c^2}}} = 2425 kg$ (m=2425 kg)

b) Find the momentum of the car as measured by the person on the ground. (3.6 x 10¹¹ kg•m/s)

$p = mv$
$= (2425kg)(0.5 \times 3.00 \times 10^8) = 3.6 \times 10^{11} kg \cdot m/s$