The Fundamentals of

PHYSICS

Volume II

Using Models

Checkpoint Answers

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1. Mass and the Gravitational Force

Check Point 1.1: Only (a) represents the type of conceptual model we'll be examining as it reflects the essential characteristics of the phenomenon, helping us understand what is going on and make predictions about the phenomenon.

Check Point 1.2: (a) magnetic force, (b) gravitational force

Check Point 1.3: The second phrase seems to imply that the force "belongs" to the rock rather than being a consequence of the rock's interaction with another object.

Check Point 1.4: 1 N west

Check Point 1.5: Equal in magnitude.

Check Point 1.6: 0.240 kg (or 240 grams)

$$F_{\mathrm{g}} = G\frac{m_1 m_2}{r^2} \tag{1.1}$$

Check Point 1.7: No, it would not be equal to 6.67408×10^{-11} N because the distance unit (ft) is not an SI unit (m). To get the force in SI units, the distance would first have to be converted to meters. If the distance was one meter rather than one foot then the gravitational force on each (due to the other) would be 6.67408×10^{-11} N.

Check Point 1.8: Yes, because although it is getting closer to the center of Earth, and so r is changing, it is changing by an amount that is very small compared to the value of r (which is the distance to the center of Earth).

$$F_{\mathrm{g}} = mg \tag{1.2}$$

Check Point 1.9: (a) Yes, when near or on the surface of Earth (and g is indicating Earth's gravitational field strength).
(b) No, it is equal to 6.67408×10^{-11}. Always.

Check Point 1.10: Yes, since the gravitational force on the ball due to me is so much smaller than the gravitational force on the ball due to Earth.

$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m} \tag{1.3}$$

Check Point 1.11: Because the electron's mass is so much smaller than the ball's.

$$\vec{a}_{\text{avg}} = \frac{\Delta \vec{v}}{\Delta t} \tag{1.4}$$

Check Point 1.12: No, the forces are not the same. The gravitational force is proportional to the object's mass, and so the gravitational force is greater on the more massive iron ball. The iron ball, being more massive, requires a greater force imbalance to accelerate the same as the wood ball.

Check Point 1.13: (a) and (c); the net force isn't zero if the object's speed or direction is changing.

2. Charge and the Electric Force

Check Point 2.1: Rub one balloon with the cloth and then another balloon with the cloth. The two balloons should repel.

Check Point 2.2: (a) The net force is neither toward or away from the negative particle. The net force is upward in this situation. (b) Yes, clockwise, which will shift it into an orientation where it will attract.

Check Point 2.3: The water molecules are dipoles, and for the distance they are separated, there can be a significant difference in the magnitude of the force on each end of the dipole, leading to a net attraction (or repulsion temporarily if oriented in a particular way).

Check Point 2.4: (a) the same amount, (b) yes, because the electrons have one-thousandth the mass of the protons

$$|\vec{F}_{\mathrm{e}}| = k\frac{q_1 q_2}{r^2} \tag{2.1}$$

Check Point 2.5: (a) charge, (b) electric force

Check Point 2.6: (a) -3.2×10^8 C (multiply one tenth of 2×10^{28} by the charge on an individual electron), (b) -2.9×10^9 C (same as for (a) but with nine-tenths of 2×10^{28} electrons), (c) There is a greater in (b) since you are removing a greater amount of positive charge, leaving a greater amount of negative charge.

Check Point 2.7: Disagree for both. Since the protons carry positive charge and the neutrons are neutral, the electric force should be repulsive, not attractive. The gravitational force is too weak compared to the electric force to keep the protons together.

3. Nucleons and the Nuclear Force

Check Point 3.1: The nuclear force of attraction between the protons and the other nucleons in the nucleus.

Check Point 3.2: Neutrons are needed as extra "glue" to hold the protons together. Without enough neutrons, the nucleus can fall apart. On the other hand, neutrons are unstable by themselves so if you have too many the neutrons can decay.

Check Point 3.3: Since they are both carbon, they both have same number of protons (six). That means that carbon-12 has six neutrons and carbon-14 has eight.

Check Point 3.4: No. Neutrons are unstable unless they are with protons.

Check Point 3.5: No. During beta minus decay, a neutron in the nucleus decays into a proton and an electron. Since the proton stays in the nucleus, the number of protons changes, and that changes the element.

Check Point 3.6: Since it has too few neutrons (too many protons), it should decay via beta-plus decay, where a proton decays into a neutron and a positron.

Check Point 3.7: No. During alpha decay, the nucleus loses two neutrons and two protons. The loss of protons means that the element has changed.

Check Point 3.8: 2 hours

Check Point 3.9: Because it doesn't get far though the air before it is stopped by the air. [It is interesting to note that the damage to us is minimal even if swallowed since the material used in a smoke detector is not soluble (not absorbed by us) and passes through our system (Americium-241 has a half-life of 432 years). It would be more dangerous in soluble form.]

4. Magnets and the Magnetic Force

Check Point 4.1: No. Magnets are neutral. The reason why magnets attract is not due to any excess charge,

Check Point 4.2: Attract.

Check Point 4.3: No. All pieces of the magnet have both a north and a south pole, no matter how small.

Check Point 4.4: No. The magnets would then repel, since the like poles are facing each other.

Check Point 4.5: It will once again be attracted, as the south pole of the magnet will align the tiny magnets inside the ferromagnet in the opposite way as the north pole did.

Check Point 4.6: The Earth is so huge that the force on each end of a magnet is the same. Smaller magnets exert a greater force on the closer end.

Check Point 4.7: Because the north poles of magnets are attracted to it. Since opposite poles attract, that must mean there is a magnetic south pole at Earth's geographic North pole.

5. Describing Fields

Check Point 5.1: No. Earth's gravitational field acts on *other* objects, like us (or a rock), pulling us (and the rock) toward it. Earth's gravitational field doesn't act on itself.

Check Point 5.2: (a) Toward planet A, (b) toward planet B, (c) toward planet A, (d) toward planet B, (e) the total gravitational field is zero there

Check Point 5.3: The positive object would be forced toward the right, in the same direction as the electric field that was present at that location. A negative object would be forced toward the left.

Check Point 5.4: (a) Away from particle A, (b) toward particle B, (c) away from particle A/toward particle B, (d) away from particle A/toward particle B, (e) away from particle A/toward particle B

Check Point 5.5: The dipoles would rotate clockwise instead of counter-clockwise, again aligning with the electric field but with the positive side of the dipole on the right and the negative side of the dipole on the left. If the electric field was non-uniform, the dipole would then be forced toward wherever the field was stronger.

Check Point 5.6: (a) toward magnet 2, (b) opposite the direction of magnet 2's magnetic field at location A, (c) magnet 1's field does not act on itself.

6. Quantifying Fields

Check Point 6.1: You would divide the gravitational force by the mass of the ball. We want to know Earth's gravitational field. The force is associated with both objects (ball and Earth). By dividing by the ball's mass, we remove the dependence on the ball.

Check Point 6.2: Zero. We find the electric field at a location by measuring the electric force on an object at that location (in this case that would be zero) and dividing by the charge of that object.

Check Point 6.3: The dielectric strength of air is 3×10^6 N/C. So, if the electric field was greater than that, the air would break down and create a spark.

Check Point 6.4: Tesla.

Check Point 6.5: The stronger magnet has a greater magnetic moment.

7. Conservation of Energy

Check Point 7.1: Increase, since conservation of energy states that the total amount of energy must remain the same.

Check Point 7.2: No. Potential energy is associated with the potential for attraction or repulsion and thus requires a system of two or more interacting objects, not a single object.

Check Point 7.3: (a) Decrease, (b) Increase, (c) Yes, since the total energy remains the same as energy is transferred from elastic to kinetic

Check Point 7.4: (a) When the comet is moving away from the sun, (b) When the comet is moving toward the sun.

Check Point 7.5: (a) The electric energy decreases, (b) the electric energy increases

Check Point 7.6: (a) Decrease, much like with the dropped rock, (b) no change, as the person started and stopped at rest, (c) energy is always conserved, so the loss in gravitational energy must be accompanied by a gain of *some* type of energy. In this case, it is likely the elastic energy of the bungee cord and the thermal energy of the air and bungee cord.

Check Point 7.7: (a) Transferred from the jumper/Earth system (to the environment), (b) Released to the surrounding environment

$$E_k = \tfrac{1}{2}mv^2 \tag{7.1}$$

Check Point 7.8: If we replace N by kg·m/s^2 then N·m is equivalent to (kg·m/s^2)·m. Since m·m is m^2, this is equivalent to kg·m^2/s^2, which is a joule.

$$P = \frac{\Delta E}{\Delta t} \tag{7.2}$$

Check Point 7.9: 2.16×10^6 J

Check Point 7.10: The incandescent bulb generates more thermal energy for the same amount of light energy as the LED bulb.

Check Point 7.11: 0.6 kWh, 12 cents

8. Chemical Reactions

$$\Delta E = F_{\text{avg}} \Delta s \tag{8.1}$$

Check Point 8.1: To separate the electron, we take the electron to a location so far away from the atom that there is no longer an electric attraction between the now-positive atom and the negative electron. We won't be using an equation to figure out the amount of energy needed to do this because the electric force changes as the electron is moved away from the rest of the atom.

Check Point 8.2: (b) absorbed, as energy is needed from the environment, which leads to an increase in the system's electric energy.

Check Point 8.3: Situation (a), because the bond dissociation energy refers to the amount of energy need to separate the two objects.

Check Point 8.4: (a) 167 kJ, (b) 942 kJ, (c) The value for a mole of N≡N bonds is greater because the N≡N bond is so much stronger (and thus requires more energy to break it).

Check Point 8.5: To determine whether energy is released or absorbed, we need to consider all of the bonds, not just the O=O and H–O bonds. On average, the bond dissociation energy for the bonds in the reactants (which includes the C–H bonds) is smaller than for the bonds in the products (which includes the C=O bonds).

Check Point 8.6: The products. Since energy is released, that means more energy is released during the formation of the bonds in the products that is required to break the bonds in the reactants. That means the bonds in the products must be stronger than those in the reactants. This is consistent with the electric energy decreasing since the electric energy decreases as attracting, opposite-charged objects come together.

9. Nuclear Reactions

Check Point 9.1: The products. Since energy is released, it must take less energy to break apart the reactants than is released when the product is formed.

Check Point 9.2: It is equal to a large number of electron-volts, since one electron-volt is only a tiny fraction of a joule.

Check Point 9.3: (a) Helium, (b) zero, since the proton is already by itself, so no energy is needed to separate it from other nucleons.

Check Point 9.4: 1802 MeV (multiply the binding energy per nucleon, 7.57 MeV/nucleon, by the number of nucleons, 238)

Check Point 9.5: It is easier to extract a proton from a uranium nucleus. The graph of binding energies indicates that the binding energy for Uranium is lower, which means it takes less energy, on average, to extract a nucleon from the uranium nucleus.

Check Point 9.6: The fusion reaction releases about two million times more per mole that was is released during the combustion of methane.

Check Point 9.7: This is because the products (Ba-141 and Kr-92) have nuclear bonds that are so much stronger than the original U-238 nucleus (8.33 MeV/nucleon and 8.51 MeV/nucleon compared to 7.57 MeV/nucleon).

10. The Flow of Charge

Check Point 10.1: Air is an insulator while metals are conductors.

Check Point 10.2: The charge transfer would result in both becoming neutral.

Check Point 10.3: So that charge doesn't build up on the container and flow through us when we touch it.

Check Point 10.4: (a) Bring a positively-charged object toward it while it is grounded, (b) Part [b]

Check Point 10.5: That any excess charge will be on the surface itself, not distributed uniformly within the conductor.

Check Point 10.6: The charge would also be distributed around the surface but more concentrated at the points.

Check Point 10.7: An insulator. Although charge, once present, can flow easily throughout the space, it first has to be extracted from another material, and that is very hard. Thus, the vacuum acts like an insulating wall around a conductor.

Check Point 10.8: Yes. Although the chairs themselves don't physically leave, the empty chairs are being replaced by "neutral" combinations of students and chairs. So, in effect, the empty chairs have left as the students enter.

Check Point 10.9: (a) Zero, (b) Zero, (c) No

11. Electric Current

Check Point 11.1: Yes. The battery is neutral and remains neutral because it provides an electron to the circuit for every electron that it takes from the circuit. The terminals of the battery might have a slight positive or negative charge, but it is not noticeable.

Check Point 11.2: The electrons pass through the filament and come out the other end.

Check Point 11.3: 5000 s

$$I_{\text{average}} = \frac{\Delta q}{\Delta t} \tag{11.1}$$

Check Point 11.4: (a) 1.5 C, (b) 9.38×10^{18}

Check Point 11.5: (a) ii, (b) i

Check Point 11.6: No, the current is the same. Just because the wire doesn't glow doesn't mean there is less current flowing through it. It just means there are less collisions between the moving electrons and the material that makes up the wire.

Check Point 11.7: No. All we know from the circuit schematic is which elements are connected. They do not illustrate the lengths of the wires connecting the elements.

Check Point 11.8: (a) No, the current has to be the same through each light bulb as whatever charge comes out of the first bulb must go through the second (current rule).
(b) Yes, the current can be different because more charge will go through the bulb that is easier for the electrons to flow through.

Check Point 11.9: The circuit on the right (circuit b). The ammeter measures the current through the meter. So, the question is really "in which circuit is the current through the meter the same as that through the light bulb?"

12. Electromagnets

Check Point 12.1: (a) Yes, otherwise the current wouldn't follow a looping pattern. (b) Yes, every part of the electromagnet is neutral.

Check Point 12.2: The electromagnet aligns the little magnets inside the ferromagnetic core, creating an additional magnet that adds to the strength of the electromagnet.

Check Point 12.3: (a) counter-clockwise, (b) right side.

Check Point 12.4: Toward the right

Check Point 12.5: Because the electromagnet's magnetic field is of equal strength at the location of each end of the permanent magnet. Consequently, the magnitude of the force is the same on each end (same magnetic field at each end) but of opposite direction (since they have opposite poles).

Check Point 12.6: Toward the west

Check Point 12.7: Yes. Neither, it points "around" it.

13. Fluids

Check Point 13.1: Instead of pressing the brake pads against the wheel, the air inside the tube is being compressed.

$$\rho = \frac{m}{V} \tag{13.1}$$

Check Point 13.2: If the water really is incompressible then its volume remains the same and so its density also remains the same. In reality, the volume decreases a tiny little bit and so the density increases a tiny little bit, but for our purposes we will consider the density as remaining the same.

$$P = \frac{F}{A} \tag{13.2}$$

Check Point 13.3: The pressure is the same throughout the water and the value increases as you press on the syringe plunger.

Check Point 13.4: At the start. A difference in water pressure is needed to get the water to flow out of the pipes (due to resistance within the pipes).

$$A_{\text{left}} v_{\text{left}} = A_{\text{right}} v_{\text{right}} \tag{13.3}$$

Check Point 13.5: According to the equation of continuity, $\pi(0.75\ \text{cm})^2(0.85\ \text{m/s}) = \pi R^2(1.6\ \text{m/s})$. Solve for R to get 0.55 cm.

14. Voltage

Check Point 14.1: When 5 A of current flows through it.

Check Point 14.2: If the bulbs are identical then they should have identical brightness, as the current is the same through all of them. If the bulbs are not identical, the current is still the same through all of them but the brightness will depend on their resistance.

Check Point 14.3: The current splits such that half goes through bulb B and half goes through bulb C (since they are identical). That means twice as much current flows through bulb A as through either bulb B or bulb C. Consequently, Bulb A is brightest. The current through bulb A would be greater even if the bulbs were not identical but it may not be brightest because that would depend on its resistance. For example, if bulb A had zero resistance, like the wires, it wouldn't get hot at all, regardless of the current, and so it wouldn't light up at all, even though more current flows through it than through either bulb B or bulb C.

Check Point 14.4: The voltage does not depend on what is connected to the battery (except for the situation we'll examine in chapter 15) but the current does.

Check Point 14.5: 1.5 V

Check Point 14.6: (a) Yes, the electric potential is greater before the bulb. (b) No, the current entering the bulb is the same as the current exiting it. (c) No, the current entering the battery is the same as the current exiting it.

Check Point 14.7: The voltage across the first wire is zero. The wire has very little resistance so the electric potential is the same on both sides (indicated as H's in the figure). The voltage across the top bulb has to be less than 1.5 V since the electric potential goes from H to mH, not from H to L.

Check Point 14.8: 3 V (one third of the 9 V). If the bulbs were not identical, we'd need to know the resistance. This is discussed in chapter 15.

Check Point 14.9: No. As additional paths are added, the total current increases, since the current through each bulb remains the same as before. The voltage across the battery remains the same regardless of the number of paths or the number of bulbs.

$$V = \frac{E}{q} \tag{14.1}$$

Check Point 14.10: The voltage is the change in electric energy divided by the charge. In this case, at the initial position (negative terminal of battery), the electron's electric energy was 1 eV greater than when it ended. Thus, the voltage is $(+1.6 \times 10^{-19}$ J) divided by $(-1.6 \times 10^{-19}$ C), which equals -1 V. This is why an eV (electron volt) is called that – it is the energy gained by an electron when it undergoes a voltage of 1 V.

$$P = IV \tag{14.2}$$

Check Point 14.11: (a) 1.25 A (divide 150 W by 120 V) and (b) 10 A (divide 1200 W by 120 V). Both are greater than that drawn by a 60-W bulb.

Check Point 14.12: (a) 5V, (b) 1V

Check Point 14.13: 1.5 V

15. Resistance

$$R_{\text{of element}} = \frac{V_{\text{across element}}}{I_{\text{through element}}} \tag{15.1}$$

Check Point 15.1: 1200 Ω (divide the voltage by the current and remember to convert the current to amps). In comparison, the resistance of a human body is around 1000 Ω when wet (and as high as 100,000 Ω when dry). For this reason, so we need to be more careful around electricity when we are wet. [Resistance values from the National Institute for Occupational Safety and Health]

Check Point 15.2: The voltage across the bulb, because the voltage and resistance need to correspond to the same element.

Check Point 15.3: (a) Yes, (b) No, the voltage would be greatest across the 3-Ω object.

Check Point 15.4: Multiply the resistance and current to get 1.2 V.

$$P = I^2 R \tag{15.2}$$

Check Point 15.5: (a) The voltage across bulb A because the brighter bulb dissipates energy at a greater rate (i.e., P is greater) and since $P = IV$, if P is greater and I is the same, that means V must be greater. (b) The resistance of bulb A because the brighter bulb dissipates energy at a greater rate (i.e., P is greater) and since $P = I^2R$, if P is greater and I is the same, that means R must be greater.

Check Point 15.6: 1.25 A. We know the voltage across each resistor must be 1.5 V. Using $V = IR$, we get the current through each resistor (0.75 A and 0.5 A), which we add together to get the total current.

Check Point 15.7: 0.5 V across the 1-Ω resistor and 1.0 V across the 2-Ω resistor. We know that the 1.5 V is split among the two resistors (based on how voltage works), with twice as much across the 2-Ω resistor (using

$V = IR$ with twice the resistance but the same current, based on what we know about current).

Check Point 15.8: (a) The 2.4-Ω resistor, (b) none of them

Check Point 15.9: (a) The top bulb is off, because the voltage across has gone to zero since the ammeter has very little resistance. (b) The bottom bulb.

Check Point 15.10: Without the extra wire, the current would be 2.49 A (easiest to calculate the total resistance first, 6.02 Ω, and then use $I = V/R$ with $V = 1.5$ V and $R = 6.02$ Ω to get the current). With the extra wire, the current would be 50 A (using $I = V/R$ with a total wire resistance of 0.03 Ω).

Check Point 15.11: Equal to 1.60 V

Check Point 15.12: 1.2 V (a drop of 0.4 V; twice as much as before)

16. Describing AC Circuits

Check Point 16.1: 1000 Hz

Check Point 16.2: 10 V

Check Point 16.3: It remains the same at 1 V. The amplitude is not affected by the frequency.

$$P_{\text{avg}} = \frac{I_{\text{max}} V_{\text{max}}}{2} \tag{16.1}$$

Check Point 16.4: Even though the light appears steady, the current is still oscillating. The average rate at which energy is being converted will be less than what it would be if the voltage and current remained steady at their maximum values.

$$P_{\text{avg}} = I_{\text{rms}} V_{\text{rms}} \tag{16.2}$$

Check Point 16.5: (a) 170 V, (b) maximum value, which makes sense because the RMS value represents a "mean" value, so the RMS should be less than the maximum value.

$$V_{\text{max}} = I_{\text{max}} R \tag{16.3}$$

$$V_{\text{rms}} = I_{\text{rms}} R \tag{16.4}$$

Check Point 16.6: (a) The RMS voltage, (b) 0.04 V

17. Impedance

Check Point 17.1: (b)

Check Point 17.2: (a)

Check Point 17.3: (a) Because charge can accumulate for a short time on each plate of the capacitor. During that time, it appears as though current is flowing through the capacitor when, in fact, it is not.
(b) Yes, just as much positive charge is placed on one plate as is removed from the other plate.

Check Point 17.4: Magnetic energy.

Check Point 17.5: Neither one, the impedance in both cases would be 100 Ω, as the impedance is the same as the resistance (at least for the resistor).

Check Point 17.6: The capacitor's impedance will be less than 100 Ω in situation (b) and greater than 100 Ω in situation (a). The inductor's impedance would be less than 100 Ω in situation (a) and greater than 100 Ω in situation (b).

$$Z = \frac{V}{I} \tag{17.1}$$

$$V = IZ \tag{17.2}$$

Check Point 17.7: 3 Ω

Check Point 17.8: (a) 3 Ω, (b) 1.5 Ω, (c) 10 A, (d) infinity, (e) zero

Check Point 17.9: It should decrease. If inductance increases, the impedance will increase also.

Check Point 17.10: 8 A. With a greater capacitance, more charge can accumulate before the capacitor gets "filled." One can also use equation 17.1, which shows that the impedance is inversely proportional to the capacitance.

That means the impedance will be less with the larger capacitor, allowing for more current to flow.

Check Point 17.11: 6 μF

Check Point 17.12: Because it increases the strength of the magnet and, as such, more electric energy is converted to/from magnetic energy.

Check Point 17.13: The inductor is along the same path as the bulb. When the bar is placed in the inductor, the impedance increases, decreasing the current through the inductor. Since the inductor is along the same path as the bulb, that also decreases the current through the bulb.

18. Magnetic Induction

Check Point 18.1: No current is induced when the magnet remains stationary, as in part (c).

Check Point 18.2: Method (2) doesn't change the magnetic field inside the solenoid, so that doesn't induce any current to flow. Method (1) changes the magnetic field, but it changes too slowly. Method (3) changes the magnetic field quickly (1000 times every second) and keeps doing it, creating an oscillating current in the solenoid that lights the bulb.

Check Point 18.3: (a) yes, (b) yes, (c) no, (d) no

Check Point 18.4: (a) no, (b) no, (c) yes

Check Point 18.5: Yes. The force is still leftward (braking).

Check Point 18.6: The generation of current would be the same but in the opposite direction.

Check Point 18.7: Yes, clockwise.

19. Sound

Check Point 19.1: 1/300 of a second (i.e., 0.0033 seconds).

Check Point 19.2: The sound represented by (c) would be the highest pitch because its period is shortest (frequency is highest). It would be just as loud as the sound represented in (a) and (d) since they all have the same amplitude.

Check Point 19.3: 10^{-7} W/m^2, 5 bels, 50 decibels

Check Point 19.4: No. Even if the intensity was the same, the 2000 Hz tone would appear louder since our ear is more sensitive to 2000 Hz.

Check Point 19.5: B

Check Point 19.6: None are waves because there needs to be an oscillation in time that leads to movement of pulses.

Check Point 19.7: (a) parallel, (b) both, (c) perpendicular

Check Point 19.8: 3.5%

Check Point 19.9: 2 m

Check Point 19.10: 0.75 m

$$v = f\lambda \tag{19.1}$$

Check Point 19.11: 0.5 m

20. Doppler Effect

Check Point 20.1: It remains the same while the car approaches, but it is higher than what it would be when the car is moving away.

Check Point 20.2: (a) The car's horn, moving, (b) you, stationary

Check Point 20.3: (a) higher than 1000 Hz, (b) lower than 1000 Hz

Check Point 20.4: (a) higher than 1000 Hz, (b) lower than 1000 Hz

Check Point 20.5: Yes. The difference is small for slow speeds but can be very different when the speed is greater (like at the speed of sound).

21. Interference

Check Point 21.1: In both cases the two pulses are superimposed on the same location but in one case there is a ridge and trough whereas in the other case we have two ridges.

Check Point 21.2: Greater than A but less than 2A

Check Point 21.3: $|A - B|$ (i.e., the absolute value of the difference)

$$f_{\text{beat}} = |f_2 - f_1| \tag{21.1}$$

$$f_{\text{average}} = \frac{f_1 + f_2}{2} \tag{21.2}$$

Check Point 21.4: (a) 435 Hz or 445 Hz, (b) 445 Hz

Check Point 21.5: The second speaker would need to be placed 0.25 m behind the first speaker. One could also place it 0.75 m, 1.25 m, and so on, but the amplitudes would differ more (where the observer happens to be) in those cases and so the destruction won't be as complete.

$$\Delta\ell = (\text{whole number}) \times \lambda \qquad [\text{constructive}] \tag{21.3}$$

Check Point 21.6: (a) 2.5, (b) 3.5, (c) 1 wavelength, (d) yes

$$\Delta\ell = (\text{half integer}) \times \lambda \qquad [\text{destructive}] \tag{21.4}$$

Check Point 21.7: (a) constructive, (b) destructive, (c) destructive, (d) constructive

22. Standing Waves

Check Point 22.1: Two

Check Point 22.2: 36 cm (the wavelength of the two traveling waves is the same as the wavelength of the resulting standing wave)

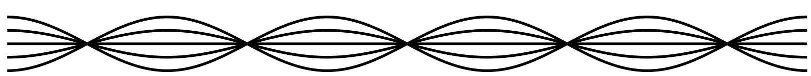
Check Point 22.3: 580.8 m/s (remember that the wavelength is twice the string length, then use $v = f\lambda$ to solve for f, keeping track of your units).

Check Point 22.4: 453.75 Hz (higher)

Check Point 22.5: 259.7 Hz (remember that the wavelength is twice the tube length, then use $v = f\lambda$ to solve for f, keeping track of your units). This is roughly equal to the frequency of a real flute (with no holes) though not exactly because a real flute is not identical to an open pipe.

Check Point 22.6: 129.9 Hz (remember that the wavelength is four times the tube length, then use $v = f\lambda$ to solve for f, keeping track of your units). This is roughly equal to the frequency of a real clarinet (with no holes) though not exactly because a real clarinet is not identical to an closed pipe.

Check Point 22.7: The wavelength is 66 cm (two onions), the wave speed is 580.8 m/s (the same as with the first normal mode), and the frequency is 880 Hz (twice as much as the first normal mode frequency)

Check Point 22.8: 

Check Point 22.9: 36 cm (there are three and half onions, or seven half onions total; divide 63 cm by 7 to get the size of each half onion; multiply by four to get the wavelength)

Check Point 22.10: The natural frequency of 2 Hz corresponds to a normal mode with one onion, since that is the first normal mode. A frequency of 1 Hz (half the frequency as before) would correspond with a normal mode with half of an onion (twice the wavelength as before), which is not possible for the given boundaries (fixed at both ends). Consequently, the rope won't respond. However, a frequency of 4 Hz (twice the frequency as before) would correspond with a normal mode with two onions (half the wavelength as before), which corresponds to the second normal mode (fixed at both ends). Consequently, the rope does respond with 4 Hz.

23. Light as a Wave

Check Point 23.1: (a) No, (b) yes

Check Point 23.2: (a) true, (b) true, (c) true

Check Point 23.3: (a) light, (b) both travel at the same speed in a vacuum

Check Point 23.4: ethyl alcohol

Check Point 23.5: (a) We can see the sun and stars, and the light from the sun and stars had to travel through the vacuum of space, (b) we can see light through a window.

Check Point 23.6: 6.8×10^{14} Hz

Check Point 23.7: 435 nm (87% of 500 nm)

Check Point 23.8: Toward shorter wavelengths because, like other waves, the observed frequency will be higher if the source and observer are moving toward each other. And, as with all waves, the wavelength is shorter when the frequency is higher (for same wave speed).

Check Point 23.9: Small differences in the lasers produce slightly different frequencies. Such small differences will be large compared to the period of the light (with red light, the period of the light wave is only 2×10^{-15} s). These small differences thus produce very high-frequency beating, preventing one from seeing a steady interference pattern.

Check Point 23.10: It is not possible to tell without knowing the orientation of the two filters. If the second polarizing filter has the same orientation as the first, no additional absorption will occur. If the second polarizing filter is oriented perpendicular to the first then all of the light is absorbed.

24. Bending of Light

Check Point 24.1: (a)

Check Point 24.2: Diffuse reflection

$$\theta_\mathrm{i} = \theta_\mathrm{r} \tag{24.1}$$

Check Point 24.3: (a) 1 meter, (b) 75 cm

Check Point 24.4: When the direction of a wave bends as it crosses the boundary between two materials (in which it travels at different speeds).

Check Point 24.5: The marcher in the faster material is traveling further, which is consistent with way the marchers turning during that time period, since the inside marcher has to travel a shorter distance (smaller radius of the circular path).

Check Point 24.6: Yes

Check Point 24.7: No. Total internal reflection can only occur when going from slower material to a faster material.

Check Point 24.8: No

Check Point 24.9: It is not possible in either case. For the illustrations shown (with the surface oriented up/down), the ray always encounters the boundary from the lower left and leaves the boundary toward the upper right.

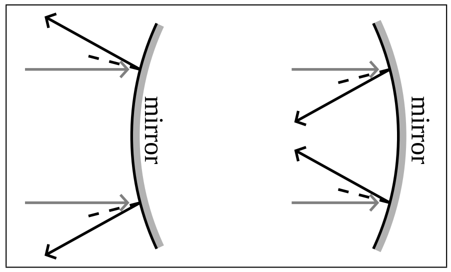
$$n_\mathrm{material} = \frac{c}{v_\mathrm{material}} \tag{24.2}$$

Check Point 24.10: Water; the greater the index of refraction the *slower* the speed of light in that material.

Check Point 24.11: It will bend more upon entering diamond, because the index of refraction for diamond (for 700 nm light) is greater than that for water.

25. Lenses and Mirrors

Check Point 25.1: The solution to each case is illustrated to the right.



Check Point 25.2: Converging

Check Point 25.3: The left three (double concave, plano-concave and concave meniscus). Those are thinner in the center than the edges.

Check Point 25.4: With a converging lens, the rays from a close source may still diverge after passing through the lens, but just less so than what they were prior to entering the lens. With a diverging lens, the rays from all sources will still diverge after passing through the lens.

Check Point 25.5: No, unless the source is really far away.

Check Point 25.6: 5 diopters

Check Point 25.7: Converging

Check Point 25.8: Because ray 1 passes through the center of the lens and at the center of the lens the two sides of the lens are essentially parallel.

Check Point 25.9: No, even though the mirror is a converging mirror, the rays continue to diverge after reflecting off the mirror because the source of the rays is too close to the mirror.

Check Point 25.10: (c) Parallel

26. Objects and Images

$$m = \frac{h_\text{i}}{h_\text{o}} \tag{26.1}$$

Check Point 26.1: (a) the image, (b) inverted

Check Point 26.2: No. You'd have to be to the left of the mirror, at [o], looking toward the right so you can see the rays being reflected back toward you, since it is from those rays that we see the image.

Check Point 26.3: No. You'd have to be to the left of the mirror, at [o], looking toward the right so you can see the rays being reflected back toward you, since it is from those rays that we see the image.

Check Point 26.4: You'd have to be to the left of the mirror, at [o], looking toward the right so you can see the rays being reflected back toward you, since it is from those rays that we see the image.

Check Point 26.5: The image would still be located where the screen used to be.

$$\frac{h_\text{i}}{h_\text{o}} = -\frac{d_\text{i}}{d_\text{o}} \tag{26.2}$$

Check Point 26.6: (a) Object distance is +20 cm and the image distance is −10 cm, (b) +0.5, (c) 2.5 cm

Check Point 26.7: The image is closer to you than the mountains and farther from you than the lens. Since the mountains are far away, light hitting the lens will be essentially parallel prior to hitting the lens. Since the lens is a diverging lens, the transmitted light will then be diverging, appearing to diverge from a point close to the lens (and on the same side of the lens as the mountains). From the point of view receiving those diverging rays, the object will appear to be between the lens and the mountains. That is the image.

Check Point 26.8: The first lens produces a real image and real images are inverted. That image is then projected backwards (farther away) by the second lens so that our eyes can focus on it.

Check Point 26.9: A near-sighted person

Check Point 26.10: The image would be on the opposite side of the mirror as the person, five feet from the mirror, and the image wold be 6 feet tall.