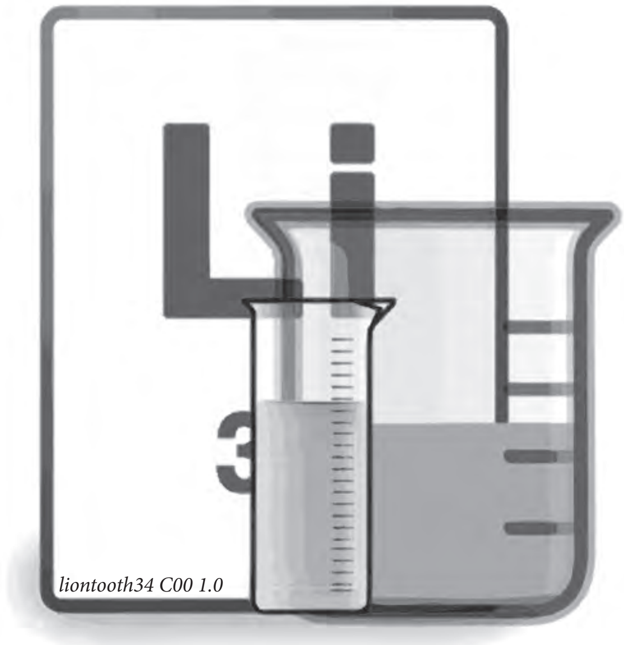
Science: Matter & Energy

Second Edition



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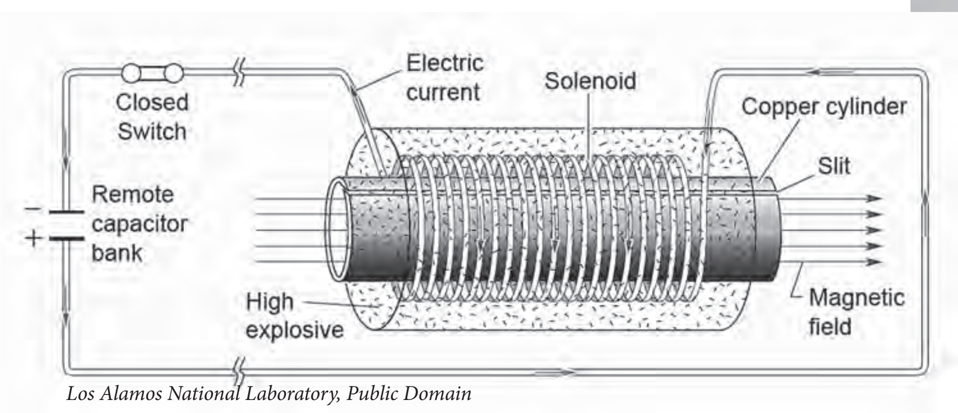

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ANSWER KEY

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Christian Liberty Press
502 West Euclid Avenue
Arlington Heights, Illinois 60004-5402
www.christianlibertypress.com

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Printed in the United States of America

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Introduction

This answer key for *Science: Matter and Energy* (second edition, copyright © 2019, 2015 Abeka) is provided by the staff of Christian Liberty Press to help the instructor successfully teach this course. We have provided answers to the Section Review questions, the Practice questions, and the Chapter Review questions. CLASS students should consult their course instructions for specific course requirements.

The Section Review questions are drawn directly from the text and should be used to determine students' knowledge of the subject matter. The Practice questions apply what has been taught to concrete situations. The Chapter Review questions cover the main concepts found in the chapter and should be used with Section Review questions to study for the chapter tests.

We have also given occasional teacher instructions in italics in the key. When the phrase *Answers may* (or *will*) *vary* is used, this means that there is not necessarily one correct answer, but the student must relate his or her answer to the question and text material as much as possible. Sample answers have been provided, in most cases, which we believe accurately reflect the textual information. We have also provided a few notes and footnotes in the key with additional information and/or clarification for the instructor.

This key should be used by the instructor not only to review the student's daily work, but also to help guide the student in answering the questions. The instructor should first read the answers to the questions, and then direct the student accordingly if he or she has any problems. The answers in this key should be considered as examples; the student does not have to use the same wording in his or her sentences, as long as the same information is given. When appropriate, we have supplied the equations that should be used to determine the answers to the questions and exercises, as an aid to the instructor.

May God grant you wisdom and diligence as you seek to teach your student about our Lord's creation.

The Staff of Christian Liberty Press

2. Charles's law states that when the pressure of the gas remains constant, the volume and temperature are directly proportional. Therefore, the volume would change to 5.6 L. ($V_1/T_1 = V_2/T_2$; so $V_2 = V_1/T_1 \times T_2$ = [7.12 L x 233.15 K] ÷ 296.15 K = 5.605 L ≈ 5.6 L)
3. Amontons's law states that when the volume is constant the temperature and pressure are directly proportional. This puts the new pressure at about 263 kPa. The vessel will need to be 80. mm thick. ($P_1/T_1 = P_2/T_2$; so $P_2 = P_1/T_1 \times T_2$ = [101 kPa x 775 K] ÷ 298 K = 262.66 kPa ≈ 263 kPa; P = 263 kPa = [2 kPa/mm]t + 110 kPa, so t = 153 kPa ÷ 2 kPa/mm = 76.5 mm ≈ 80. mm thick)
4. The buoyant force = the volume times the density of the fluid times the gravitational constant (9.81 m/s), so the $F_b = V \times \rho \times g$ = 0.014 m^3 x 1030 kg/m^3 x 9.81 m/s = 141.46 N ≈ 140 N.
5. In order to give the cube neutral buoyancy, the total mass of the cube must equal the mass of the water displaced. The cube has a volume of 32 cm^3 and must displace 32 cm^3 of water, which has a mass of m = ρv = (1.00 g/cm^3)(32 cm^3) = 32 g. The empty cube has a mass of 20. g, so the amount of mass that must be placed inside the cube is 32 g – 20. g = 12 g.

Chapter 5—Energy

♦ *Section Review 5.1—Page 116*

Concept Review

1. "Energy is the ability to do work and change matter" (p. 114).
2. The SI unit of energy is the joule (J). "One J of energy is the energy required to do 1 J of work" (pp. 114–115).
3. "Mechanical energy is energy from motion or forces that affect a whole object" (p. 115).
4. The equation is $E = mc^2$, which means that the energy (E) derived is equal to the mass (m) of the matter involved multiplied by the speed of light squared (c^2) (p. 116).
5. The name given to the law of conservation of energy when mass-energy equivalence is accounted for is the law of conservation of mass and energy (p. 116).

Application

The law of conservation of energy does still apply; the forces of friction (with the air and the ground) and gravity work together to cause drag. The energy is expended there, and it will eventually bring the ball to a stop.

♦ *Practice 5.2—Page 118*

1. If the same object were moving at 20. km/hr, the kinetic energy would be 40. J. "Doubling the object's speed multiplies the kinetic energy 4 (2^2) times" (p. 117).
2. A vehicle with a mass of 1.00 Mg would have a kinetic energy of 425 kJ. (When the mass is halved, the energy is also halved.)
3. The kinetic energy of a 5.0 kg object traveling at 4.0 m/s is 40. J. ($E_k = ½mv^2$; E_k = ½ x 5.0 kg x [4.0 m/s]^2 = ½ x 5.0 kg x 16.0 m^2/s^2 = 40. kg• m^2/s^2 = 40. J)
4. The work performed on the box is 8.0 x 10^2 J (*see p. 67*). (W= Fd = 250 N x 3.2 m = 800 J ≈ 8.0 x 10^2 J) Since 1 J of work indicates 1 J of energy (p. 115), the final kinetic energy is 8.0 x 10^2 J.

♦ *Section Review 5.2, page 120*

Concept Review

1. "Kinetic energy is the energy of motion" (p. 117).
2. "The simplest form of kinetic energy is whole-body kinetic energy" (p. 117).

3. "The simplest form of motion is translational motion" (p. 117).
4. Circular motion is motion in a circle with the center of the circle outside the object (p. 117).
5. The four factors that affect rotational kinetic energy are mass, speed, size, and shape (p. 119).

Application

1. First, 39 km/h must be converted to about 11 m/s. Thus, the kinetic energy traveling at top speed is 1,800,000 J or 1.8 MJ. ($E_k = ½mv^2 = ½•[30,300 \text{ kg}•(11 \text{ m/s})^2] = 1,833,150 \text{ J} \approx 1,800,000 \text{ J}$ or 1.8 MJ)
2. The mass is about 8.9 kg. ($E_k = ½mv^2 = 35 \text{ J} = ½m•[2.8 \text{ m/s}]^2 = ½m \times 7.84 \text{ m}^2/\text{s}^2$; so $m = [2 \times 35 \text{ J}] \div 7.84 \text{ m}^2/\text{s}^2 = 70 \text{ kg}•\text{m}^2/\text{s}^2 \div 7.84 \text{ m}^2/\text{s}^2 = 8.9286 \text{ kg} \approx 8.9 \text{ kg}$)

♦ *Practice 5.3, page 122*

1. The potential energy is about 59 J. ($E_p = mgh = 3.0 \text{ kg} \times 9.81 \text{ m/s}^2 \times 2.0 \text{ m} = 58.86 \text{ J} \approx 59 \text{ J}$)
2. The object's mass is about 1.5 kg. ($m = E_p \div gh = 12 \text{ J} \div [9.81 \text{ m/s}^2 \times 0.8 \text{ m}] = 1.530 \text{ kg} \approx 1.5 \text{ kg}$)
3. The speed will be about 9.2 m/s. ($E_p = mgh = 0.145 \text{ kg} \times 9.81 \text{ m/s}^2 \times 4.3 \text{ m} = 6.116 \text{ J}$; so $E_k = ½mv^2$; so $v^2 = 6.116 \text{ J} \div [½ \times 0.145 \text{ kg}] = 84.36 \text{ m}^2/\text{s}^2$; $v = \sqrt{84.36 \text{ m}^2/\text{s}^2} = 9.185 \text{ m/s} \approx 9.2 \text{ m/s}$)

♦ *Section Review 5.3—Page 124*

Concept Review

1. "Potential energy is … associated with the position of an object and the forces acting upon it" (p. 120).
2. The following are the four fundamental forces, from strongest to weakest. (1) The strong nuclear force "acts only within the nuclei … of atoms.… This forces binds subatomic particles together to form the nucleus of an atom." (2) "The electromagnetic force affects only objects with an electric charge … [and] is responsible for all known forces in the universe except for the gravitational force and some subatomic forces." (3) "The weak nuclear force affects certain subatomic (smaller than atoms) particles.… [I]t is over 10^{33} times stronger than the gravitational force." (4) "The gravitational force is an attractive force between all material objects"; this force depends on the masses of two objects and the distance between them (pp. 120–123).
3. Gravitational potential energy depends on "the object's mass, the strength of the gravitational field, and the object's height off the ground" (p. 121).
4. The electromagnetic force is the fundamental force responsible for elastic potential energy (pp. 122–123).
5. The strong nuclear force holds atomic nuclei together (p. 123).

Application

1. The gravitational potential energy is 740 J. ($E_p = mgh$; $15 \text{ kg} \times 9.81 \text{ m/s}^2 \times 5.0 \text{ m} = 735.75 \text{ J} \approx 740 \text{ J}$)
2. He is traveling at 14 m/s. ($E_p = mgh = 77 \text{ kg} \times 9.81 \text{ m/s}^2 \times 10. \text{ m} = 7553.7 \text{ J}$; so $E_k = ½mv^2$; so $v^2 = 7553.7 \text{ J} \div [½ \times 77 \text{ kg}] = 196.2 \text{ m}^2/\text{s}^2$; $v = \sqrt{196.2 \text{ m}^2/\text{s}^2} = 14.007 \text{ m/s} \approx 14 \text{ m/s}$)

Chapter 5 Review—Pages 124–125

♦ *Define*

1. **kinetic energy**—the energy of motion (p. 115)
2. **translational kinetic energy**—whole-body kinetic energy (the motion itself is not the energy) caused by transitional motion (motion in which an object moves in space and changes its position; the simplest form of motion) ($E_k = ½mv^2$)(p. 117).

   rotational kinetic energy—the kinetic energy caused by rotational motion (spinning around an internal axis) (p. 119)

3. **thermal energy—**"energy that the object possesses due to the random motion of its molecules" (p. 119)

   wave energy—"energy caused by a disturbance moving through a substance" (p. 120)

4. **fundamental forces—**"the natural forces that cause potential energy" (p. 120)
5. **gravitational field—**"a model that represents the direction and strength of the body's gravity at every point in space" (p. 120)
6. **magnetic potential energy—**the "electromagnetic potential energy caused by interacting magnetic fields" (p. 123)

   chemical energy—"the energy resulting from the chemical combination of atoms into molecules" (p. 123)

   elastic potential energy—the result of a restorative elastic force that tries to return a deformed object to its original position; the potential energy caused by the restorative electromagnetic force that attempts to maintain an optimal distance between neighboring atoms and molecules (p. 123)

7. **nuclear potential energy—**"the potential energy caused by the strong nuclear force," which "binds subatomic particles together to form the nucleus of an atom" (p. 123)

♦ *Identify*

1. "Energy is the ability to do work and change matter" (p. 114).
2. The equation relating mass to energy is $E = mc^2$; that is, energy = mass x (speed of light)^2 (p. 116).
3. The four factors affecting rotational kinetic energy are mass, speed, size, and shape (p. 119).
4. "Potential energy is the energy associated with the position of an object and the forces acting upon it" (p. 120).
5. The four fundamental forces (weakest to strongest) are gravitational force, weak nuclear force, electromagnetic force, and strong nuclear force (pp. 120–123).
6. Two fundamental forces that only affect subatomic particles are weak nuclear force (p. 122) and strong nuclear force (p. 123).

♦ *Explain*

1. "Energy cannot be measured directly.… Since energy is the ability to do work, an amount of energy can be measured by the amount of work it is able to do" (p. 114). Because energy is measured based on the amount of work, the SI unit for work and energy is the same (the joule) (p. 115).
2. *Answers will vary. See the first paragraph under the heading "Energy Changes" on page 115 for examples listed in the textbook. Many other examples are possible.*
3. "Mechanical energy is energy from motion or forces that affect a whole object.… Nonmechanical energy consists primarily of energy caused by internal motion and forces at the atomic and molecular level" (p. 115).
4. *Answers will vary. See the paragraph under the subheading "Conservation of energy" on page 115.*
5. Mass and energy "can be considered two different ways of measuring the same physical property. Every object that has mass has a certain amount of energy simply because of its mass." Adding energy to an object increases its mass. This relationship is called the mass-energy equivalence and explains the law of conservation of mass and energy in that the total mass and energy is constant. Energy or mass may be transferred from object to object or changed into another form, but the total remains the same (pp. 115–116).
6. Circular motion and rotational motion are not the same; "an object in circular motion changes its position along a circular path, while an object in rotational motion spins in place" (p. 118).

7. Energy is the ability to do work and is measured by the amount of work it is able to do (p. 114). "Gravitational potential energy is potential energy that an object gains from the work used to move it against a gravitational field" (p. 121). Increasing the mass and/or the height of an object increases the amount of work that is done to lift it. Therefore, increasing the mass and/or height increases the amount of potential energy.
8. The electromagnetic force is responsible for most physical interactions. *Examples will vary.* For example, if one pushed a book across a table, the repulsive electromagnetic force between electrons in the person's hand and the electrons in the book is what caused the book to move (pp. 122–123).
9. "Gravitational potential energy is potential energy that an object gains from the work used to move it against a gravitational field" (p. 121). However, "electric potential energy is the electromagnetic potential energy that a stationary charged object has from the work needed to move it through another stationary object's electric field" (pp. 122–123). The fundamental forces involved are different, one being gravitational and one being electromagnetic. The electromagnetic force is much stronger than the gravitational force. The electric energy involves only charged objects, but the gravitational involves all objects. The electric energy is affected by the strengths of the charges of the two objects involved, but the gravitational is affected by the masses of the two objects involved.

♦ *Apply*

1. In a particle accelerator, energy is added to particles as they are accelerated. This added energy in the form of speed increases the mass of each particle. We know this because of the law of conservation of mass and energy, which "says that the total mass and energy (determined using the equivalence equation $E = mc^2$) is constant" (p. 116). $m = E/c^2$, so when E increases, m increases.
2. The amount of work required for the spaceship to accelerate from 0 m/s to its current speed is 2.5 TJ or 2.5×10^{12} J. "The amount of kinetic energy an object has equals the work required to bring it from a speed of zero (stationary) to its current speed" (p. 117).
3. If an increase in speed doubles the momentum of a moving object, then the object's speed has doubled; since $\vec{\rho} = m\vec{v}$, so $2\vec{\rho} = 2m\vec{v}$ (p. 69). If the object's speed doubles, or $v_{new} = 2 \times v_{old}$, its kinetic energy quadruples; since $E_k = ½mv^2$, so $E_{k(new)} = ½m(v_{new})^2 = ½m(2 \times v_{old})^2 = ½m \times 4 \times v_{old}{}^2 = E_{k(old)} \times 4$ (p. 117). One of the differences between momentum and kinetic energy is that "kinetic energy represents how much work a moving object can perform; momentum does not. An object with a greater kinetic energy can transfer more energy to another object, even while momentum is conserved" (p. 118).
4. From the top of the first hill to just before the end of the ride, 18,000 J of gravitational potential energy is converted to 14,000 J of kinetic energy. The law of conservation of energy is not violated because the "missing" 4,000 J of energy was not lost, but instead transferred elsewhere, for example, to the air and to the rails in the form of thermal energy and sound energy (p. 115).
5. The final kinetic energy of the weight dropped on the floor would be nearly the same as its gravitational potential energy before it was dropped because an object's weight is essentially constant, and the air resistance in a short drop is negligible (p. 121).

♦ *Problems*

1. The kinetic energy of the baseball is equal to $½(0.145 \text{ kg}) \times (40.2 \text{ m/s})^2 = 117.162 \text{ J} \approx 117 \text{ J}$.
2. $E_k = ½mv^2 = 130 \text{ kJ} = ½m(75 \text{ km/h})^2$ (in which 130 kJ = 130,000 J and 75 km/h = 20.8 m/s); so $m = 130{,}000 \text{ J} \div ½(20.8 \text{ m/s})^2 = 602 \text{ kg}$; so the magnitude of the momentum equals mass times speed, $\rho = mv = 602 \text{ kg} \times 20.8 \text{ m/s} = 12{,}500 \text{ kg•m/s}$. If the speed doubles to 150 km/h, then the momentum would double ($602 \text{ kg} \times 41.6 \text{ m/s} = 25{,}043.2 \text{ kg•m/s} \approx 25{,}000 \text{ kg•m/s}$) and the kinetic energy would quadruple ($E_k = ½ \times 602 \text{ kg} \times [41.6 \text{ m/s}]^2 = 520{,}898.56 \text{ J} \approx 520{,}000 \text{ J}$ or 520 kJ).

3. The gravitational potential energy is 24 J. (E_p = mgh = 12 kg x [9.81 m/s^2] x 0.20 m = 23.5 J ≈ 24 J)
4. The velocity of the arrow when it hits the ground is about 78.6 m/s. ($E_p = E_k$, so mgh = ½mv^2 . So, gh = ½ v^2 , so v = $\sqrt{[2gh]}$ = $\sqrt{[2][9.81 m/s^2][315 m]}$ = $\sqrt{[6180.3 m^2/s^2]}$ = 78.615 m/s ≈ 78.6 m/s)
5. The amount of work the archer did in shooting the arrow is equal to the total energy put into the arrow, or about 72.5 J. Immediately after shooting the arrow, its initial speed was 66.9 m/s. At the peak of the flight, the arrow had both gravitational potential energy and kinetic energy. First, convert the mass of the arrow into the SI unit: (32.4 g)(1 kg / 1000 g) = 0.0324 kg. Next, the total energy $E_p + E_k$ = mgh + ½mv^2 = (0.0324 kg)(9.81 m/s^2)(57.2 m) + (½)(0.0324 kg)(57.9 m/s)^2 = 18.18 J + 54.31 J = 72.49 J ≈ 72.5 J. At ground level, where E_p = zero, all 72.49 J of energy put into the arrow was kinetic energy, so E_k = ½ mv^2 = 72.49 J, so $v^2 = E_k$ ÷ [(½)(m)] = 72.49 J ÷ [(½)(0.0324 kg)] = 4474.69 m^2/s^2, so v = $\sqrt{(4474.69 m^2/s^2)}$ = 66.89 m/s ≈ 66.9 m/s
6. The height from which the object was dropped is about 1.25 m. (E_k = ½mv^2 = mgh, then v^2 = 2gh and [4.95 m/s]^2 = 2 x [9.81 m/s^2] x h, so h = 24.5 m^2/s^2 ÷ 19.62 m/s^2 = 1.248 m ≈ 1.25 m)

Chapter 6—Heat

♦ *Practice 6.1—Page 131*

1. The iron absorbs 6.8 J. (Q = cmΔT = 0.45 J/[g•°C] x 1.0 g x 15°C = 6.8 J)
2. The aluminum absorbs more heat compared to copper, since it has a much higher specific heat. (Since the specific heat of copper = 0.38 and the specific heat of aluminum = 0.90, and ΔT = 100°C – 22°C = 78°C; then the heat gained for 1 g of copper Q = cmΔT = 0.38 J/[g•°C] x 1.0 g x 78°C = 30 J, and the heat gained for 1 g of aluminum Q = cmΔT = 0.90 J/[g•°C] x 1.0 g x 78°C = 70 J)
3. The heat capacity of the sample is 0.65 J/°C. The specific heat of gold is 0.13 J/g•°C.

   The heat capacity of the sample is Q/ΔT = 12.9 J ÷ 20°C = 0.65 J/°C.
   Since Q = cmΔT = 12.9 J and ΔT = 35°C – 15°C = 20°C, then 12.9 J = c x 5.0 g x 20°C = c x 100, so the specific heat of gold is 12.9/100 = 0.129 J/[g•°C] ≈ 0.13 J/[g•°C].
4. The water gained 630 J. The specific heat of the sample is 0.703 J/g•°C. (ΔT_{water} = 25.0°C – 23.0°C = + 2.0°C; heat gained by water Q = cmΔT = [4.18 J/g•°C][(75.0 g)(2.0°C)] = 627 J ≈ 630 J; the amount of heat gained by the water equals the amount of heat lost by the sample, or –627 J; ΔT_{sample} = 100.0°C – 25.0°C = –75.0°C; specific heat of sample c = Q/[mΔT] = (– 627 J/[(11.9 g)(– 75.0°C)] = 0.70252 J/g•°C ≈ 0.703 J/g•°C)

♦ *Section Review 6.1—Page 131*

Concept Review

1. Thermal energy is “the internal energy that an object has because of the random motions of its individual molecules” (p. 126).
2. The three factors affecting thermal energy are temperature, state, and mass (pp. 126–127).
3. “Heat is the transfer of thermal energy from an object of higher temperature to an object of lower temperature” (p. 127). The heat flows from the hotter object to the cooler object.
4. Heat capacity is the amount of heat needed to change an object’s temperature by a certain amount; it indicates the object’s ability to absorb and store thermal energy (p. 128).
5. Specific heat is “the ratio of an object’s heat capacity to the object’s mass” (p. 128).
6. Two non-SI units of heat are the calorie (cal) or Calorie (C) and British thermal unit (Btu) (p. 130).
7. A calorimeter is “a device designed to measure the heat involved in physical and chemical changes” (p. 130).