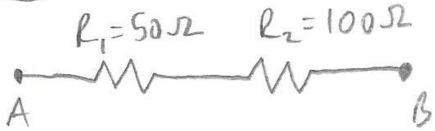
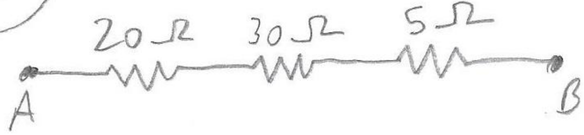
Find the equivalent resistance of each arrangement of resistors going from A to B

1.



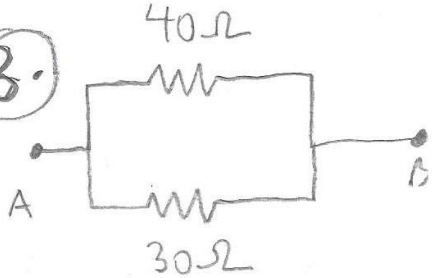
2.



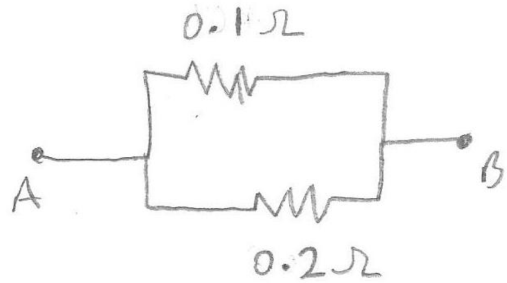
(answers...I think!)

1. $R_T = 150\ \Omega$
2. $R_T = 55\ \Omega$
3. $R_T = 17\ \Omega$
4. $R_T = 0.07\ \Omega$
5. $R_T = 65\ \Omega$
6. $R_T = 77\ \Omega$
7. $R_T = 31\ \mu\Omega$
8. $R_T = 1.5\ k\Omega$

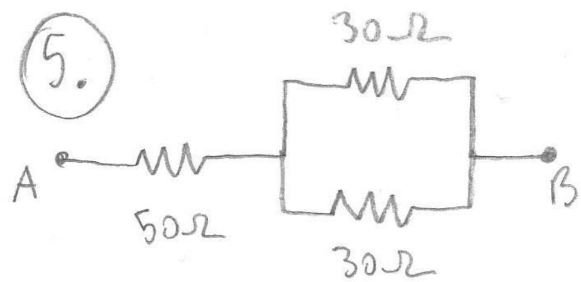
3.



4.



5.



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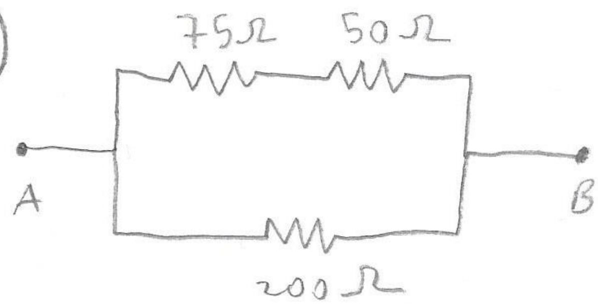

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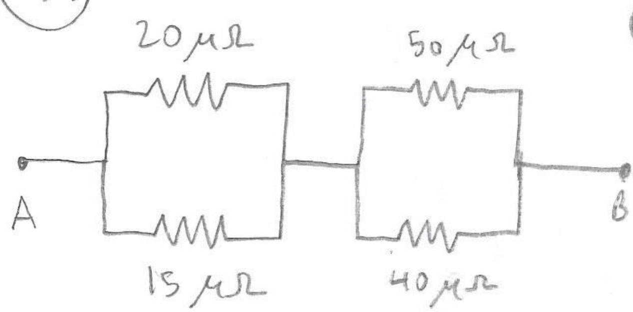
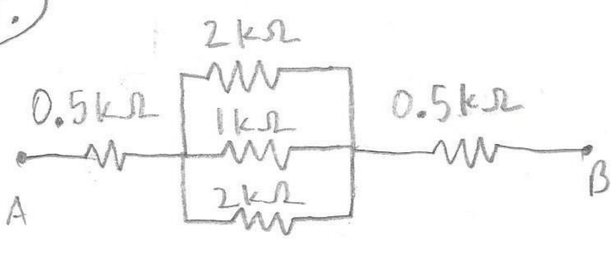


$\mu\Omega$ = microohm = $10^{-6}\ \Omega$

8.



Circuits Analysis

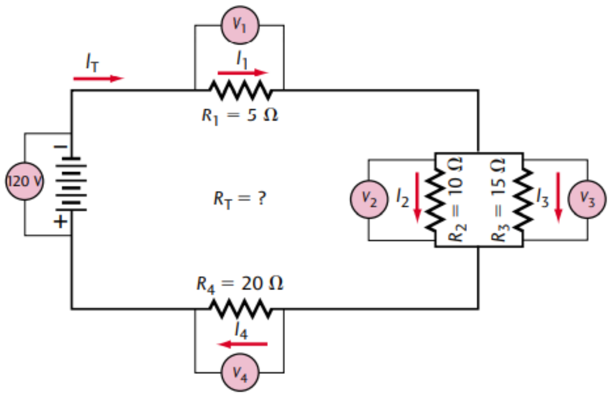
We don't always want to have to build circuits in order to predict current, voltage, etc, so we can apply some of our findings from the previous pages in circuit analysis. Some general strategies:

Here is a summary of some strategies that will be useful when analyzing circuits:

- **Identify quantities we know already**
- **Look for quantities we can easily obtain (ex. current in series remains constant)**
- **Replace resistances in series or parallel with their equivalent resistances**
- **Use V = IR when you know two out of the three**
- **You guessed it – persistence and determination!**

And some useful formulas…

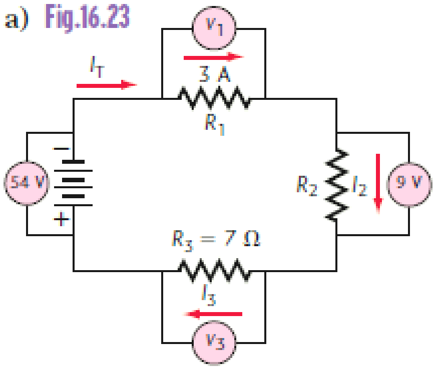
Series Circuits	**Parallel Circuits**	**Other**
$V_T = V_1 + V_2 + V_3$ $I_T = I_1 = I_2 = I_3$ $R_T = R_1 + R_2 + R_3 \ldots + R_N$	$I_T = I_1 + I_2 + I_3$ $V_T = V_1 = V_2 = V_3$ $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots + \frac{1}{R_N}$	$V = IR$



Name	V (V)	I (A)	R (Ω)
R_1			
R_2			
R_3			
R_4			
Total, R_0			

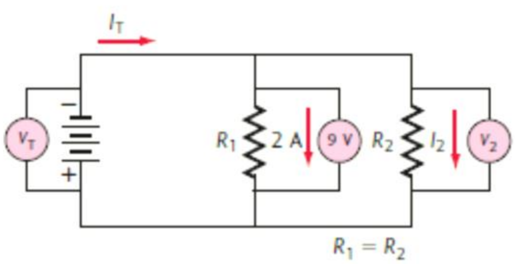
35. Determine all missing values. You might need to use other paper.

a) Fig.16.23



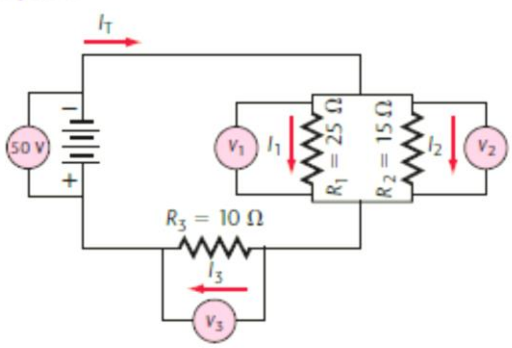
Name	V (V)	I (A)	R (Ω)
R_1			
R_2			
R_3			
Total, R_0			

b) Fig.16.24



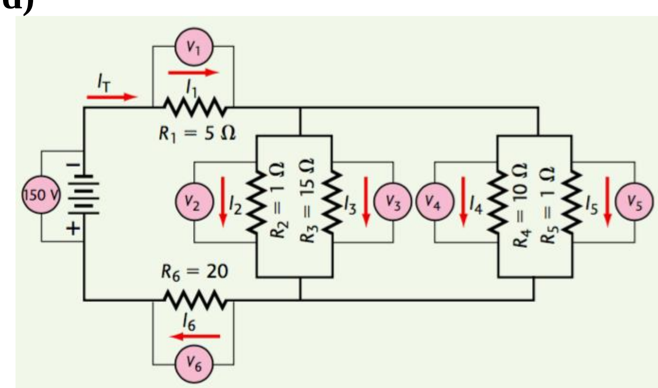
Name	V (V)	I (A)	R (Ω)
R_1			
R_2			
Total, R_0			

c) Fig.16.25



Name	V (V)	I (A)	R (Ω)
R_1			
R_2			
R_3			
Total, R_0			

d)



Name	V (V)	I (A)	R (Ω)
R_1			
R_2			
R_3			
R_4			
R_5			
R_6			
Total, R_0			

The following simulations will help us learn some basic concepts of electromagnetism…

A. Classifying materials
Visit www.explorelearning.com, then log in and find the Magnetism activity. Choose the magnetic forces tab. You have access to different types of objects: magnetic objects, ferromagnetic objects, non-magnetic objects.
Learning Goal: To learn about the magnetic interaction between any two objects.

B. Field Lines
Option 1: Remain in Magnetism activity of www.explorelearning.com, but choose the Magnetic Field Lines tab. Option 2: https://phet.colorado.edu/en/simulation/legacy/magnet-and-compass
Learning Goal: To learn about the characteristics of magnetic field lines created by magnets.

C. Earth's Magnetic Field
Visit the following simulation: https://phet.colorado.edu/en/simulation/legacy/magnet-and-compass. Click on "Show Planet Earth"
Learning Goal: To learn about the magnetic fields surrounding planet earth

D. Oersted's Principle
Option 1: www.explorelearning.com, then find the Magnetic Induction activity
Option 2: https://javalab.org/en/oersteds_experiment_en/
Learning Goal: To discover what Hans Christian Oersted discovered (by accident) in 1820

E: Faraday's Law of Induction
First visit https://phet.colorado.edu/en/simulation/legacy/faraday and select Electromagnet
Visit https://phet.colorado.edu/en/simulation/faradays-law
Learning Goal: To discover Faraday's Law of Induction

SO WHAT?
LET'S LOOK AT A FEW PRACTICAL APPLICATIONS

F: Step-up/Step-down Transformer
Visit https://javalab.org/en/electric_transformer_en/

G: Electromagnetic Generator
Visit https://phet.colorado.edu/sims/cheerpj/faraday/latest/faraday.html?simulation=generator

H: DC Motor
Visit https://javalab.org/en/dc_motor_en/

I: And just because it made me laugh…
Visit https://phet.colorado.edu/en/simulation/john-travoltage

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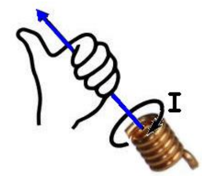
SPH 3U – Electricity & Magnetism Directions

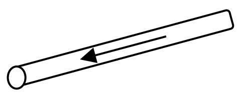
Note: The rules below assume we are looking at the direction of the flow of electrons (negative to positive). Many textbooks will use "conventional current" which is current flow from positive to negative, in which case the right hand rule is used. When electricity was discovered there was no way to know *what* was actually moving and in what direction, and Benjamin Franklin guessed wrong.

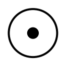
LHR (for straight conductors)
Using your left hand, point your thumb in the direction of the electron current and the fingers curl in the direction of the magnetic field.

LHR (for coiled conductors – solenoids)
Curve fingers of left hand point in the direction of electron current and the thumb points in the direction of the magnetic field inside the coil

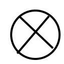


1) Draw the magnetic fields around the following objects. The arrows indicate the direction of electron current flow.

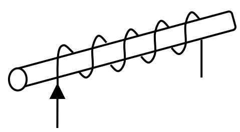




Out of the page

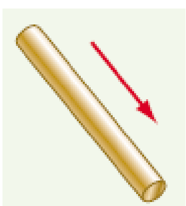
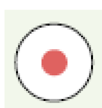
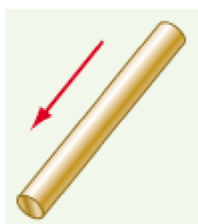
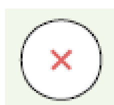
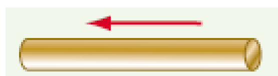


Into the page

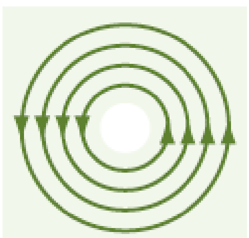
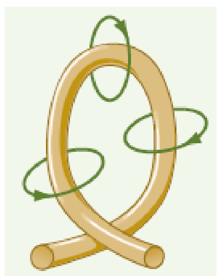


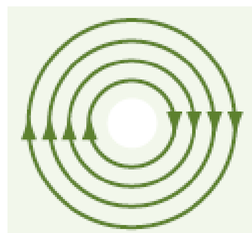
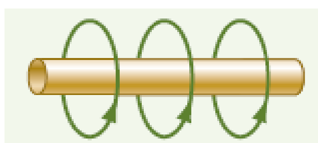
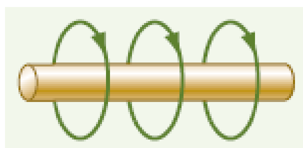
Magnetic fields in coiled conductors
- The magnetic field inside the solenoid is uniform (same strength and same direction)
- Magnetic field *B* can be adjusted depending on the current (double the current → double the magnetic field)
- Magnetic field can be adjusted depending on the number of turns (if you double the number of turns, you double the magnetic field)

1. For each current-carrying conductor, sketch a view of the magnetic field, based on the direction of the current shown (current represents electron flow)

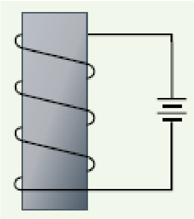
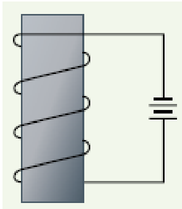
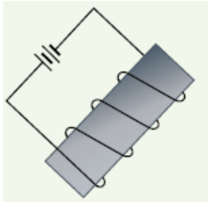
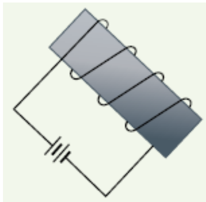
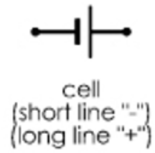






2. For each current-carrying conductor, show the direction of current (electron flow), based on the magnetic field shown.

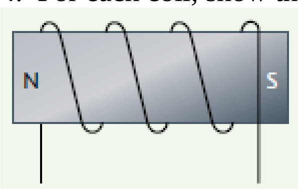



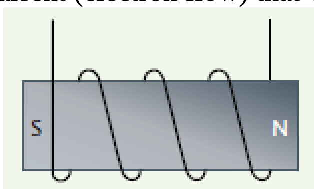




3. For each current-carrying solenoid (an electromagnetic coil), sketch a view of the magnetic field around the coil, based on the direction of current flow shown. On each, label the north and south poles of the electromagnet.

4. For each coil, show the direction of current (electron flow) that would cause the labelled magnetic polarity.





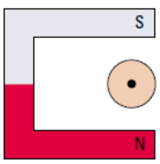
SPH 3U – Electricity & Magnetism – Motor Principle	**Name: ________________**

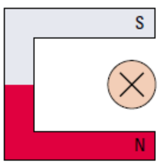
The motor principle: A current-carrying conductor experiences a force when it is placed in an external magnetic field. The force exerted is perpendicular to the direction of current and the external magnetic field.

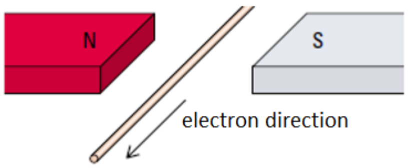
LHR (for the motor principle)
On the left hand, the fingers point in the direction of the magnetic field, the thumb points in the direction of the electron current flow. The palm points in the direction of the force produced.

Examples

1) Find the direction of the force

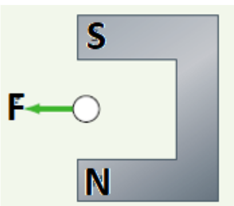


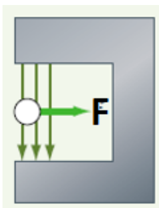


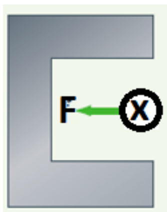


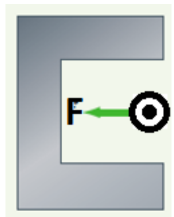
Recall: Magnetic poles are drawn from north to south

2) Label the magnetic poles, the magnetic field and the direction of electron current

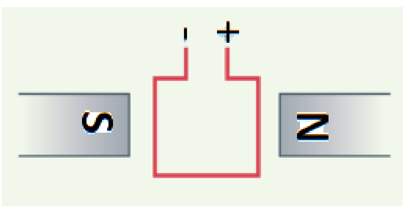


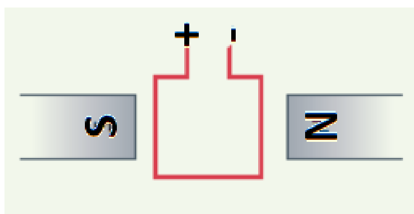






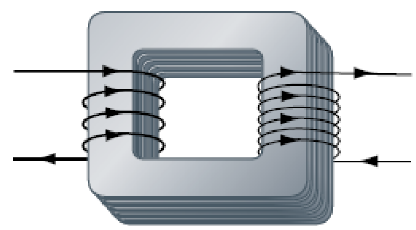
3) Show which way the loops will turn





18.4 Transformers and the Distribution of Electrical Power (from Irwin Physics 11 p615)

Fig.18.13 A step-up transformer



The simple transformer, shown in Fig. 18.13, uses both Faraday's principle and Oersted's principle to transform current and voltage in a circuit. The primary side uses an alternating current to produce an electromagnet. The changing magnetic field in the secondary side uses Faraday's principle to produce a new alternating current. If the number of turns in the primary and secondary sides of the transformers is different, then the voltage on the primary and secondary is different. Increasing the number of turns (N) in the secondary compared to the primary increases the secondary voltage proportionally.

Output power in the secondary coil must be equal to the input power in the primary coil. (Energy must be conserved!)
Note that P = VI where P = power (Watts, 1 W = 1 J/s)
v = voltage or electric potential difference (Volts)
I = current (Amperes)

$$P_{primary} = P_{secondary}$$
$$I_{primary}V_{primary} = I_{secondary}V_{secondary}$$

Rearranging yields: $$\frac{V_{primary}}{V_{secondary}} = \frac{I_{secondary}}{I_{primary}}$$

Fig.18.14 Voltage and Current Changes in a Transformer

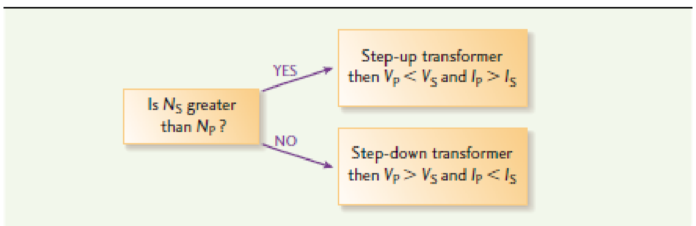
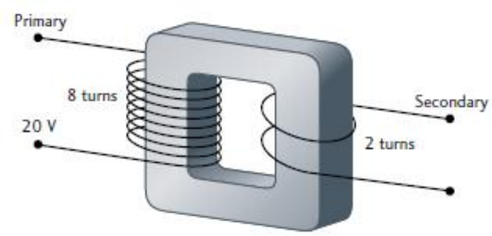


Fig.18.15



Factor in the number of turns, N, on the primary and secondary sides (N_P and N_S)

$$\frac{V_{primary}}{V_{secondary}} = \frac{I_{secondary}}{I_{primary}} = \frac{N_{primary}}{N_{secondary}}$$

1. A step-up transformer with 50 primary turns and 250 secondary turns is used to generate a current of 2.5 A at a voltage of 10 V. Find
a) the turns ratio.
b) the primary voltage.
c) the primary current.
d) the average power delivered to the secondary side.
e) the average power of the primary side
f) the resistance of the load on the output side.

2. A step-down transformer is used to convert 120 V from the wall source to an audio receiver voltage. If there is a 0.80 A current on the primary side and the turns ratio is 13:1, find
a) the voltage across the secondary side.
b) the current delivered to the stereo.
c) the resistance of the stereo components.
d) the power delivered to the secondary side.
e) the power delivered to the primary side.

Answers:
1a) 1:5 b) 2V c) 12.5 A d) 25W e) 25W f) 4 Ω
2a) 9.23V b) 10.4A c) 0.89 Ω d) 96W e) 96W

SPH 3U – Electricity & Magnetism – Summary   Name: _________________

1) Complete the following statements:

Kirchhoff's Voltage Law (KVL): In a complete circuit loop, the total of all electric potential increases is equal to …

Kirchhoff's Current Law (KCL): At any junction point in an electric circuit, the total electric current into a junction point is equal to …

Ohm's Law: $V = IR$ or $I =$

Oersted's Principle: Current moving through a conductor produces (or induces) …

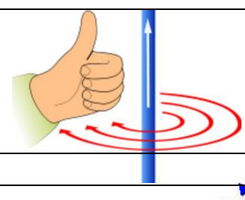
Faraday's Law: A magnetic field that is moving or changing intensity near a conductor causes (or induces) …

Lenz's Law: The direction of the induced current creates an induced magnetic field that _______________ the motion of the inducing magnetic field.

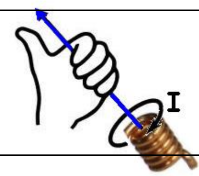
The Motor Principle: A current-carrying conductor experiences a _____________ when it is placed in an external magnetic field. This is because the conductor creates is own ___________________________ as well.

Magnetic Fields: Magnetic field lines come out of the ___________ pole and go into the __________ pole. They are 3D, and do not cross.

***LHR* #1 straight conductors:** Grasp a conductor with the *left* hand.
The thumb points in the direction of …
and the curved fingers point in the direction of …



***LHR* #2 coiled conductors: Grasp a conductor with the *left* hand.**
The curved fingers point in the direction of …
and the thumb point in the direction of …



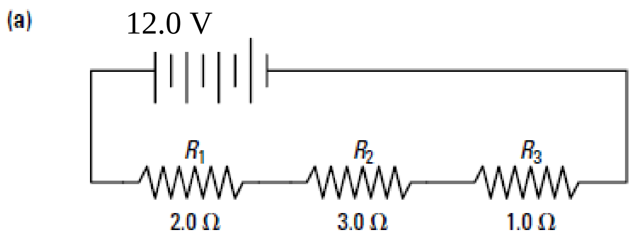
***LHR* #3 the motor principle**: Open the *left* hand,
the fingers point in the direction of the …
the thumb points in the direction of …
and the palm points in the direction of the …

SPH 3U – Electricity & Magnetism – Problem Set Name: ________________

1) A small light bulb with a resistance of 15.0 Ω is connected to a 9.0-V battery for 30.0 s.
   a) What is the current through the bulb?
   b) What power is dissipated by the bulb?
   c) How much energy is used by the bulb?
   d) How much charge is transferred through the bulb?
   e) How many electrons pass through the bulb?

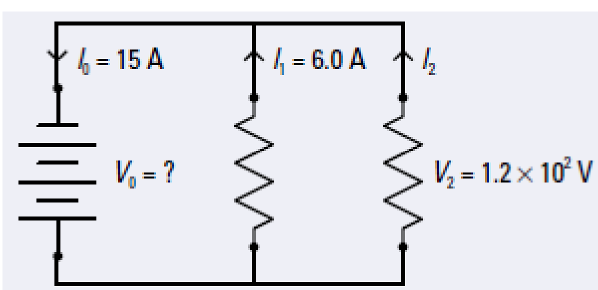
2) The following appliances are operated in a 120.0-V circuit for a thirty-day month:
   • six 100.0 W light bulbs for 8.0 h/d
   • a 10.0 Ω kettle for 10.0 min/d
   • a bread machine drawing on 6.0 A for 1.0 h/d
   Calculate the electric bill for the month at an average cost of 8.5¢/kW•h.

3) For each of the electric circuits, solve for all V, I, and R's.



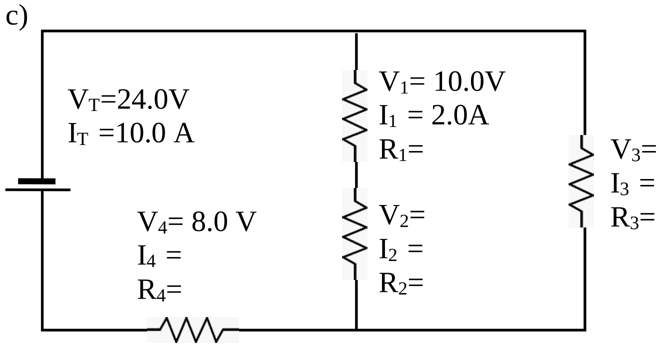
Name	V (V)	I (A)	R (Ω)
R_1			
R_2			
R_3			
Total			

b)



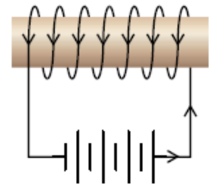
Name	V (V)	I (A)	R (Ω)
R_1			
R_2			
Total			

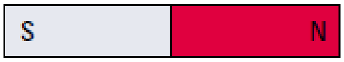
c)

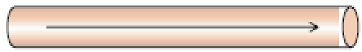


Name	V (V)	I (A)	R (Ω)
R_1			
R_2			
R_3			
R_4			
Total			

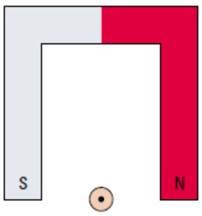
4) Draw the magnetic lines for each of the diagrams.
(a) one bar magnets (b) a current-carrying conductor (c) current through a solenoid

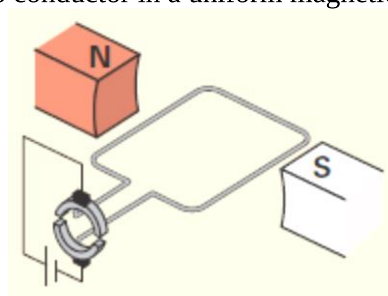
(c)


(a)


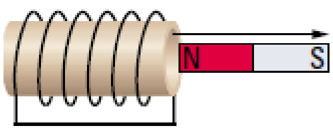
(b)


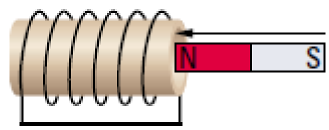
5) Indicate the magnetic field and the direction of the force on each current-carrying conductor.
(a) a conductor near a U-shaped magnet (b) loop conductor in a uniform magnetic field



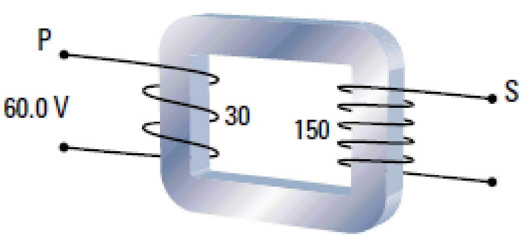


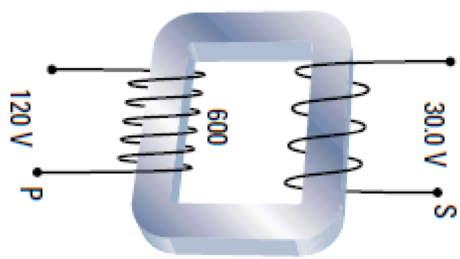
6) Indicate the direction of the induced current (electron flow).
(a) a magnet being pulled out of a solenoid (b) a magnet being pushed into a solenoid





7) For each of the following transformers, state whether it is a step-up or step-down transformer and calculate the
(a) electric potential difference in the secondary circuit (b) number of windings in the secondary circuit

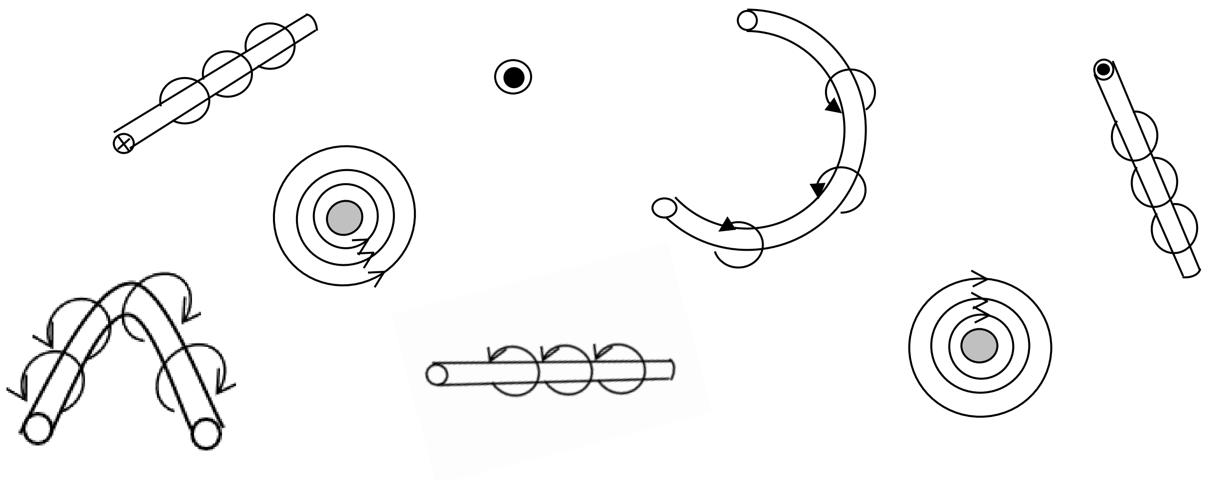




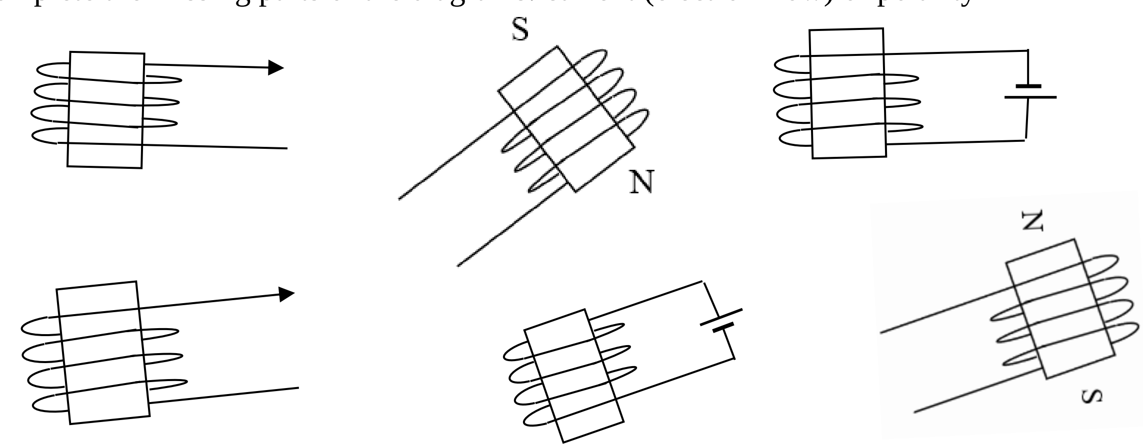
Answers
1a) 0.6A 1b) 5.4 W 1c) 162 J 1d) 18C 1e) 1.125x10^{20}*e 2) $14.69*
3a) $I_T=I_1=I_2=I_3=2A$ *3b)* $I_2=9.0A$ $R_T=9.0$ *Ohms 3c)* $I_T=1.0$ *A* $I_1=1.0A$ $I_2=I_3=I_4=0.5A$

SPH 3U – Electricity & Magnetism – extra practice   Name: _________________

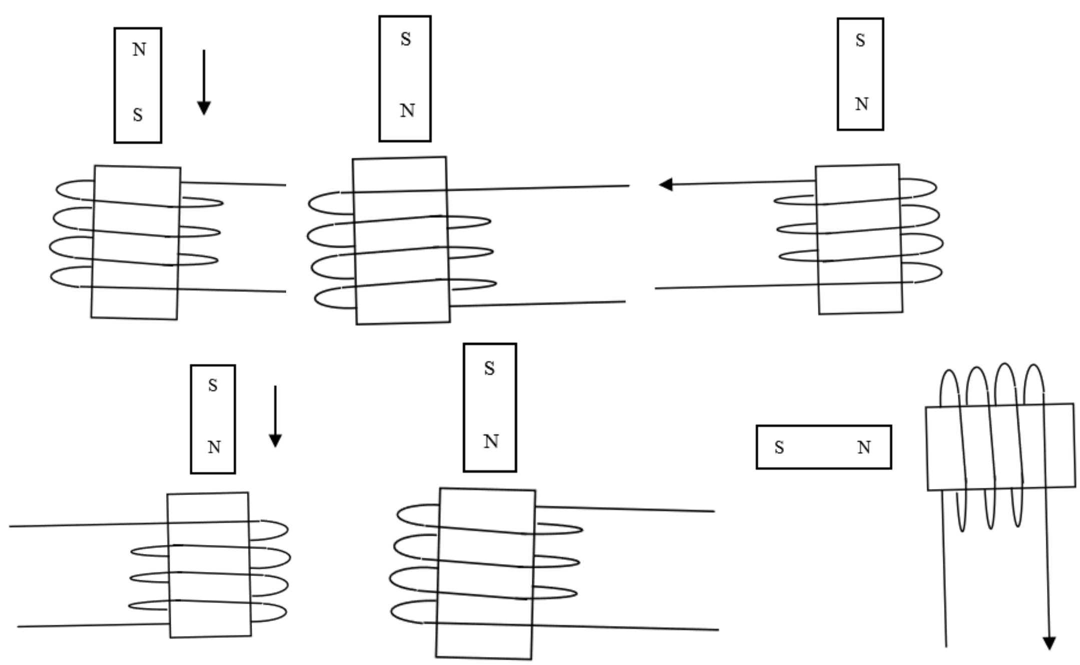
1) Complete the diagrams by drawing the direction of current (electron flow) or magnetic field lines.



2) Complete the missing parts of the diagrams: current (electron flow) or polarity



3) Complete the missing parts: current (electron flow), polarity and direction of magnet motion



SPH3U: Properties of waves in a coiled spring

How do waves and pulses behave in a coiled spring? We'll continue using phet.colorado.edu/en/simulation/wave-on-a-string

A: Ideal Waves and Pulses

As a real wave or pulse travels or *propagates* through a medium it may gradually change.

1. Create a single pulse with a fixed end, and set the "Damping" to somewhere in the middle. Describe how the pulse changes while it travels back and forth through the medium.

Real waves lose energy as they travel causing their amplitude to decrease. We will always ignore these important and realistic effects and instead focus on studying *ideal waves* in a medium that does not lose energy or cause wave shapes to change.

Set the damping to none for the rest of the investigations.

B: Speed of Waves

Make a pulse which will be your "standard" pulse. Record the amplitude and width of your standard pulse.

1. Can you make your pulse travel slower? Faster? Vary the pulse in a number of different ways and make a rough judgement about the speed – does it appear to travel back and forth faster, slower or the same? Remember to only vary one thing at once.

Characteristic to Vary	Observations
Amplitude	
Wavelength (pulse width)	
Tension	

2. Use a ruler and timer to measure the distance and time the wave travels to a fixed end. Then calculate the wave speed.

Tension	Distance	Time	Speed
High			
Medium			
Low			

D: Wavelength and Frequency

Create a wave (set to oscillate), set the frequency and pause the wave once you have a full wavelength.

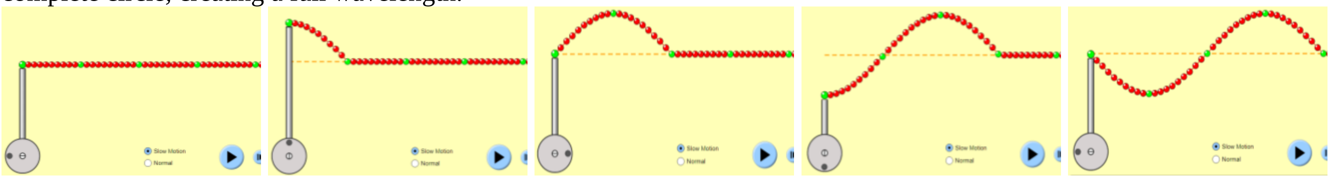
1. How are wavelength and frequency related? (generally speaking…don't need numbers/calculators)

2. Write the relationship between frequency f and period T (if you can't remember, look back to first slide/page of yesterday).

Frequency	Wavelength (measure these using simulation)
0.6 Hz	
1.2 Hz	
2.4 Hz	

E: Speed, Wavelength and Frequency

Let's explore the relationship between speed, wavelength, frequency and period. The diagrams below indicate a disc moving in one complete circle, creating a full wavelength.



1. What fraction of a cycle does the circle/piston move between each picture?

2. What fraction of a wavelength do we see in each diagram? Label these wavelengths on the diagrams.

3. Generally speaking, how far does a wave travel in the time of 1 period?

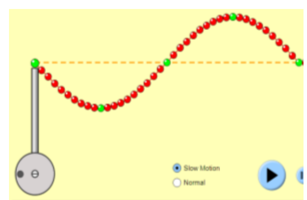
Pro tip: use the ❙▶ button to go frame by

4. Write an equation for the speed of the wave using its period T and wavelength λ. Hint: velocity = distance / time

The speed of a wave v (m/s) can also be expressed with the *universal wave equation,* $v = f\lambda$, with frequency f (Hz) and wavelength λ (m). Note that a change in frequency affects the wavelength and vice versa, but **do not affect the wave speed**.

5. Set your wave to oscillate, press play and pause it when you see one full wavelength. Calculate the wave speed using the universal wave equation: $v = f\lambda$. Compare your speeds to those on the previous page. Are they the same?

Tension	wavelength	frequency	Speed
High			
Medium			
Low			



E: Standing Waves

Standing waves are produced when certain points along the wave are not moving very far from the central axis, while other points are moving very far from the axis. The pattern should remain fairly stable.

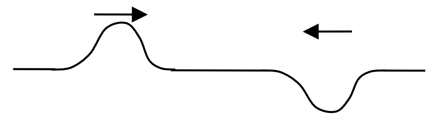
1. Try to produce different standing waves in your coiled spring by adjusting frequency. It is possible to produce standing waves with different numbers of crests/troughs. What was the frequency in order to produce this pattern? Draw each pattern produced and write down the frequency required to produce the pattern. [Standing wave demonstration](#).

Add a small amount of damping when doing this question, and make sure you have a Fixed End

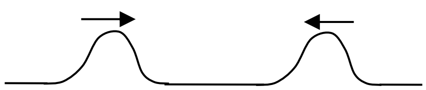
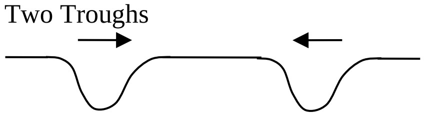
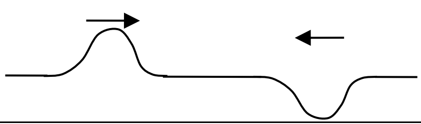
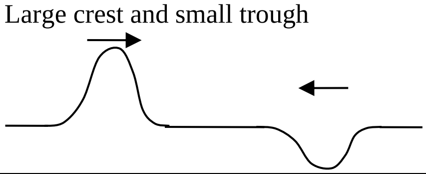
SPH3U: Interference

A: When Waves Meet

1. What happens when two waves travel through the same medium and meet?
   Suppose two waves are heading towards each other. What might happen? Give some options.



2. Watch the video and draw your observations of the spring when the pulses overlap and after they have overlapped.

Before	Overlapping	After
Two crests 		
Two Troughs 		
Equal crest and trough 		
Large crest and small trough 		

3. Describe what happens when the waves overlap.

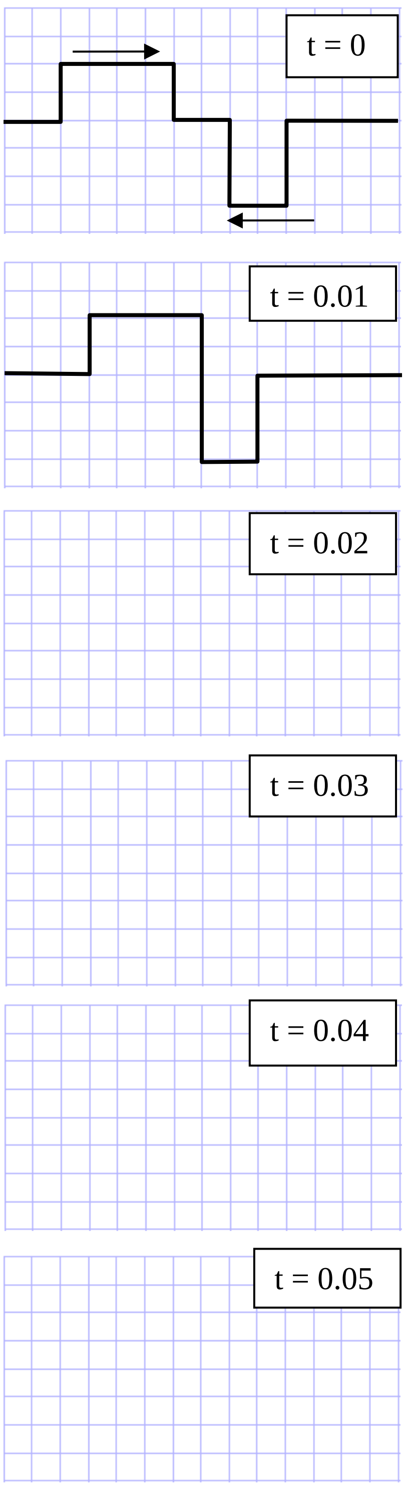
4. Do the waves bounce off one another or do they travel through one another?

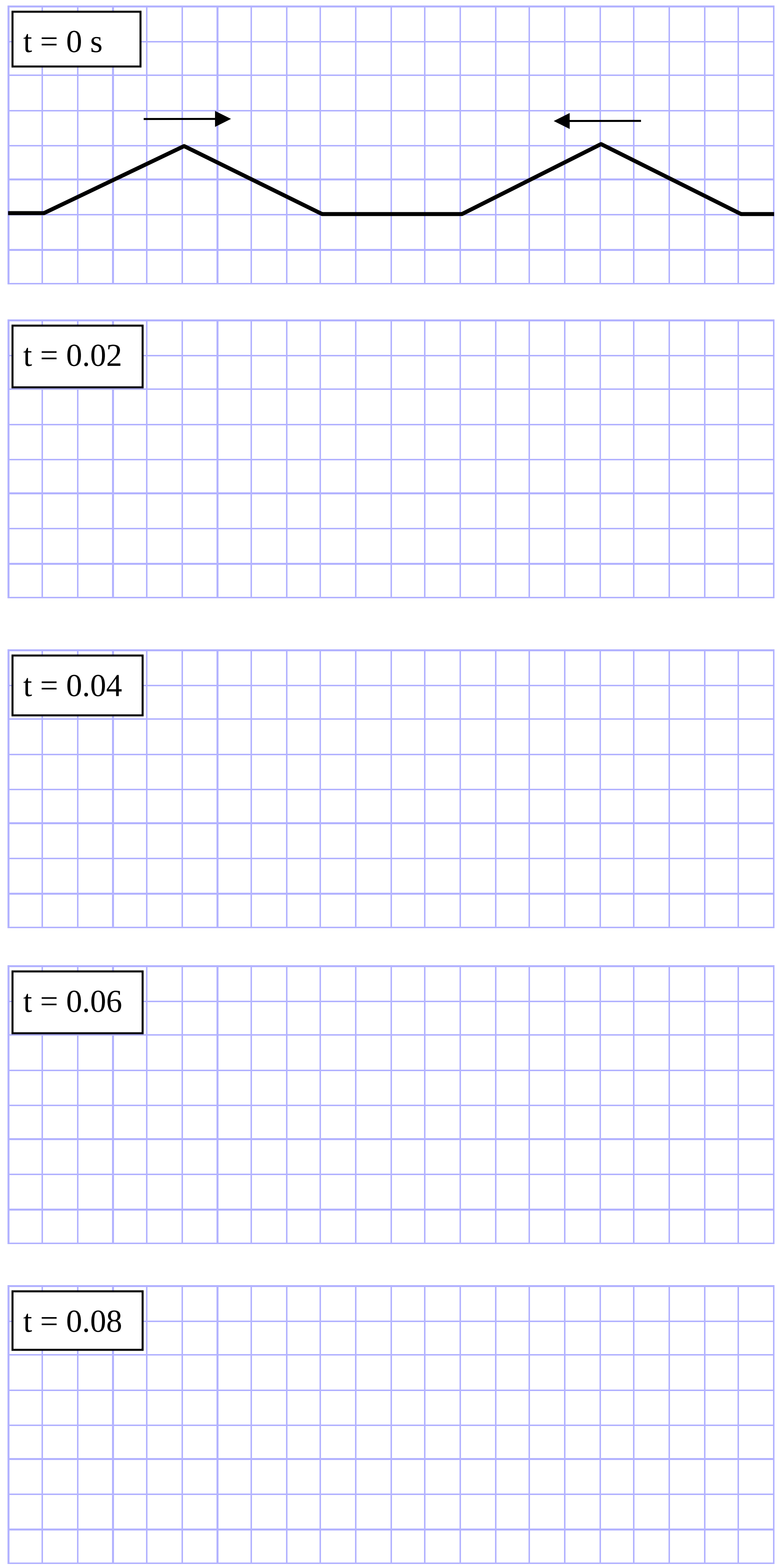
When two ideal waves overlap, one does not in any way alter the travel of the other. While overlapping, the displacement of each particle in the medium is the sum of the two displacements it would have had from each wave independently. This is the *principle of superposition* which describes the combination of overlapping waves or *wave interference*. When a crest overlaps with a crest, a *supercrest* is produced. When a trough and a trough overlap, a *supertrough* is produced. If the result of two waves interfering is a greater displacement in the medium *constructive interference* has occurred. If the result is a smaller displacement, *destructive interference* has occurred.

5. Label each example in the “Overlapping” column of your chart as either constructive or destructive interference.

B: Interference Frozen in Time

Let's apply the principle of superposition to some sample waves and learn how to predict the resulting wave shapes. Each pulse moves with a speed of 100 cm/s. Each block represents 1 cm.



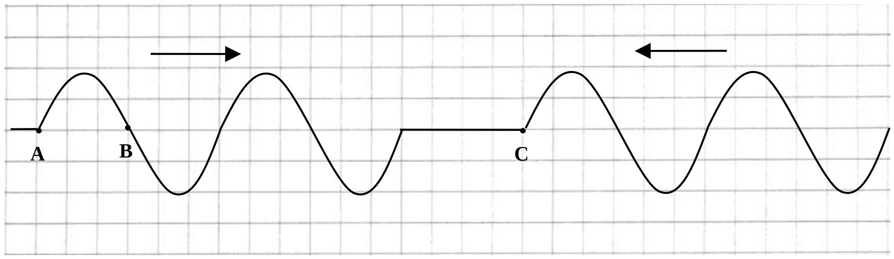


SPH3U: Standing Waves

A: When Continuous Waves Interfere

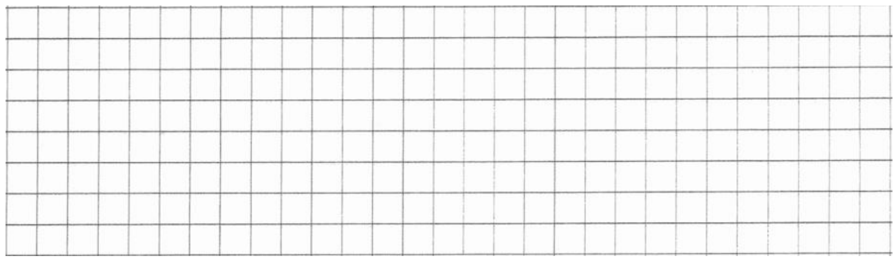
The diagram to the right shows two waves travelling in opposite directions in a spring.

The points A, B, and C are points of constant phase and **travel with the wave**. We will use these to help keep track of the wave.

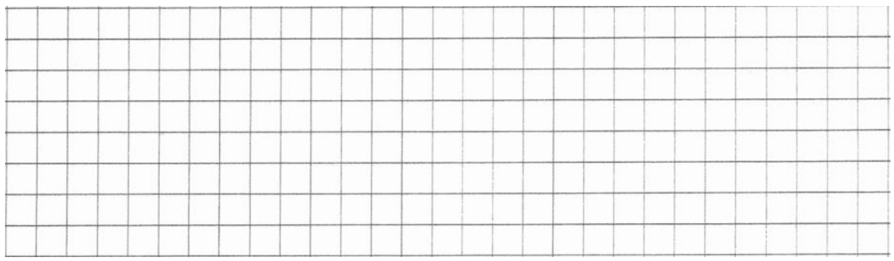


1. Use dotted lines to draw the shapes of the individual waves when points B and C coincide. Draw the displacement of the actual medium using a solid line. You should be able to do this without detailed math work.

   Label the regions where constructive or destructive interference occurs.



2. Use dotted lines to draw the shapes of the individual waves when points A and C coincide. Draw the displacement of the actual medium using a solid line.



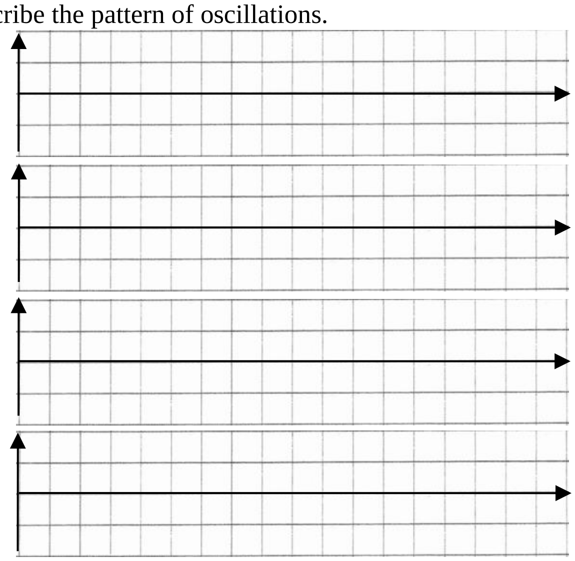
B: Representing Standing Waves

When the interfering process we examined above repeats, a standing wave is created. We will continue to use phet.colorado.edu/en/simulation/wave-on-a-string , this time to make a standing wave.

1. **Reason**. Why do you think the term "standing wave" is used?

2. **Observe.** Do all particles in the medium oscillate equal amounts? Describe the pattern of oscillations.

3. **Observe.** Your teacher will freeze the video to help us study the standing wave pattern at different moments in time, separated by ¼ period. Sketch the displacement of the medium at each moment.



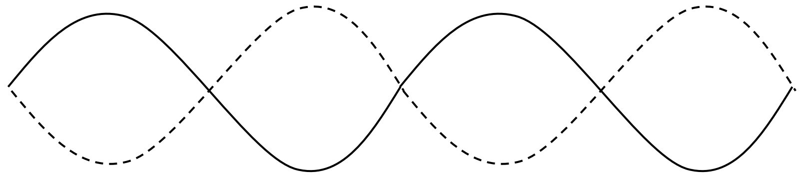
A *standing wave* is a wave pattern created by the interference of two continuous waves travelling in opposite directions in the same medium. It is called a standing wave because there are locations in the medium where the waves always interfere destructively and the particles do not move (or hardly move). These locations are called *nodes* or *minima*. There are other locations where the waves always interfere constructively. These locations are called *antinodes* or *maxima*.

4. **Represent.** Label the locations in the medium where nodes and antinodes are found in your sketches.

Since a standing wave pattern is a moving phenomena, we need a *standing wave diagram* to represent it. In this diagram, we show the wave at the two moments in time when the greatest displacements occur, as shown below.

5. **Represent.** Label locations in the medium where nodes and antinodes occur in the standing wave diagram.

6. **Reason.** What fraction of a cycle has elapsed between the two images of the wave?



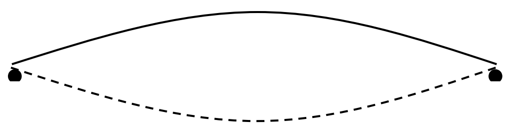
C: Standing Wave Patterns

We will continue using the phet simulation phet.colorado.edu/en/simulation/wave-on-a-string.
Add a VERY small amount of Damping and set Tension to Medium. Set Amplitude to 0.75 m.

1. **Observe. S**tart with a very low frequency and gradually increase the driving frequency until it is as high as possible. Try to create some standing waves – you want certain balls to move a lot and others to move just a little.

2. **Observe.** Create a standing wave with the lowest frequency you can manage. You've got the correct pattern if there is only one anti-node. Measure and record the length of the spring and the period of the wave in the table below.

3. **Observe.** Gradually increase the frequency driving the spring until you find the next standing wave pattern or oscillation *harmonic*. Every time, a new node should appear. Measure the period. Repeat this and complete the chart below.

Harmonic/ Mode #	# of Anti-Nodes	# of Nodes	Length (λ)	Diagram
1	1	2	½	
2				
3				

4. **Predict.** What is the standing wave pattern and all its characteristics for the 4th mode. Sketch it below.

$$\lambda_n = \frac{2L}{n}$$

where λ_n=wavelength of nth mode
n = mode #
L = length of medium

Patterns like those above are examples of *resonance*, where a small, periodic driving force can cause an object to vibrate with a large amplitude. An object will *resonate* when the *driving frequency* matches the object's *resonant frequency*. The value of the resonance frequency depends on the composition and construction of the object. If the driving frequency is slightly higher or lower than the resonance frequency, the amplitude of waves in the object is much smaller and the vibrating pattern will not be regular .

SPH3U: Standing Wave / Resonance Homework

A: Pure as the Driven Spring

A spring is stretched out and held fixed on the ground at two points 2.9 m apart. Its wave speed at that length is 4.5 m/s.

1. **Calculate and Explain.** What is the wavelength when vibrating in the first and second harmonics? Explain your result.

2. **Calculate.** What frequency should the student use to create a standing wave in the first and second harmonics?

3. **Explain.** You create a wave that has a wavelength of 84 cm in a spring stretched out to a distance of 126 cm. Will resonance occur? (Will a standing wave be created?) Use a standing wave diagram to help explain.

4. **Calculate and Explain.** The two ends of a spring are held fixed on the ground 5.3 m apart. Waves travel in the spring at 4.7 m/s. A student drives the spring using a frequency of 2.9 Hz. Will resonance occur? Explain how you decide.

5. You have a spring stretched along the floor to a length of 3.9 m.
   (a) **Calculate and Represent.** Draw a standing wave diagram for the first three harmonics. Determine the wavelength of each harmonic.

   (b) **Calculate and Describe.** Waves travel with a speed of 6.1 m/s in your spring. Determine the first three resonant frequencies for your spring. What do you notice about the pattern of frequencies?

	Standing Wave Diagram	λ	f
1			
2			
3			

6. **Reason and Calculate.** You hold one end of a new meter stick against the desk. The length of the vibrating part of the stick is 0.75 m and it vibrates in its first harmonic with a frequency of 5.3 Hz. What are the frequencies of the next two harmonics? (Hint: use the fact that all the lengths are the same)

	Standing Wave Diagram	L=__ λ	f
1			
2			
3			