

Utah Physics Standards Correlation

Utah Science Core Curriculum: Physics

	Physics for Scientists and Engineers	Principles of Physics	Conceptual Physics	Virtual Physics Labs
STANDARD I: Students will understand how to measure, calculate, and describe the motion of an object in terms of position, time, velocity, and acceleration.				
Objective 1: Describe the motion of an object in terms of position, time, and velocity.				
a. Calculate the average velocity of a moving object using data obtained from measurements of position of the object at two or more times.	2.3 Velocity 2.4 Average velocity 2.6 Position-time graph and velocity 2.8 Interactive problem: match the graph using velocity 2.13 Calculus and motion	2.3 Velocity 2.4 Average velocity 2.6 Position-time graph and velocity 2.8 Interactive problem: match the graph using velocity	2.3 Velocity 2.4 Average velocity 2.6 Position-time graph and velocity	Winning at Skee-Ball, Exercise 2A
b. Distinguish between distance and displacement.	2.2 Displacement	2.2 Displacement	2.2 Displacement	
c. Distinguish between speed and velocity.	2.3 Velocity	2.3 Velocity	2.3 Velocity	Navigating race tracks, Exercises 1 and 2
d. Determine and compare the average and instantaneous velocity of an object from data showing its position at given times.	2.5 Instantaneous velocity 2.6 Position-time graph and velocity	2.5 Instantaneous velocity 2.6 Position-time graph and velocity	2.5 Instantaneous velocity 2.6 Position-time graph and velocity	
e. Collect, graph, and interpret data for position vs. time to describe the motion of an object and compare this motion to the motion of another object.	2.6 Position-time graph and velocity 2.7 Interactive problem: draw a position-time graph 2.8 Interactive problem: match a graph using velocity 2.15 Interactive problem: tortoise and hare scandal	2.6 Position-time graph and velocity 2.7 Interactive problem: draw a position-time graph 2.8 Interactive problem: match a graph using velocity 2.13 Interactive problem: tortoise and hare scandal	2.6 Position-time graph and velocity 2.7 Interactive problem: draw a position-time graph	
Objective 2: Analyze the motion of an object in terms of velocity, time, and acceleration.				
a. Determine the average acceleration of an object from data showing velocity at given times.	2.10 Acceleration 2.11 Average acceleration 2.13 Calculus and motion	2.10 Acceleration 2.11 Average acceleration	2.8 Acceleration 2.9 Average acceleration	Winning at Skee-ball, Exercise 3A
b. Describe the velocity of an object when its acceleration is zero.	2.11 Sample problem: velocity and acceleration	2.11 Sample problem: velocity and acceleration	2.11 Sample problem: velocity and acceleration	
c. Collect, graph, and interpret data for velocity vs. time to describe the motion of an object.	2.9 Velocity graph and displacement 2.12 Instantaneous acceleration 2.15 Interactive problem: tortoise and hare scandal 2.18 Interactive problem: what's wrong with the rabbits?	2.9 Velocity graph and displacement 2.12 Instantaneous acceleration 2.13 Interactive problem: tortoise and hare scandal 2.16 Interactive problem: what's wrong with the rabbits?	2.10 Instantaneous acceleration 2.13 Interactive problem: what's wrong with the rabbits?	
d. Describe the acceleration of an object moving in a circular path at constant speed (i.e., constant speed, but changing direction).	9.4 Centripetal acceleration	9.4 Centripetal acceleration	8.3 Centripetal acceleration	Navigating race tracks, Exercise 2
e. Analyze the velocity and acceleration of an object over time.	Chapter 2	Chapter 2	Chapter 2	Winning at Skee-ball Firing cannons Juggling objects Navigating race tracks
Objective 3: Relate the motion of objects to a frame of reference.				
a. Compare the motion of an object relative to two frames of reference.	4.22 Reference frames 4.23 Relative velocity	4.21 Reference frames 4.22 Relative velocity	4.14 Reference frames 4.15 Relative velocity	
b. Predict the motion of an object relative to a different frame of reference (e.g., an object dropped from a moving vehicle observed from the vehicle and by a person standing on the sidewalk).	4.24 Sample problem: relative velocity 4.25 Galilean transformation equations	4.23 Sample problem: relative velocity		
c. Describe how selecting a specific frame of reference can simplify the description of the motion of an object.	4.22 Reference frames 9.10 Accelerating reference frames and fictitious forces	4.21 Reference frames 9.9 Accelerating reference frames and fictitious forces	4.14 Reference frames	
Objective 4: Use Newton's first law to explain the motion of an object.				
a. Describe the motion of a moving object on which balanced forces are acting.	5.2 Newton's first law	5.2 Newton's first law	5.2 Newton's first law	Helicopters in flight, Exercise 1
b. Describe the motion of a stationary object on which balanced forces are acting.	5.2 Newton's first law	5.2 Newton's first law	5.2 Newton's first law	
c. Describe the balanced forces acting on a moving object commonly encountered (e.g., forces acting on an automobile moving at constant velocity, forces that maintain a body in an upright position while walking).	5.1 Force (lifting a barbell at constant velocity) 5.21 Interactive checkpoint: moving the couch 5.30 Air resistance (terminal velocity)	5.1 Force (lifting a barbell at constant velocity) 5.21 Interactive checkpoint: moving the couch 5.30 Air resistance (terminal velocity)	5.1 Force (lifting a barbell at constant velocity) 5.19 Interactive checkpoint: moving the couch 5.24 Air resistance (terminal velocity)	
STANDARD II: Students will understand the relation between force, mass, and acceleration.				

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Objective 1: Analyze forces acting on an object.				
a. Observe and describe forces encountered in everyday life (e.g., braking of an automobile - friction, falling rain drops - gravity, directional compass - magnetic, bathroom scale - elastic or spring).	5.1 Force (hitting a ball - a contact force, force between magnets) 5.11 Normal force (force on a block sitting on a table) 5.12 Tension (force transmitted by a rope) 5.18 Friction (allows car tires to grip the road, experienced when pushing a box along the floor) 5.28 Hooke's law and spring force 5.30 Air resistance (biking, skiing, parachuting) 23.7 Electrostatic force (force between charged balloons) 30.5 Physics at work: compasses and the Earth	5.1 Force (hitting a ball - a contact force, force between magnets) 5.11 Normal force (force on a block sitting on a table) 5.12 Tension (force transmitted by a rope) 5.18 Friction (allows car tires to grip the road, experienced when pushing a box along the floor) 5.28 Hooke's law and spring force 5.30 Air resistance (biking, skiing, parachuting) 23.7 Electrostatic force (force between charged balloons) 30.5 Physics at work: compasses and the Earth	5.1 Force (hitting a ball - a contact force, force between magnets) 5.11 Normal force (force on a block sitting on a table) 5.12 Tension (force transmitted by a rope) 5.16 Friction (allows car tires to grip the road, experienced when pushing a box along the floor) 5.23 Hooke's law and spring force 5.24 Air resistance (biking, skiing, parachuting) 22.6 Electrostatic force (force between charged balloons) 28.5 Physics at work: compasses and the Earth	Helicopters in flight (helicopter lift force, air resistance)
b. Use vector diagrams to represent the forces acting on an object.	5.14 Free-body diagrams Sample problems and Interactive checkpoints in Chapters 5 and 6 that use free-body diagrams: 5.15, 5.16, 5.22, 5.23, 5.24, 5.25, 5.26, 5.27, 5.29, 6.1, 6.2, 6.3, 6.4, 6.6, 6.7, 6.9, 6.11, 6.12.	5.14 Free-body diagrams Sample problems and Interactive checkpoints in Chapters 5 and 6 that use free-body diagrams: 5.15, 5.16, 5.22, 5.23, 5.24, 5.25, 5.26, 5.27, 5.29, 6.1, 6.2, 6.3, 6.4, 6.6, 6.7, 6.9, 6.11, 6.12.	5.14 Free-body diagrams Sample problems and Interactive checkpoints in Chapters 5 and 6 that use free-body diagrams: 5.15, 5.20, 5.21, 5.22.	Helicopters in flight, Exercises 3 and 6
c. Measure the forces on an object using appropriate tools.	5.4 Gravitational force: weight (scales)	5.4 Gravitational force: weight (scales)	5.4 Gravitational force: weight (scales)	
d. Calculate the net force acting on an object.	5.13 Newton's second and third laws (determining which forces act on object) 5.14 Free-body diagrams Numerous examples, sample problems, interactive checkpoints, and interactive problems in chapters 5 and 6 provide practice.	5.13 Newton's second and third laws (determining which forces act on object) 5.14 Free-body diagrams Numerous examples, sample problems, interactive checkpoints, and interactive problems in chapters 5 and 6 provide practice.	5.13 Newton's second and third laws (determining which forces act on object) 5.14 Free-body diagrams Numerous examples, sample problems, interactive checkpoints, and interactive problems in chapters 5 and 6 provide practice.	Helicopters in flight
Objective 2: Using Newton's second law, relate the force, mass, and acceleration of an object.				
a. Determine the relationship between the net force on an object and the object's acceleration.	5.5 Newton's second law Sample problems, Interactive checkpoints, and Interactive problems in Chapters 5 and 6 that provide practice with Newton's second law: 5.6, 5.7, 5.8, 5.9, 5.16, 5.17, 5.22, 5.23, 5.24, 5.25, 5.26, 5.27, 5.29, 5.32, 6.1 - 6.13.	5.5 Newton's second law Sample problems, Interactive checkpoints, and Interactive problems in Chapters 5 and 6 that provide practice with Newton's second law: 5.6, 5.7, 5.8, 5.9, 5.16, 5.17, 5.22, 5.23, 5.24, 5.25, 5.26, 5.27, 5.29, 5.31, 6.1 - 6.13.	5.5 Newton's second law Sample problems, Interactive checkpoints, and Interactive problems in Chapter 5 that provide practice with Newton's second law: 5.6, 5.7, 5.8, 5.9, 5.20, 5.21, 5.22.	Helicopters in flight, Exercises 2 and 3
b. Relate the effect of an object's mass to its acceleration when an unbalanced force is applied.	5.5 Newton's second law Sample problems, Interactive checkpoints, and Interactive problems in Chapters 5 and 6 that provide practice with Newton's second law when there is a non-zero net force: 5.6, 5.7, 5.8, 5.9, 5.16, 5.17, 5.22, 5.23, 5.24, 5.25, 5.26, 5.27, 5.32, 6.3, 6.4, 6.5, 6.9, 6.10, 6.11, 6.12, 6.13.	5.5 Newton's second law Sample problems, Interactive checkpoints, and Interactive problems in Chapters 5 and 6 that provide practice with Newton's second law when there is a non-zero net force: 5.6, 5.7, 5.8, 5.9, 5.16, 5.17, 5.22, 5.23, 5.24, 5.25, 5.26, 5.27, 5.31, 6.3, 6.4, 6.5, 6.9, 6.10, 6.11, 6.12, 6.13.	5.5 Newton's second law Sample problems, Interactive checkpoints, and Interactive problems in Chapter 5 that provide practice with Newton's second law when there is a non-zero net force: 5.6, 5.7, 5.8, 5.9, 5.20, 5.21, 5.22.	Helicopters in flight
c. Determine the relationship between force, mass, and acceleration from experimental data and compare the results to Newton's second law.				Helicopters in flight, Exercise 2
d. Predict the combined effect of multiple forces (e.g., friction, gravity, and normal forces) on an object's motion.	The Sample problems, Interactive checkpoints and Interactive problems in Chapters 5 and 6 provide practice with multiple forces.	The Sample problems, Interactive checkpoints and Interactive problems in Chapters 5 and 6 provide practice with multiple forces.	The Sample problems, Interactive checkpoints and Interactive problems in Chapter 5 provide practice with multiple forces.	Helicopters in flight
Objective 3: Explain that forces act in pairs as described by Newton's third law.				
a. Identify pairs of forces (e.g., action-reaction, equal and opposite) acting between two objects (e.g., two electric charges, a book and the table it rests upon, a person and a rope being pulled).	5.10 Newton's third law 5.13 Newton's second and third laws (identify which pairs of forces are action-reaction pairs and which are not)	5.10 Newton's third law 5.13 Newton's second and third laws (identify which pairs of forces are action-reaction pairs and which are not)	5.10 Newton's third law 5.13 Newton's second and third laws (identify which pairs of forces are action-reaction pairs and which are not)	
b. Determine the magnitude and direction of the acting force when magnitude and direction of the reacting force is known.	5.10 Newton's third law	5.10 Newton's third law	5.10 Newton's third law	
c. Provide examples of practical applications of Newton's third law (e.g., forces on a retaining wall, rockets, walking).	5.10 Newton's third law (leaning on a wall)	5.10 Newton's third law (leaning on a wall)	5.10 Newton's third law (leaning on a wall)	
d. Relate the historical development of Newton's laws of motion to our current understanding of the nature of science (e.g., based upon previous knowledge, empirical evidence, replicable observations, development of scientific law).	5.0 (Provides some background on beliefs before Newton)	5.0 (Provides some background on beliefs before Newton)	5.0 (Provides some background on beliefs before Newton)	
STANDARD III: Students will understand the factors determining the strength of gravitational and electric forces.				
Objective 1: Relate the strength of the gravitational force to the distance between two objects and the mass of the objects (i.e., Newton's law of universal gravitation).				

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a. Investigate how mass affects the gravitational force (e.g., spring scale, balance, or other method of finding a relationship between mass and the gravitational force).	13.1 Newton's law of gravitation	13.1 Newton's law of gravitation	12.1 Newton's law of gravitation	Orbiting satellites, Exercise 2
b. Distinguish between mass and weight.	5.4 Gravitational force: weight	5.4 Gravitational force: weight	5.4 Gravitational force: weight	
c. Describe how distance between objects affects the gravitational force (e.g., effect of gravitational forces of the moon and sun on objects on Earth).	5.1 Force 13.1 Newton's law of gravitation 13.9 Sample problem: gravitational force of multiple bodies	5.1 Force 13.1 Newton's law of gravitation	5.1 Force 12.1 Newton's law of gravitation	Orbiting satellites, Exercise 2
d. Explain how evidence and inference are used to describe fundamental forces in nature, such as the gravitational force.	13.0 Introduction (Discusses Galileo's experiments of dropping balls to study gravity) 13.12 Newton's cannon (thought experiment used to understand how gravity causes the Moon's orbit) 32.0 Introduction (Discusses Faraday's experiments with the relationship between electric and magnetic forces)	13.0 Introduction (Discusses Galileo's experiments of dropping balls to study gravity) 13.8 Newton's cannon (thought experiment used to understand how gravity causes the Moon's orbit) 32.0 Introduction (Discusses Faraday's experiments with the relationship between electric and magnetic forces)	12.0 Introduction (Discusses Galileo's experiments of dropping balls to study gravity) 12.7 Newton's cannon (thought experiment used to understand how gravity causes the Moon's orbit) 29.0 Introduction (Discusses Faraday's experiments with the relationship between electric and magnetic forces)	
e. Research the importance of gravitational forces in the space program.				Mission to Mars, Exercises 4, 5 and 6
Objective 2: Describe the factors that affect the electric force (i.e., Coulomb's law).				
a. Relate the types of charge to their effect on electric force (i.e., like charges repel, unlike charges attract).	23.7 Electrostatic force	23.7 Electrostatic force	22.6 Electrostatic force	Electric Golf, Exercise 2
b. Describe how the amount of charge affects the electric force.	23.9 Coulomb's law: calculating electrostatic forces	23.9 Coulomb's law: calculating electrostatic forces	22.8 Coulomb's law: calculating electrostatic forces	Electric Golf, Exercise 2
c. Investigate the relationship of distance between charged objects and the strength of the electric force.	23.9 Coulomb's law: calculating electrostatic forces	23.9 Coulomb's law: calculating electrostatic forces	22.8 Coulomb's law: calculating electrostatic forces	Electric Golf, Exercise 1
d. Research and report on electric forces in everyday applications found in both nature and technology (e.g., lightning, living organisms, batteries, copy machine, electrostatic precipitators).	23.15 Physics at work: laser printers 24.13 Physics at work: spacecraft powered by electric fields 27.14 Sample problem: solar panels 28.4 Physics at work: capacitors and computer keyboards 28.14 Physics in medicine: defibrillator (also electric fish) 29.2 Electromotive force (batteries)	23.15 Physics at work: laser printers 24.13 Physics at work: spacecraft powered by electric fields 27.9 Sample problem: solar panels 28.4 Physics at work: capacitors and computer keyboards 28.11 Physics in medicine: defibrillator (also electric fish) 29.2 Electromotive force (batteries)	22.12 Physics at work: laser printers 23.10 Physics at work: spacecraft powered by electric fields 25.8 Sample problem: solar panels 26.3 Physics at work: capacitors and computer keyboards 26.6 Physics in medicine: defibrillator (also electric fish) 27.2 Electromotive force (batteries)	
STANDARD IV: Students will understand transfer and conservation of energy.				
Objective 1: Determine kinetic and potential energy in a system.				
a. Identify various types of potential energy (i.e., gravitational, elastic, chemical, electrostatic, nuclear).	7.16 Potential energy (gravitational) 15.20 Work and the potential energy of a spring 25.1 Electric potential energy 44.0 Introduction (Nuclear Physics) 44.9 Nuclear binding energy	7.13 Potential energy (gravitational) 15.18 Work and the potential energy of a spring 25.1 Electric potential energy 43.0 Introduction (Nuclear Physics) 43.9 Nuclear binding energy	6.10 Potential energy (gravitational) 24.1 Electric potential energy 38.0 Introduction (Nuclear Physics) 38.9 Nuclear binding energy	
b. Calculate the kinetic energy of an object given the velocity and mass of the object.	7.8 Kinetic energy 7.12 Sample problem: work-kinetic energy theorem 7.13 Interactive problem: work-kinetic energy theorem	7.6 Kinetic energy 7.9 Sample problem: work-kinetic energy theorem 7.10 Interactive problem: work-kinetic energy theorem	6.4 Kinetic energy 6.6 Sample problem: work-kinetic energy theorem 6.7 Interactive problem: work-kinetic energy theorem	
c. Describe the types of energy contributing to the total energy of a given system.	7.22 Conservation of energy 7.26 Potential energy curves 13.28 Orbits and energy 15.21 Total energy (mass on a spring) 20.10 Kinetic energy and temperature 33.4 Energy in an LC circuit 41.23 Mass and energy (mass-energy equivalence)	7.19 Conservation of energy 13.21 Orbits and energy 15.19 Total energy (mass on a spring) 20.10 Kinetic energy and temperature 40.16 Mass and energy (mass-energy equivalence)	6.16 Conservation of energy 12.17 Orbits and energy 19.9 Kinetic energy and temperature 35.12 Mass and energy (mass-energy equivalence)	Mission to Mars, Exercise 2
Objective 2: Describe conservation of energy in terms of systems.				
a. Describe a closed system in terms of its total energy.	7.22 Conservation of energy 7.26 Potential energy curves 13.28 Orbits and energy 15.21 Total energy (mass on a spring) 33.4 Energy in an LC circuit	7.19 Conservation of energy 13.21 Orbits and energy 15.19 Total energy (mass on a spring)	6.16 Conservation of energy 12.17 Orbits and energy	Mission to Mars, Exercise 2

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b. Relate the transformations between kinetic and potential energy in a system (e.g., moving magnet induces electricity in a coil of wire, roller coaster, internal combustion engine).	7.23 Sample problem: conservation of energy (bouncing on a trampoline) 7.24 Interactive checkpoint: conservation of energy (swinging on a rope) 7.25 Interactive problem: conservation of energy (rolling down a hill) 7.26 Potential energy curves (mass and spring system) 15.21 Total energy (mass and spring system) 21.3 Heat engines 32.1 Motional electromagnetic induction (moving a wire through a magnetic field) 32.3 Induction: a coil and a magnet 32.17 Electric generators	7.20 Sample problem: conservation of energy (bouncing on a trampoline) 7.21 Interactive checkpoint: conservation of energy (swinging on a rope) 7.22 Interactive problem: conservation of energy (rolling down a hill) 15.19 Total energy (mass and spring system) 21.3 Heat engines 32.1 Motional electromagnetic induction (moving a wire through a magnetic field) 32.3 Induction: a coil and a magnet 32.14 Electric generators	6.17 Sample problem: conservation of energy (bouncing on a trampoline) 6.18 Interactive checkpoint: conservation of energy (swinging on a rope) 6.19 Interactive problem: conservation of energy (rolling down a hill) 20.3 Heat engines 29.1 Motional electromagnetic induction (moving a wire through a magnetic field) 29.3 Induction: a coil and a magnet	Mission to Mars, Exercise 3
c. Gather data and calculate the gravitational potential energy and the kinetic energy of an object (e.g., pendulum, water flowing downhill, ball dropped from a height) and relate this to the conservation of energy of a system.				Mission to Mars, Exercise 1A
d. Evaluate social, economic, and environmental issues related to the production and transmission of electrical energy.	27.14 Sample problem: solar panels 27.18 Sample problem: power transmission 44.13 Fission (nuclear power plants)	27.9 Sample problem: solar panels 27.13 Sample problem: power transmission 43.13 Fission (nuclear power plants)	25.8 Sample problem: solar panels 25.11 Sample problem: power transmission 38.13 Fission (nuclear power plants)	
Objective 3: Describe common energy transformations and the effect on availability of energy.				
a. Describe the loss of useful energy in energy transformations.	7.29 Friction and conservation of energy 8.11 Collisions 8.20 Inelastic collisions 22.2 Second law of thermodynamics 33.7 RLC circuit: damped oscillations	7.23 Friction and conservation of energy 8.10 Collisions 8.18 Inelastic collisions 22.2 Second law of thermodynamics	6.20 Friction and conservation of energy 7.8 Collisions 7.13 Inelastic collisions 21.2 Second law of thermodynamics	
b. Investigate the transfer of heat energy by conduction, convection, and radiation.	19.25 Conduction 19.26 Thermal conduction quantified 19.28 Convection 19.29 Radiation 19.30 Radiation quantified	19.22 Conduction 19.23 Thermal conduction quantified 19.25 Convection 19.26 Radiation 19.37 Radiation quantified	18.17 Conduction 18.18 Thermal conduction quantified 18.19 Convection 18.20 Radiation	
c. Describe the transformation of mechanical energy into electrical energy and the transmission of electrical energy.	32.1 Motional electromagnetic induction (moving a wire through a magnetic field) 32.3 Induction: a coil and a magnet 32.17 Electric generators 27.18 Sample problem: power transmission	32.1 Motional electromagnetic induction (moving a wire through a magnetic field) 32.3 Induction: a coil and a magnet 32.14 Electric generators 27.13 Sample problem: power transmission	29.1 Motional electromagnetic induction (moving a wire through a magnetic field) 29.3 Induction: a coil and a magnet 25.11 Sample problem: power transmission	Generators and transformers
d. Research and report on the transformation of energy in electrical generation plants (e.g., chemical to heat to electricity, nuclear to heat to mechanical to electrical, gravitational to kinetic to mechanical to electrical), and include energy losses during each transformation.	44.13 Fission	43.13 Fission	38.13 Fission	
STANDARD V: Students will understand the properties and applications of waves.				
Objective 1: Demonstrate an understanding of mechanical waves in terms of general wave properties.				
a. Differentiate between period, frequency, wavelength, and amplitude of waves.	15.4 Period and frequency (in context of mass on spring) 15.6 Amplitude (in context of mass on spring) 15.7 Interactive problem: match the curve 16.4 Amplitude (waves in general) 16.5 Wavelength (waves in general) 16.6 Period and frequency (waves in general)	15.3 Period and frequency (in context of mass on spring) 15.5 Amplitude (in context of mass on spring) 15.6 Interactive problem: match the curve 16.4 Amplitude (waves in general) 16.5 Wavelength (waves in general) 16.6 Period and frequency (waves in general)	14.3 Period and frequency (in context of mass on spring) 14.5 Amplitude (in context of mass on spring) 14.6 Interactive problem: match the curve 15.4 Amplitude (waves in general) 15.5 Wavelength (waves in general) 15.6 Period and frequency (waves in general)	Birds on a wire, Exercises 2 and 3
b. Investigate and compare reflection, refraction, and diffraction of waves.	chapters 36, 37, and 40	chapters 35, 36, and 39	chapters 31, 32, and 34	Helicopters vs. Submarines (refraction and total internal reflection)
c. Provide examples of waves commonly observed in nature and/or used in technological applications.	17.1 Sound waves 18.7 Harmonics (standing waves in stringed instruments) 18.10 Music from wind instruments 35.8 Creating electromagnetic waves: antennas 35.21 Polarization (polaroid sunglasses) 35.26 Optically active substances (stress analysis and polarimetry) 35.27 Physics at work: liquid crystal displays (LCDs)	17.1 Sound waves 18.7 Harmonics (standing waves in stringed instruments) 18.10 Music from wind instruments 34.5 Creating electromagnetic waves: antennas 34.17 Polarization (polaroid sunglasses) 34.22 Optically active substances (stress analysis and polarimetry) 34.23 Physics at work: liquid crystal displays (LCDs)	16.1 Sound waves 17.4 Harmonics (standing waves in stringed instruments) 30.5 Creating electromagnetic waves: antennas 30.8 Polarization (polaroid sunglasses) 30.10 Physics at work: liquid crystal displays (LCDs)	

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d. Identify the relationship between the speed, wavelength, and frequency of a wave.	16.7 Wave speed	16.7 Wave speed	15.7 Wave speed	Birds on a wire, Exercises 3, 4, and 5
e. Explain the observed change in frequency of a mechanical wave coming from a moving object as it approaches and moves away (i.e., Doppler effect).	17.14 Doppler effect: moving sound source 17.15 Sample problem: Doppler effect 17.16 Derivation: Doppler effect 17.17 Doppler effect: moving listener or source 17.18 Sample problem: Doppler, moving listener and source 17.19 Interactive checkpoint: Doppler effect 17.20 Interactive problem: bat on the hunt	17.12 Doppler effect: moving sound source 17.13 Sample problem: Doppler effect 17.14 Doppler effect: moving listener or source 17.15 Sample problem: Doppler, moving listener and source 17.16 Interactive checkpoint: Doppler effect 17.17 Interactive problem: bat on the hunt	16.7 Doppler effect: moving sound source 16.8 Sample problem: Doppler effect	
f. Explain the transfer of energy through a medium by mechanical waves.	16.19 Energy of a wave in a string			
Objective 2: Describe the nature of electromagnetic radiation and visible light.				
a. Describe the relationship of energy to wavelength or frequency for electromagnetic radiation.	42.6 Photoelectric effect	41.6 Photoelectric effect	36.5 Photoelectric effect	
b. Distinguish between the different parts of the electromagnetic spectrum (e.g., radio waves and x-rays or visible light and microwaves).	35.1 The electromagnetic spectrum	34.1 The electromagnetic spectrum	30.1 The electromagnetic spectrum	
c. Explain that the different parts of the electromagnetic spectrum all travel through empty space and at the same speed.	35.1 The electromagnetic spectrum 35.2 Electromagnetic waves	34.1 The electromagnetic spectrum 34.2 Electromagnetic waves	30.1 The electromagnetic spectrum 30.2 Electromagnetic waves	
d. Explain the observed change in frequency of an electromagnetic wave coming from a moving object as it approaches and moves away (i.e., Doppler effect, red/blue shift).	41.19 Doppler shift for light	40.14 Doppler shift for light	35.10 Doppler shift for light	
e. Provide examples of the use of electromagnetic radiation in everyday life (e.g., communications, lasers, microwaves, cellular phones, satellite dishes, visible light).	35.1 The electromagnetic spectrum (radios; cellular phones and microwave ovens; visible light; medical x-ray; gamma-knife surgery) 37.13 Sample problem: fiber optic cable 40.3 Physics at work: computer chips (photolithography) 40.17 Physics at play: CDs and DVDs 40.22 Physics at work: x-ray diffraction (used to analyze molecular structure)	34.1 The electromagnetic spectrum (radios; cellular phones and microwave ovens; visible light; medical x-ray; gamma-knife surgery) 36.12 Sample problem: fiber optic cable 39.3 Physics at work: computer chips (photolithography) 39.14 Physics at play: CDs and DVDs 39.16 Physics at work: x-ray diffraction (used to analyze molecular structure)	30.1 The electromagnetic spectrum (radios; cellular phones and microwave ovens; visible light; medical x-ray; gamma-knife surgery) 34.10 Physics at play: CDs and DVDs	Helicopters vs Submarines (lasers)