ELECTRICITY & MAGNETISM

TOPIC A: *Static Electricity*

❷ PART 2: Conservation of Charge

249) The diagram below represents two electrically charged identical-sized metal spheres, *A* and *B*.

If the spheres are brought into contact, which sphere will have a net gain of electrons?

A) *A*, only
B) *B*, only
C) both *A* and *B*
D) neither *A* nor *B*

250) Metal sphere *A* has a charge of -2 units and an identical metal sphere, *B*, has a charge of -4 units. If the spheres are brought into contact with each other and then separated, the charge on sphere *B* will be

A) -3 units
B) 0 units
C) -2 units
D) +4 units

❸ PART 3: Elementary Charge

251) What is the net electrical charge on a magnesium ion that is formed when a neutral magnesium atom loses two electrons?

A) $+3.2 \times 10^{-19}$ C
B) -3.2×10^{-19} C
C) -1.6×10^{-19} C
D) $+1.6 \times 10^{-19}$ C

❹ PART 4: Quantity of Charge

252) Which of the following quantities of excess electric charge could be found on an object?

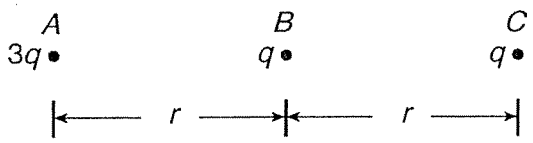
A) 4.80×10^{-19} C
B) 6.25×10^{-19} C
C) 6.25 elementary charges
D) 1.60 elementary charges

PART 5: COULOMB'S LAW (ELECTROSTATIC FORCE)

253) If the distance separating an electron and a proton is halved, the magnitude of the electrostatic force between these charged particles will be

A) quadrupled
B) unchanged
C) doubled
D) quartered

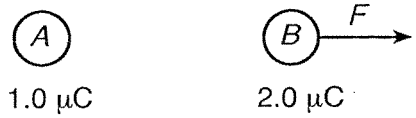
254) The diagram below shows the arrangement of three small spheres, A, B, and C, having charges of $3q$, q, and q, respectively. Spheres A and C are located distance r from sphere B.



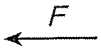
Compared to the magnitude of the electrostatic force exerted by sphere B on sphere C, the magnitude of the electrostatic force exerted by sphere A on sphere C is

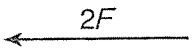
A) $\frac{3}{4}$ as great
B) the same
C) twice as great
D) $\frac{3}{2}$ as great

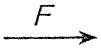
255) Two metal spheres, A and B, possess charges of 1.0 microcoulomb and 2.0 microcoulombs, respectively. In the diagram below, arrow F represents the electrostatic force exerted on sphere B by sphere A.



Which arrow represents the magnitude and direction of the electrostatic force exerted on sphere A by sphere B?

A) 

B) 

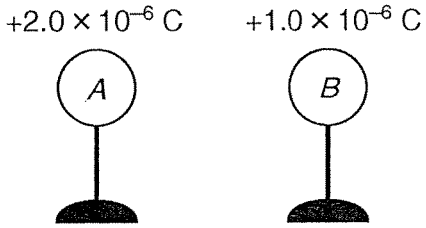
C) 

D) 

256) What is the magnitude of the electrostatic force between two electrons separated by a distance of 1.00×10^{-8} meter?

A) 2.30×10^{-12} N
B) 2.56×10^{-22} N
C) 2.30×10^{-20} N
D) 1.44×10^{-1} N

257) Two similar metal spheres, A and B, have charges of $+2.0 \times 10^{-6}$ coulomb and $+1.0 \times 10^{-6}$ coulomb, respectively, as shown in the diagram below. The magnitude of the electrostatic force on A due to B is 2.4 newtons.



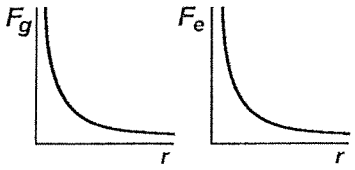
What is the magnitude of the electrostatic force on B due to A?

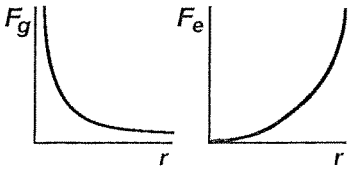
A) 2.4 N
B) 1.2 N
C) 4.8 N
D) 9.6 N

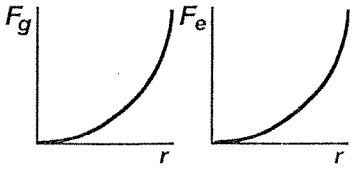
258) A distance of 1.0 meter separates the centers of two small charged spheres. The spheres exert gravitational force F_g and electrostatic force F_e on each other. If the distance between the spheres' centers is increased to 3.0 meters, the gravitational force and electrostatic force, respectively, may be represented as

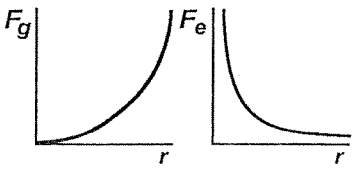
A) $\frac{F_g}{9}$ and $\frac{F_e}{9}$
B) $\frac{F_g}{3}$ and $\frac{F_e}{3}$
C) $3F_g$ and $3F_e$
D) $9F_g$ and $9F_e$

259) The distance between an electron and a proton is varied. Which pair of graphs *best* represents the relationship between gravitational force, F_g, and distance, r, and the relationship between electrostatic force, F_e, and distance, r, for these particles?

A) 

B) 

C) 

D) 

⊙ PART 6: ELECTRIC FIELDS

260) Which of the following quantities and units are correctly paired?

A) electric field strength and $\frac{N}{C}$

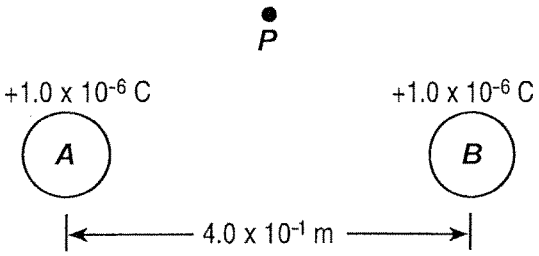
B) resistivity and $\frac{\Omega}{m}$

C) potential difference and eV

D) current and C • s

Questions 261 and 262 refer to the following:

Two small metallic spheres, *A* and *B*, are separated by a distance of 4.0×10^{-1} meter, as shown. The charge on each sphere is $+1.0 \times 10^{-6}$ coulomb. Point *P* is located near the spheres.



261) What is the magnitude of the electrostatic force between the two charged spheres shown?

A) 5.6×10^{-2} N

B) 2.2×10^{-2} N

C) 2.2×10^{4} N

D) 5.6×10^{4} N

262) Which arrow *best* represents the direction of the resultant electric field at point *P* due to the charges on spheres *A* and *B* shown?

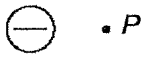
A)

C) 

B) 

D) 

263) In the diagram below, P is a point near a negatively charged sphere.



Which of the following vectors *best* represents the direction of the electric field at point P?

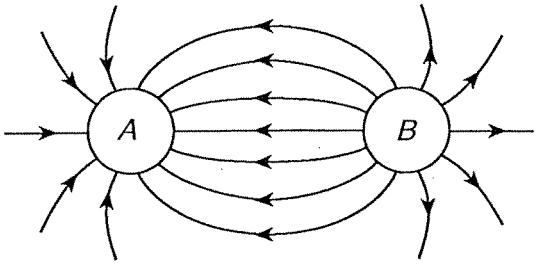
A)

C) 

B)

D) 

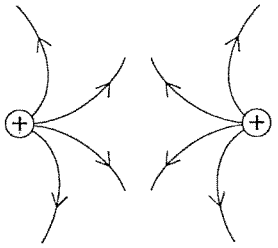
264) The diagram below represents the electric field surrounding two charged spheres, A and B.

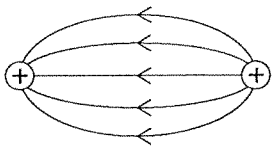


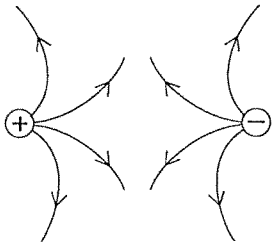
What is the sign of the charge of each sphere?

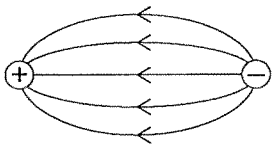
A) Sphere A is negative and sphere B is positive.
B) Sphere A is positive and sphere B is negative.
C) Both spheres are positive.
D) Both spheres are negative.

265) Which one of the following diagrams represents the electric field lines between two small electrically charged spheres?

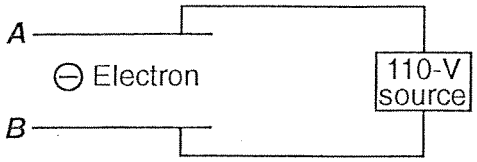
A) 

B) 

C) 

D) 

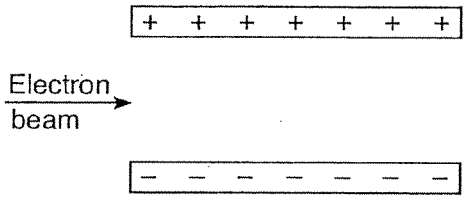
266) An electron is located in the electric field between two parallel metal plates as shown in the diagram below.



If the electron is attracted to plate *A*, then plate *A* is charged

A) positively, and the electric field is directed from plate *A* toward plate *B*
B) positively, and the electric field is directed from plate *B* toward plate *A*
C) negatively, and the electric field is directed from plate *A* toward plate *B*
D) negatively, and the electric field is directed from plate *B* toward plate *A*

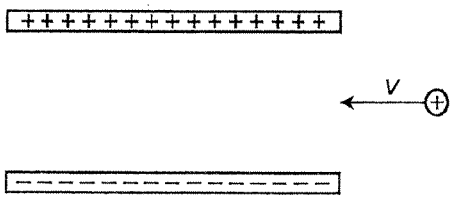
267) A beam of electrons is directed into the electric field between two oppositely charged parallel plates, as shown in the diagram below.



The electrostatic force exerted on the electrons by the electric field is directed

A) toward the top of the page
B) into the page
C) out of the page
D) toward the bottom of the page

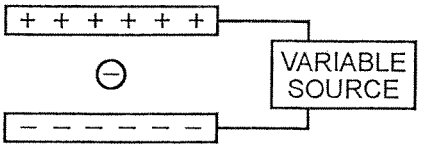
268) The diagram below represents a positively charged particle about to enter the electric field between two oppositely charged parallel plates.



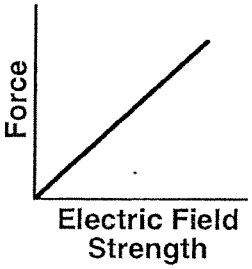
The electric field will deflect the particle

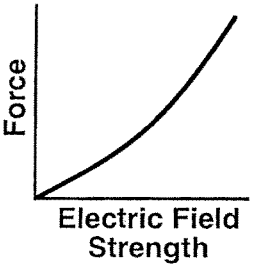
A) toward the bottom of the page
B) into the page
C) out of the page
D) toward the top of the page

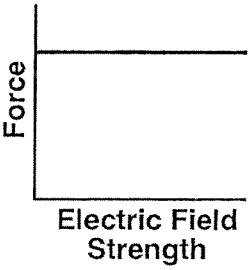
269) Two parallel metal plates are connected to a variable source of potential difference. When the potential difference of the source is increased, the magnitude of the electric field strength between the plates increases. The diagram below shows an electron located between the plates.

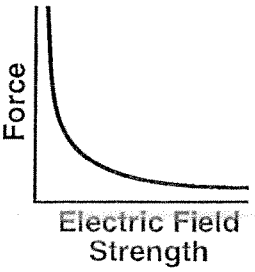


Which one of the following graphs represents the relationship between the magnitude of the electrostatic force on the electron and the magnitude of the electric field strength between the plates?

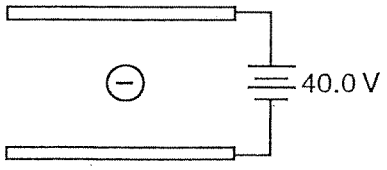
A)


B)


C)


D)


270) The diagram below represents an electron within an electric field between two parallel plates that are charged with a potential difference of 40.0 volts.



If the magnitude of the electric force on the electron is 2.00×10^{-15} newton, what is the magnitude of the electric field strength between the charged plates?

A) 1.25×10^{4} N/C
B) 3.20×10^{-34} N/C
C) 2.00×10^{-14} N/C
D) 2.00×10^{16} N/C

❼ PART 7: POTENTIAL DIFFERENCE

271) Which of the following electrical units is equivalent to one joule?

A) coulomb • volt
B) volt per meter
C) ampere • volt
D) volt per coulomb

272) If 20 joules of work is used to transfer 20 coulombs of charge through a 20-ohm resistor, the potential difference across the resistor is

A) 1 V
B) 20 V
C) 0.05 V
D) 400 V

273) If 1.0 joule of work is required to move 1.0 coulomb of charge between two points in an electric field, the potential difference between the two points is

A) 1.0×10^{0} V
B) 9.0×10^{9} V
C) 6.3×10^{18} V
D) 1.6×10^{-19} V

274) If 60. joules of work is required to move 5.0 coulombs of charge between two points in an electric field, what is the potential difference between these points?

A) 12 V
B) 5.0 V
C) 60. V
D) 300 V

275) A potential difference of 10.0 volts exists between two points, *A* and *B*, within an electric field. What is the magnitude of charge that requires 2.0×10^{-2} joule of work to move it from *A* to *B*?

A) 2.0×10^{-3} C
B) 5.0×10^{2} C
C) 2.0×10^{-1} C
D) 5.0×10^{-2} C

TOPIC B: *Electric Current*

❷ PART 2: CURRENT

276) Charge flowing at the rate of 2.50×10^{16} elementary charges per second is equivalent to a current of

A) 4.00×10^{-3} A
B) 2.50×10^{13} A
C) 6.25×10^{5} A
D) 2.50×10^{-3} A

277) A circuit consists of a resistor and a battery. Increasing the voltage of the battery while keeping the temperature of the circuit constant would result in an increase in

A) current, only
B) resistance, only
C) both current and resistance
D) neither current nor resistance

278) In a simple electric circuit, a 24-ohm resistor is connected across a 6.0-volt battery. What is the current in the circuit?

A) 0.25 A C) 140 A
B) 1.0 A D) 4.0 A

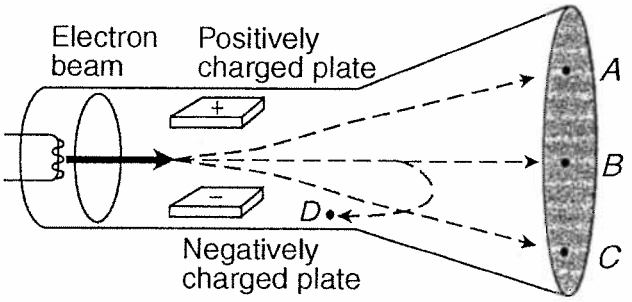
279) What is the current through a wire if 240 coulombs of charge pass through the wire in 2.0 minutes?

A) 2.0 A C) 0.50 A
B) 120 A D) 0.0083 A

280) What is the current in a 100.-ohm resistor connected to a 0.40-volt source of potential difference?

A) 4.0 mA C) 40. mA
B) 250 mA D) 2.5 mA

281) The diagram below shows a beam of electrons fired through the region between two oppositely charged parallel plates in a cathode ray tube.

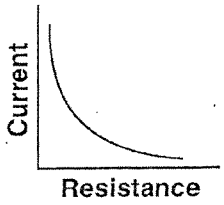


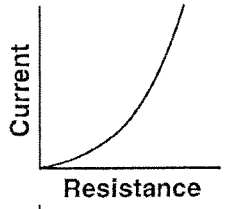
After passing between the charged plates, the electrons will most likely travel path

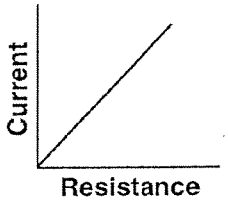
A) *A* B) *B* C) *C* D) *D*

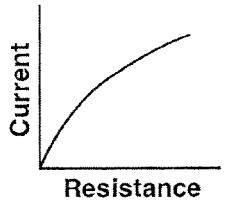
PART 3: RESISTANCE

282) A constant potential difference is applied across a variable resistor held at constant temperature. Which of the following graphs *best* represents the relationship between the resistance of the variable resistor and the current through it?

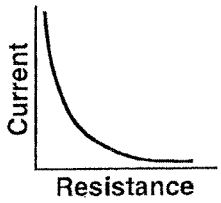
A) 

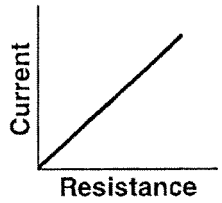
C) 

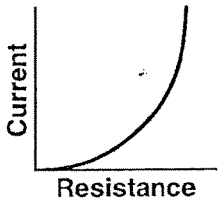
B) 

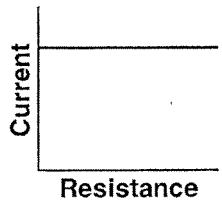
D) 

283) An electric circuit contains a variable resistor connected to a source of constant potential difference. Which graph *best* represents the relationship between current and resistance in the circuit?

A) 

C) 

B) 

D) 

284) An electric circuit consists of a variable resistor connected to a source of constant potential difference. If the resistance of the resistor is doubled, the current through the resistor is

A) halved
B) doubled
C) quartered
D) quadrupled

285) At 20 °C, four conducting wires made of different materials have the same length and the same diameter. Which of the following wires has the *least* resistance?

A) gold
B) aluminum
C) nichrome
D) tungsten

286) A 0.686-meter-long wire has a cross-sectional area of 8.23×10^{-6} meter^2 and a resistance of 0.125 ohm at 20° Celsius. This wire could be made of

A) nichrome
B) aluminum
C) copper
D) tungsten

287) The electrical resistance of a metallic conductor is inversely proportional to its

A) cross-sectional area
B) temperature
C) length
D) resistivity

288) A copper wire of length L and cross-sectional area A has resistance R. A second copper wire at the same temperature has a length of $2L$ and a cross-sectional area of A. What is the resistance of the second copper wire?

A) $4R$
B) R
C) $2R$
D) $\frac{1}{2}R$

289) A 150-watt lightbulb is brighter than a 60.-watt lightbulb when both are operating at a potential difference of 110 volts. Compared to the resistance of and the current drawn by the 150-watt lightbulb, the 60.-watt lightbulb has

A) more resistance and draws less current
B) less resistance and draws more current
C) less resistance and draws less current
D) more resistance and draws more current

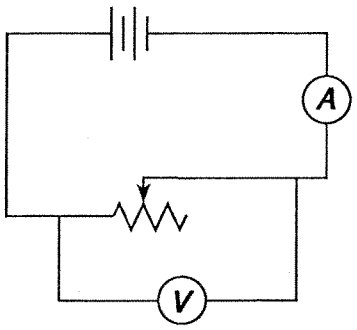
290) A 4.50-volt personal stereo uses 1,950 joules of electrical energy in one hour. What is the electrical resistance of the personal stereo?

A) 37.4 Ω
B) 433 Ω
C) 96.3 Ω
D) 0.623 Ω

PART 4: CIRCUITS

OHM'S LAW

291) The diagram below represents a simple circuit consisting of a variable resistor, a battery, an ammeter, and a voltmeter.



What is the effect of increasing the resistance of the variable resistor from 1,000 Ω to 10,000 Ω? [*Assume constant temperature.*]

A) The ammeter reading decreases.
B) The ammeter reading increases.
C) The voltmeter reading decreases.
D) The voltmeter reading increases.

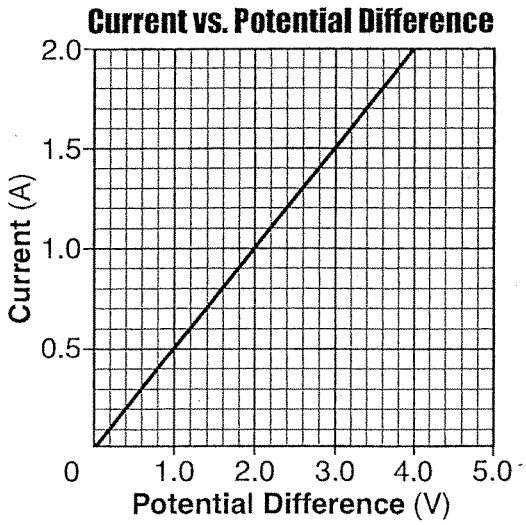
292) The current through a 10.-ohm resistor is 1.2 amperes. What is the potential difference across the resistor?

A) 12 V
B) 8.3 V
C) 14 V
D) 120 V

293) A charge of 30. coulombs passes through a 24-ohm resistor in 6.0 seconds. What is the current through the resistor?

A) 5.0 A
B) 1.3 A
C) 7.5 A
D) 4.0 A

294) The graph below represents the relationship between the current in a metallic conductor and the potential difference across the conductor at constant temperature.

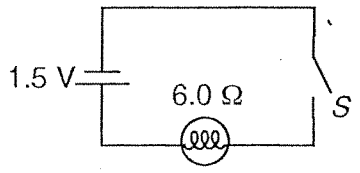


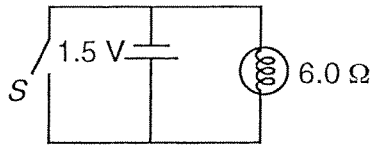
The resistance of the conductor is

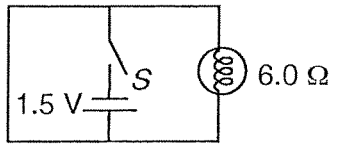
A) 2.0 Ω
B) 1.0 Ω
C) 0.50 Ω
D) 4.0 Ω

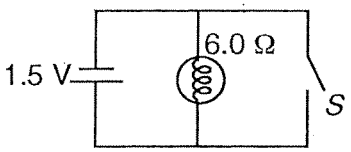
◆ Series Circuits

295) A 6.0-ohm lamp requires 0.25 ampere of current to operate. In which circuit below would the lamp operate correctly when switch *S* is closed?

A) 

B) 

C) 

D) 

296) Circuit *A* has four 3.0-ohm resistors connected in series with a 24-volt battery, and circuit *B* has two 3.0-ohm resistors connected in series with a 24-volt battery. Compared to the total potential drop across circuit *A*, the total potential drop across circuit *B* is

A) the same
B) one-half as great
C) twice as great
D) four times as great

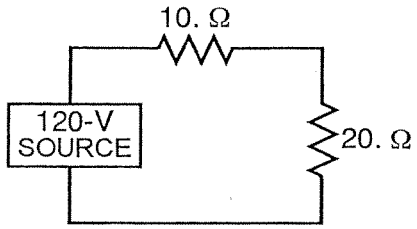
297) A 3.0-ohm resistor and a 6.0-ohm resistor are connected in series in an operating electric circuit. If the current through the 3.0-ohm resistor is 4.0 amperes, what is the potential difference across the 6.0-ohm resistor?

A) 24 V
B) 8.0 V
C) 2.0 V
D) 12 V

298) A 2.0-ohm resistor and a 4.0-ohm resistor are connected in series with a 12-volt battery. If the current through the 2.0-ohm resistor is 2.0 amperes, the current through the 4.0-ohm resistor is

A) 2.0 A
B) 1.0 A
C) 3.0 A
D) 4.0 A

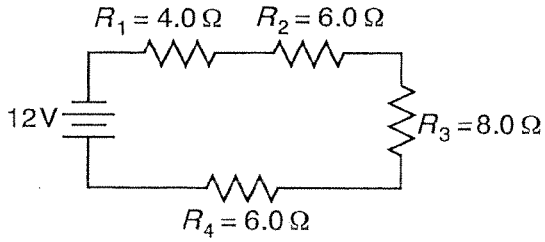
299) The diagram below represents a circuit consisting of two resistors connected to a source of potential difference.



What is the current through the 20.-ohm resistor?

A) 4.0 A
B) 0.25 A
C) 6.0 A
D) 12 A

300) The circuit diagram below represents four resistors connected to a 12-volt source.



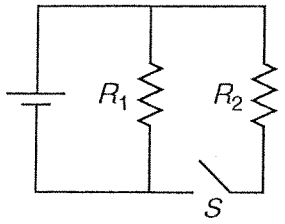
What is the total current in the circuit?

A) 0.50 A
B) 2.0 A
C) 8.6 A
D) 24 A

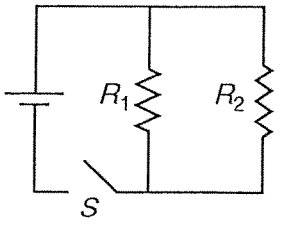
♦ Parallel Circuits

301) In which circuit would current flow through resistor R_1, but *not* through resistor R_2 while switch S is open?

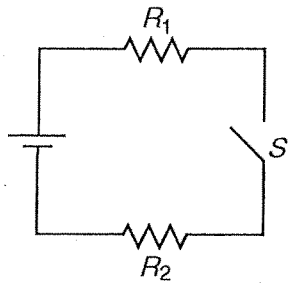
A)



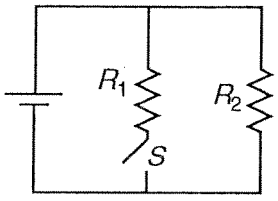
B)



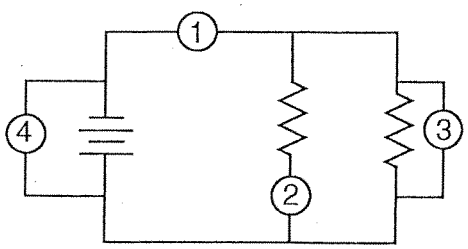
C)



D)



302) In the electric circuit diagram below, possible locations of an ammeter and a voltmeter are indicated by circles 1, 2, 3, and 4.

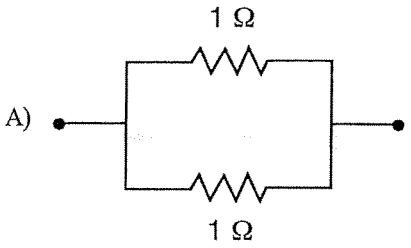


Where should an ammeter be located to correctly measure the total current, and where should a voltmeter be located to correctly measure the total voltage?

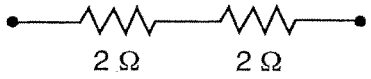
A) ammeter at 1 and voltmeter at 4
B) ammeter at 2 and voltmeter at 3
C) ammeter at 3 and voltmeter at 4
D) ammeter at 1 and voltmeter at 2

303) Which of the following combinations of resistors has the *smallest* equivalent resistance?

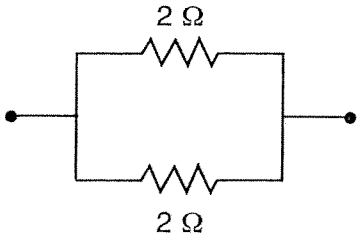
A)



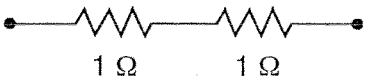
B)



C)

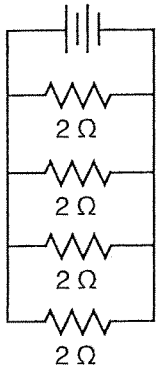


D)

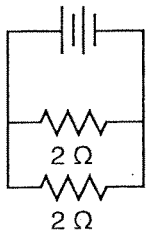


304) Which of the following circuits has the *smallest* equivalent resistance?

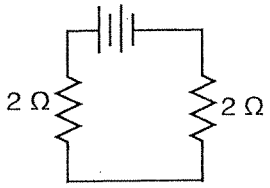
A)



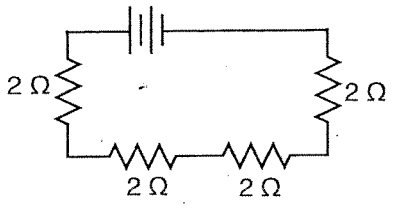
B)



C)



D)



305) A circuit consists of a 10.0-ohm resistor, a 15.0-ohm resistor, and a 20.0-ohm resistor connected in parallel across a 9.00-volt battery. What is the equivalent resistance of the circuit?

A) 4.62 Ω
B) 0.200 Ω
C) 1.95 Ω
D) 45.0 Ω

306) Three resistors, 4 ohms, 6 ohms, and 8 ohms, are connected in parallel in an electric circuit. The equivalent resistance of the circuit is

A) less than 4 Ω
B) between 4 Ω and 8 Ω
C) between 10. Ω and 18 Ω
D) 18 Ω

307) Three identical lamps are connected in parallel with each other. If the resistance of each lamp is X ohms, what is the equivalent resistance of this parallel combination?

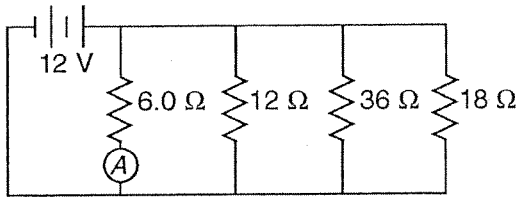
A) $\frac{X}{3}$ Ω
B) X Ω
C) $3X$ Ω
D) $\frac{3}{X}$ Ω

308) What is the total current in a circuit consisting of six operating 100-watt lamps connected in parallel to a 120-volt source?

A) 5 A
B) 20 A
C) 600 A
D) 12,000 A

Questions 309 and 310 refer to the following:

The diagram below represents an electric circuit consisting of four resistors and a 12-volt battery.



309) What is the current measured by ammeter A shown in the diagram?

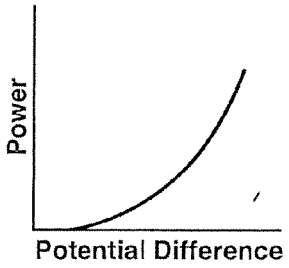
A) 2.0 A
B) 0.50 A
C) 72 A
D) 4.0 A

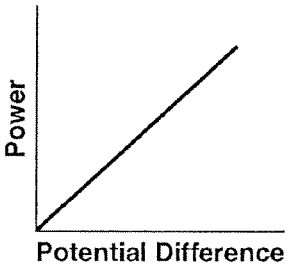
310) What is the equivalent resistance of the circuit shown?

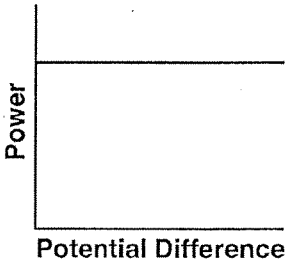
A) 3.0 Ω
B) 72 Ω
C) 18 Ω
D) 0.33 Ω

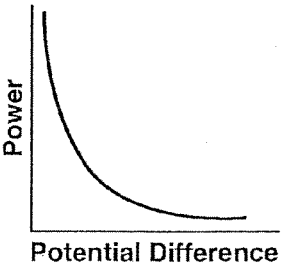
◆ Electrical Power and Energy

311) Which graph *best* represents the relationship between the power expended by a resistor that obeys Ohm's Law and the potential difference applied to the resistor?

A)


B)


C)


D)


312) An electric circuit contains a variable resistor connected to a source of constant voltage. As the resistance of the variable resistor is increased, the power dissipated in the circuit

A) decreases
B) increases
C) remains the same

313) How much total energy is dissipated in 10. seconds in a 4.0-ohm resistor with a current of 0.50 ampere?

A) 10. J C) 5.0 J
B) 2.5 J D) 20. J

314) An electric drill operating at 120. volts draws a current of 3.00 amperes. What is the total amount of electrical energy used by the drill during 1.00 minute of operation?

A) 2.16×10^4 J C) 3.60×10^2 J
B) 2.40×10^3 J D) 4.00×10^1 J

315) An operating 100.-watt lamp is connected to a 120-volt outlet. What is the total electrical energy used by the lamp in 60. seconds?

A) 6.0×10^3 J C) 1.7 J
B) 0.60 J D) 7.2×10^3 J

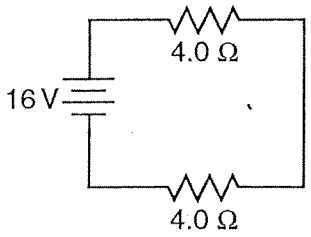
316) An electric heater operating at 120. volts draws 8.00 amperes of current through its 15.0 ohms of resistance. The total amount of heat energy produced by the heater in 60.0 seconds is

A) 5.76×10^4 J C) 8.64×10^4 J
B) 7.20×10^3 J D) 6.91×10^6 J

317) An electrical appliance draws 9.0 amperes of current when connected to a 120-volt source of potential difference. What is the total amount of power dissipated by this appliance?

A) 1,100 W C) 110 W
B) 13 W D) 130 W

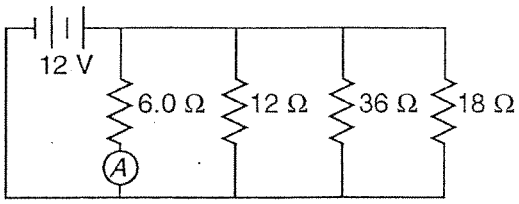
318) In the circuit diagram below, two 4.0-ohm resistors are connected to a 16-volt battery as shown.



What is the rate at which electrical energy is expended in the circuit?

A) 32 W
B) 8.0 W
C) 16 W
D) 64 W

319) The diagram below represents an electric circuit consisting of four resistors and a 12-volt battery.



How much power is dissipated in the 36-ohm resistor shown in the diagram?

A) 4.0 W
B) 110 W
C) 48 W
D) 3.0 W

TOPIC C: *Magnetism*

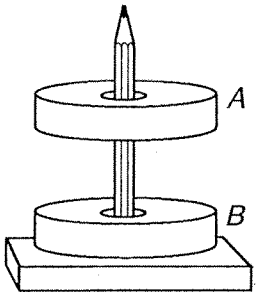
320) Magnetic fields are produced by particles that are

A) moving and charged
B) moving and neutral
C) stationary and charged
D) stationary and neutral

321) Moving a length of copper wire through a magnetic field may cause the wire to have a

A) potential difference across it
B) lower temperature
C) lower resistivity
D) higher resistance

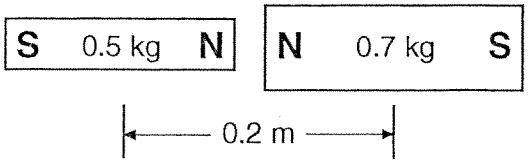
322) When two ring magnets are placed on a pencil, magnet *A* remains suspended above magnet *B*, as shown below.



Which of the following statements describes the gravitational force and the magnetic force acting on magnet *A* due to magnet *B*?

A) The gravitational force is attractive and the magnetic force is repulsive.
B) The gravitational force is repulsive and the magnetic force is attractive.
C) Both the gravitational force and the magnetic force are attractive.
D) Both the gravitational force and the magnetic force are repulsive.

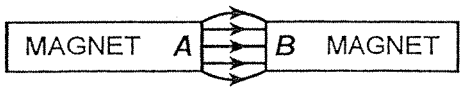
323) The diagram below represents a 0.5-kilogram bar magnet and a 0.7-kilogram bar magnet with a distance of 0.2 meter between their centers.



Which of the following statements *best* describes the forces between the bar magnets?

A) Gravitational force is attractive and magnetic force is repulsive.
B) Gravitational force and magnetic force are both repulsive.
C) Gravitational force is repulsive and magnetic force is attractive.
D) Gravitational force and magnetic force are both attractive.

324) The diagram below shows the magnetic field lines between two magnetic poles, *A* and *B*.



Which one of the following statements describes the polarity of magnetic poles *A* and *B*?

A) *A* is a north pole and *B* is a south pole.
B) *A* is a south pole and *B* is a north pole.
C) Both *A* and *B* are north poles.
D) Both *A* and *B* are south poles.

TOPIC D: *Electromagnetic Induction*

325) Which fundamental force is primarily responsible for the attraction between protons and electrons?

A) electromagnetic
B) strong
C) weak
D) gravitational

326) Which of the following statements *best* describes a proton that is being accelerated?

A) It produces electromagnetic radiation.
B) The magnitude of its charge increases.
C) It absorbs a neutron to become an electron.
D) It is attracted to other protons.

TOPIC E: Constructed Response Questions

PART 1: Static Electricity

327) A tau lepton decays into an electron, an electron antineutrino, and a tau neutrino, as represented in the reaction below.

$$\tau \longrightarrow e + \bar{\nu}_e + \nu_\tau$$

On the spaces provided below, show how this reaction obeys the Law of Conservation of Charge by indicating the amount of charge on each particle.

_____e ⟶ _____e + _____e + _____e

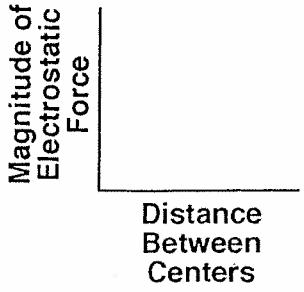
328) Two small identical metal spheres, *A* and *B*, on insulated stands, are each given a charge of $+2.0 \times 10^{-6}$ coulomb. The distance between the spheres is 2.0×10^{-1} meter. Calculate the magnitude of the electrostatic force that the charge on sphere *A* exerts on the charge on sphere *B*. [*Show all work, including the equation and substitution with units.*]

Questions 329 through 331 refer to the following:

The centers of two small charged particles are separated by a distance of 1.2×10^{-4} meter. The charges on the particles are $+8.0 \times 10^{-19}$ coulomb and $+4.8 \times 10^{-19}$ coulomb, respectively.

329) Calculate the magnitude of the electrostatic force between the two particles described in the reading passage. [*Show all work, including the equation and substitution with units.*]

330) On the axes provided below, sketch a graph showing the relationship between the magnitude of the electrostatic force between the two charged particles described in the reading passage and the distance between the centers of these particles.



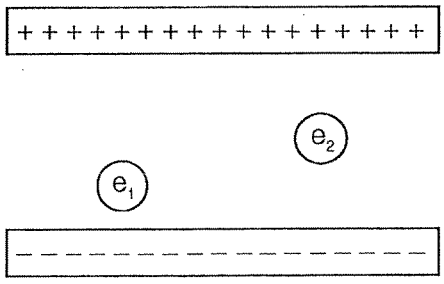
331) On the diagram provided below, draw *at least* four electric field lines in the region between the two positively charged particles.

8.0×10^{-19} C ⊕ ⊕ 4.8×10^{-19} C

332) On the diagram below, sketch *at least* four electric field lines with arrowheads that represent the electric field around a negatively charged conducting sphere.

333) Two oppositely charged parallel metal plates, 1.00 centimeter apart, exert a force with a magnitude of 3.60×10^{-15} newton on an electron placed between the plates. Calculate the magnitude of the electric field strength between the plates. [*Show all work, including the equation and substitution with units.*]

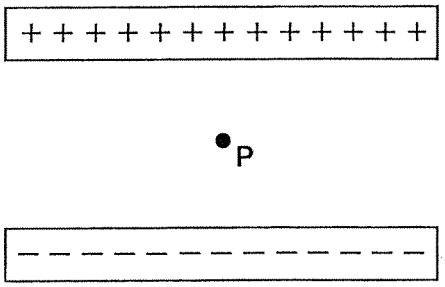
334) The diagram below represents two electrons, e_1 and e_2, located between two oppositely charged parallel plates.



Compare the magnitude of the force exerted by the electric field on e_1 to the magnitude of the force exerted by the electric field on e_2.

Questions 335 and 336 refer to the following:

The magnitude of the electric field strength between two oppositely charged parallel metal plates is 2.0 10^3 newtons per coulomb. Point *P* is located midway between the plates as shown in the diagram below.



335) On the diagram provided, sketch *at least* five electric field lines to represent the field between the two oppositely charged plates. [*Draw an arrowhead on each field line to show the proper direction.*]

336) An electron is located at point *P* between the plates shown. Calculate the magnitude of the force exerted on the electron by the electric field. [*Show all work, including the equation and substitution with units.*]

PART 2: ELECTRIC CURRENT

RESISTANCE

337) Calculate the resistance of a 900.-watt toaster operating at 120 volts. [*Show all work, including the equation and substitution with units.*]

338) Calculate the resistance of a 1.00-kilometer length of nichrome wire with a cross-sectional area of 3.50×10^{-6} meter^2 at 20 °C. [*Show all work, including the equation and substitution with units.*]

339) A length of copper wire and a 1.00-meter-long silver wire have the same cross-sectional area and resistance at 20 °C. Calculate the length of the copper wire. [*Show all work, including the equation and substitution with units.*]

340) A simple circuit consists of a 100.-ohm resistor connected to a battery. A 25-ohm resistor is to be connected in the circuit. Determine the *smallest* equivalent resistance possible when *both* resistors are connected to the battery.

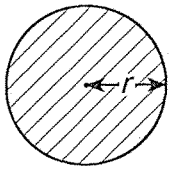
341) A 3.50-meter length of wire with a crosssectional area of 3.14×10^{-6} meter^2 is at 20° Celsius. The current in the wire is 24.0 amperes when connected to a 1.50-volt source of potential difference.

(a) Determine the resistance of the given wire.

(b) Calculate the resistivity of the given wire. [*Show all work, including the equation and substitution with units.*]

342) A 10.0-meter length of copper wire is at 20 °C. The radius of the wire is 1.0×10^{-3} meter.

Cross Section of Copper Wire



$r = 1.0 \times 10^{-3}$ m

(a) Determine the cross-sectional area of the given wire.

(b) Calculate the resistance of the given wire. [*Show all work, including the equation and substitution with units.*]

Questions 343 and 344 refer to the following:

A copper wire at 20 °C has a length of 10.0 meters and a cross-sectional area of 1.00×10^{-3} meter^2. The wire is stretched, becomes longer and thinner, and returns to 20 °C.

343) What effect does the stretching have on the given wire's resistance?

344) What effect does the stretching have on the given wire's resistivity?

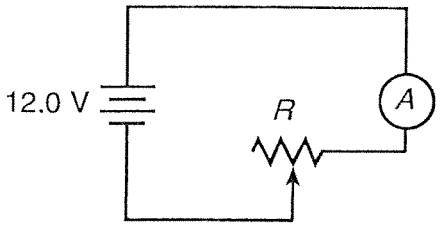
◆ CIRCUITS

345) A 6-ohm resistor and a 4-ohm resistor are connected in series with a 6-volt battery in an operating electric circuit. A voltmeter is connected to measure the potential difference across the 6-ohm resistor.

Draw a diagram of this circuit including the battery, resistors, and voltmeter using symbols from the *Reference Tables for Physical Setting/Physics*. Label each resistor with its value. [*Assume the availability of any number of wires of negligible resistance.*]

346) An electric circuit contains a source of potential difference and 5-ohm resistors that combine to give the circuit an equivalent resistance of 15 ohms. Draw a diagram of this circuit using circuit symbols given in the *Reference Tables for Physical Setting/Physics*. [*Assume the availability of any number of 5-ohm resistors and wires of negligible resistance.*]

347) A circuit contains a 12.0-volt battery, an ammeter, a variable resistor, and connecting wires of negligible resistance, as shown below.



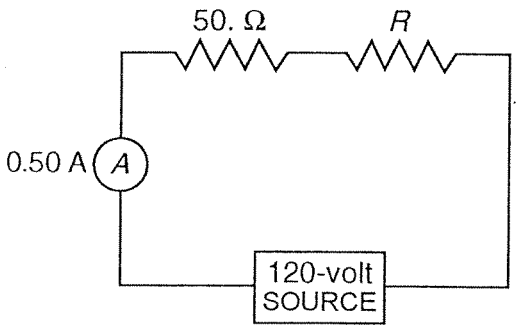
The variable resistor is a nichrome wire, maintained at 20.°C. The length of the nichrome wire may be varied from 10.0 centimeters to 90.0 centimeters. The ammeter reads 2.00 amperes when the length of the wire is 10.0 centimeters.

(a) Determine the resistance of the 10.0-centimeter length of nichrome wire.

(b) Calculate the cross-sectional area of the nichrome wire. [*Show all work, including the equation and substitution with units.*]

Questions 348 through 350 refer to the following:

A 50.-ohm resistor, an unknown resistor R, a 120-volt source, and an ammeter are connected in a complete circuit. The ammeter reads 0.50 ampere.



348) Calculate the equivalent resistance of the circuit shown. [*Show all work, including the equation and substitution with units.*]

349) Determine the resistance of resistor R shown in the diagram.

350) Calculate the power dissipated by the 50.-ohm resistor shown in the diagram. [*Show all work, including the equation and substitution with units.*]

Questions 351 through 353 refer to the following:

A 5.0-ohm resistor, a 10.0-ohm resistor, and a 15.0-ohm resistor are connected in parallel with a battery. The current through the 5.0-ohm resistor is 2.4 amperes.

351) Using the circuit symbols found in the *Reference Tables for Physical Setting/Physics*, draw a diagram of the electric circuit described in the reading passage.

352) Using the given information, calculate the amount of electrical energy expended in the 5.0-ohm resistor in 2.0 minutes. [*Show all work, including the equation and substitution with units.*]

353) A 20.0-ohm resistor is added to the given circuit in parallel with the other resistors. Describe the effect the addition of this resistor has on the amount of electrical energy expended in the 5.0-ohm resistor in 2.0 minutes.

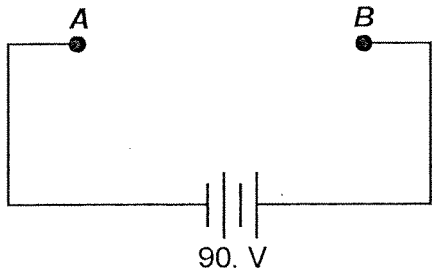
354) In the space below, draw a diagram of an operating circuit that includes:

(1) a battery as a source of potential difference

(2) two resistors in parallel with each other

(3) an ammeter that reads the total current in the circuit

355) A 15-ohm resistor, R_1, and a 30.-ohm resistor, R_2, are to be connected in parallel between points *A* and *B* in a circuit containing a 90.-volt battery.



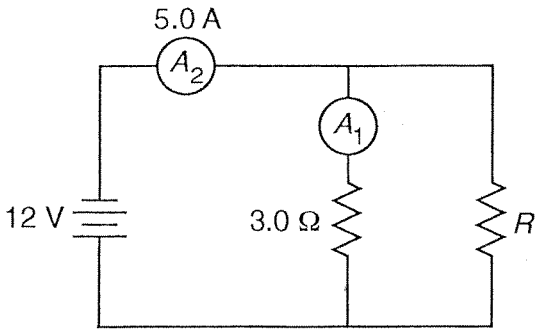
(a) Complete the diagram provided to show the two resistors connected in parallel between points *A* and *B*.

(b) Determine the potential difference across resistor R_1.

(c) Calculate the current in resistor R_1. [*Show all work, including the equation and substitution with units.*]

Questions 356 through 358 refer to the following:

A 3.0-ohm resistor, an unknown resistor, R, and two ammeters, A_1 and A_2, are connected as shown below with a 12-volt source. Ammeter A_2 reads a current of 5.0 amperes.



356) Determine the equivalent resistance of the circuit shown.

357) Calculate the current measured by ammeter A_1 in the diagram shown. [*Show all work, including the equation and substitution with units.*]

358) Calculate the resistance of the unknown resistor, R in the diagram shown. [*Show all work, including the equation and substitution with units.*]

---

359) A generator produces a 115-volt potential difference and a maximum of 20.0 amperes of current. Calculate the total electrical energy the generator produces operating at maximum capacity for 60. seconds. [*Show all work, including the equation and substitution with units.*]

360) The heating element in an automobile window has a resistance of 1.2 ohms when operated at 12 volts. Calculate the power dissipated in the heating element. [*Show all work, including the equation and substitution with units.*]

WAVE PHENOMENA

TOPIC A: *Introduction to Waves*

361) A pulse traveled the length of a stretched spring. The pulse transferred

A) energy, only
B) mass, only
C) both energy and mass
D) neither energy nor mass

362) What type of wave requires a material medium through which to travel?

A) mechanical wave
B) radio wave
C) microwave
D) light wave

363) What type of wave requires a material medium through which to travel?

A) sound
B) electromagnetic
C) infrared
D) radio

364) Which of the following types of waves requires a material medium through which to travel?

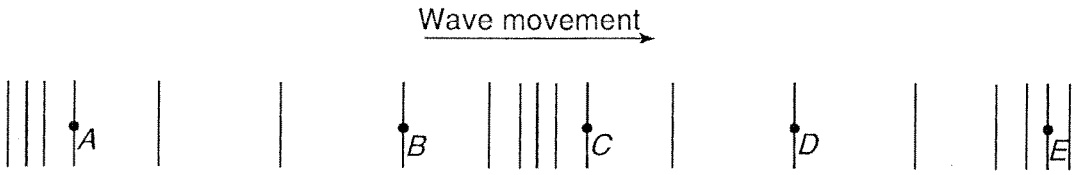
A) sound
B) radio
C) television
D) x-ray

365) A ringing bell is located in a chamber. When the air is removed from the chamber, why can the bell be seen vibrating but *not* be heard?

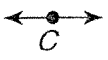
A) Light waves can travel through a vacuum, but sound waves cannot.
B) Sound waves have greater amplitude than light waves.
C) Light waves travel slower than sound waves.
D) Sound waves have higher frequency than light waves.

Questions 366 through 368 refer to the following:

A longitudinal wave moves to the right through a uniform medium, as shown below. Points *A*, *B*, *C*, *D*, and *E* represent the positions of particles of the medium.



366) Which diagram *best* represents the motion of the particle at position *C* as the given wave moves to the right?

A) 

C) 

B) 

D) 

367) The wavelength of the given wave is equal to the distance between points

A) *A* and *C*
B) *A* and *B*
C) *B* and *C*
D) *B* and *E*

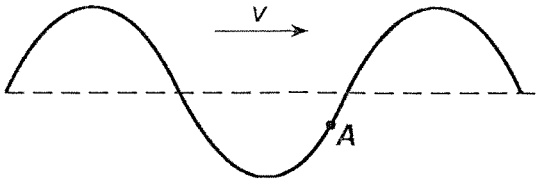
368) The energy of the given wave is related to its

A) amplitude
B) period
C) speed
D) wavelength

369) As a transverse wave travels through a medium, the individual particles of the medium move

A) perpendicular to the direction of wave travel
B) parallel to the direction of wave travel
C) in circles
D) in ellipses

370) The diagram below represents a transverse wave traveling to the right through a medium. Point *A* represents a particle of the medium.



In which direction will particle *A* move in the next instant of time?

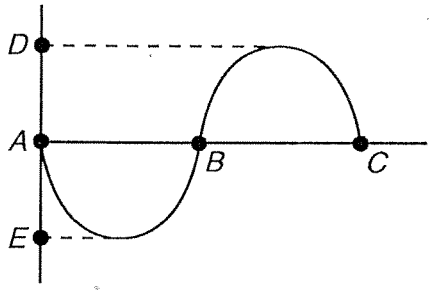
A) down
B) up
C) left
D) right

TOPIC B: *Properties of Waves*

❶ PART 1: Characteristics of Waves

◆ *Amplitude*

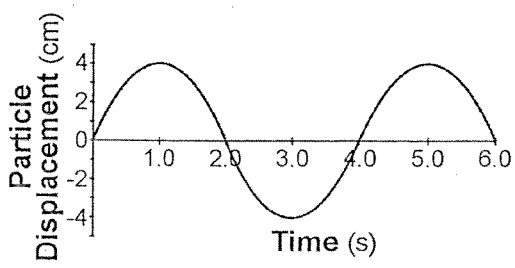
371) The diagram below represents a transverse wave.



The distance between which two points identifies the amplitude of the wave?

A) *A* and *E*
B) *A* and *B*
C) *A* and *C*
D) *D* and *E*

372) The graph below represents the displacement of a particle in a medium over a period of time.



What is the amplitude of the wave?

A) 4 cm
B) 4.0 s
C) 6.0 s
D) 8 cm

373) If the amplitude of a wave traveling in a rope is doubled, the speed of the wave in the rope will

A) remain the same
B) decrease
C) increase

374) Increasing the amplitude of a sound wave produces a sound with

A) greater loudness
B) lower speed
C) higher pitch
D) shorter wavelength

375) Which of the following statements correctly describes one characteristic of a sound wave?

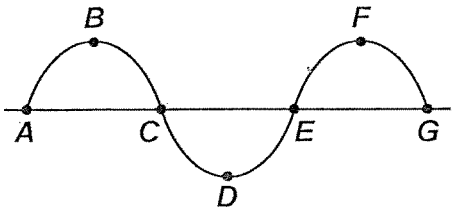
A) The amount of energy a sound wave transmits is directly related to the wave's amplitude.
B) A sound wave can travel through a vacuum.
C) A sound wave is a transverse wave.
D) The amount of energy a sound wave transmits is inversely related to the wave's frequency.

376) A periodic wave is produced by a vibrating tuning fork. The amplitude of the wave would be *greater* if the tuning fork were

A) struck harder
B) struck more softly
C) replaced by a lower frequency tuning fork
D) replaced by a higher frequency tuning fork

◆ Wavelength

377) The diagram below represents a transverse wave.



The wavelength of the wave is equal to the distance between points

A) *B* and *F*
B) *A* and *G*
C) *C* and *E*
D) *D* and *F*

378) What is the wavelength of a periodic wave having a frequency of 5.0 hertz and a speed of 10. meters per second?

A) 2.0 m
B) 0.50 m
C) 5.0 m
D) 50. m

379) What is the wavelength of a 256-hertz sound wave in air at STP?

A) 1.29 m
B) 1.17×10^{6} m
C) 0.773 m
D) 8.53×10^{-7} m

◆ Frequency

380) The product of a wave's frequency and its period is

A) one
B) its velocity
C) its wavelength
D) Planck's constant

381) If the amplitude of a wave is increased, the frequency of the wave will

A) remain the same
B) decrease
C) increase

382) The sound wave produced by a trumpet has a frequency of 440 hertz. What is the distance between successive compressions in this sound wave as it travels through air at STP?

A) 0.75 m
B) 1.5×10^{-6} m
C) 1.3 m
D) 6.8×10^{5} m

383) Astronauts traveling toward Earth in a fast-moving spacecraft receive a radio signal from an antenna on Earth. Compared to the frequency and wavelength of the radio signal emitted from the antenna, the radio signal received by the astronauts has a

A) higher frequency and a shorter wavelength
B) lower frequency and a shorter wavelength
C) lower frequency and a longer wavelength
D) higher frequency and a longer wavelength

◆ Period

384) The time required for a wave to complete one full cycle is called the wave's

A) period
B) frequency
C) velocity
D) wavelength

385) What is the period of a water wave if 4.0 complete waves pass a fixed point in 10. seconds?

A) 2.5 s
B) 0.25 s
C) 0.40 s
D) 4.0 s

386) What is the period of a 60.-hertz electromagnetic wave traveling at 3.0×10^{8} meters per second?

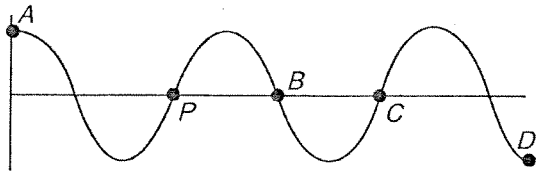
A) 1.7×10^{-2} s
B) 2.0×10^{-7} s
C) 6.0×10^{1} s
D) 5.0×10^{6} s

387) An electromagnetic wave traveling through a vacuum has a wavelength of 1.5×10^{-1} meter. What is the period of this electromagnetic wave?

A) 5.0×10^{-10} s
B) 1.5×10^{-1} s
C) 4.5×10^{7} s
D) 2.0×10^{9} s

◆ PHASE

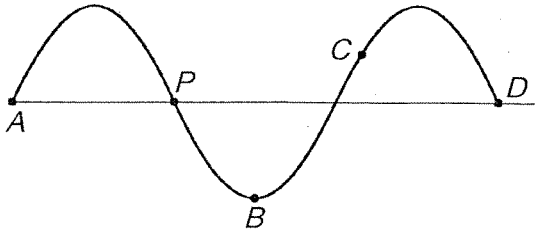
388) The diagram below represents a periodic wave.



Which point on the wave is in phase with point *P*?

A) *A*
B) *B*
C) *C*
D) *D*

389) The diagram below represents a periodic wave.



Which point on the wave is 90° out of phase with point *P*?

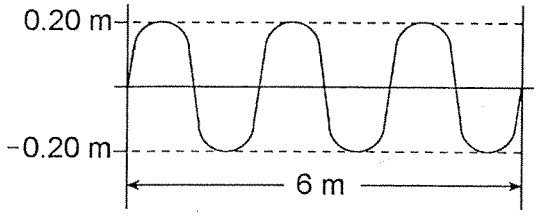
A) *A*
B) *B*
C) *C*
D) *D*

◆ SPEED

390) Which of the following units is equivalent to meters per second?

A) Hz•m
B) Hz•s
C) s/Hz
D) m/Hz

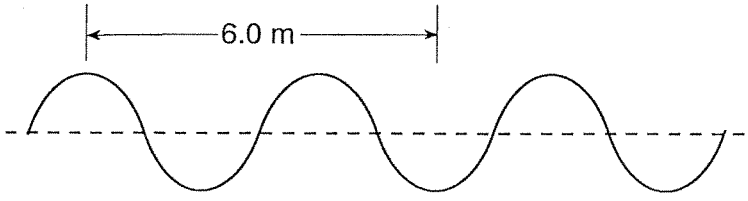
391) The diagram below represents a wave.



What is the speed of the wave if its frequency is 8.0 hertz?

A) 16 m/s
B) 48 m/s
C) 3.2 m/s
D) 1.6 m/s

392) The diagram below represents a periodic wave traveling through a uniform medium.



If the frequency of the wave is 2.0 hertz, what is the speed of the wave?

A) 8.0 m/s
B) 6.0 m/s
C) 2.0 m/s
D) 4.0 m/s

393) At an outdoor physics demonstration, a delay of 0.50 second was observed between the time sound waves left a loudspeaker and the time these sound waves reached a student through the air. If the air is at STP, how far was the student from the speaker?

A) 1.7×10^2 m
B) 1.5×10^{-3} m
C) 6.6×10^2 m
D) 1.5×10^8 m

❷ PART 2: Movement of Waves Traveling Between Mediums

394) A sound wave has a wavelength of 5.5 meters as it travels through air at STP. What is the wavelength of this sound in a medium where its speed is 1,324 meters per second?

A) 22 m
B) 1.4 m
C) 2.2 m
D) 14 m

395) Compared to the speed of a sound wave in air, the speed of a radio wave in air is

A) greater
B) less
C) the same

❸ PART 3: Doppler Effect

396) A student sees a train that is moving away from her and sounding its whistle at a constant frequency. Compared to the sound produced by the whistle, the sound observed by the student is

A) lower in pitch
B) greater in amplitude
C) a transverse wave rather than a longitudinal wave
D) higher in pitch

397) A car's horn produces a sound wave of constant frequency. As the car speeds up going away from a stationary spectator, the sound wave detected by the spectator

A) decreases in amplitude and decreases in frequency
B) decreases in amplitude and increases in frequency
C) increases in amplitude and decreases in frequency
D) increases in amplitude and increases in frequency

398) A car's horn is producing a sound wave having a constant frequency of 350 hertz. If the car moves toward a stationary observer at constant speed, the frequency of the car's horn detected by this observer may be

A) 380 Hz
B) 320 Hz
C) 330 Hz
D) 350 Hz

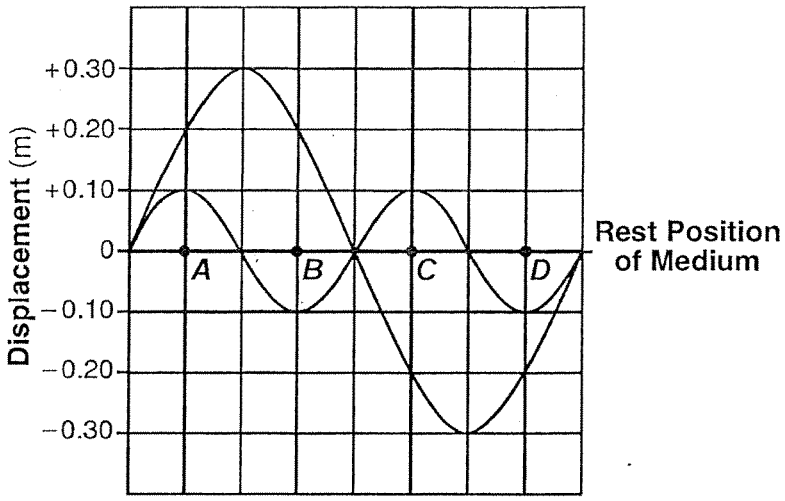
399) A police car traveling at a speed of 30.0 meters per second sounds its siren, which has a frequency of 1.00×10^3 hertz. As the police car approaches a stationary pedestrian, the pedestrian detects a siren frequency of

A) 1.10×10^3 Hz
B) 30.0 Hz
C) 9.19×10^2 Hz
D) 1.00×10^3 Hz

❹ PART 4: Interference

◆ Constructive and Destructive Interference

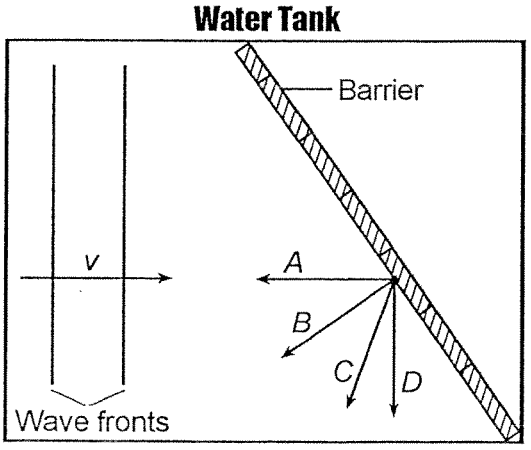
400) The diagram below shows two waves traveling in the same medium. Points *A*, *B*, *C*, and *D* are located along the rest position of the medium. The waves interfere to produce a resultant wave.



The superposition of the waves produces the *greatest* positive displacement of the medium from its rest position at point

A) *A* B) *B* C) *C* D) *D*

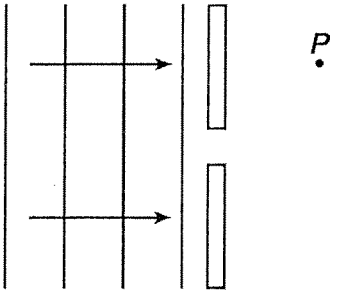
401) The diagram below represents a view from above of a tank of water in which parallel wave fronts are traveling toward a barrier.



Which arrow represents the direction of travel for the wave fronts after being reflected from the barrier?

A) *A* C) *C*
B) *B* D) *D*

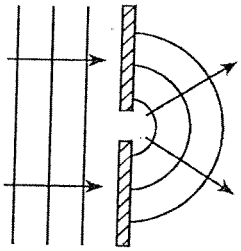
402) The diagram below shows a series of wave fronts approaching an opening in a barrier. Point *P* is located on the opposite side of the barrier.

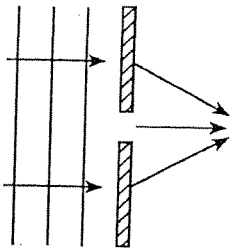


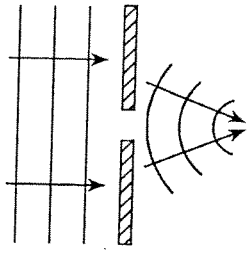
The wave fronts reach point *P* as a result of

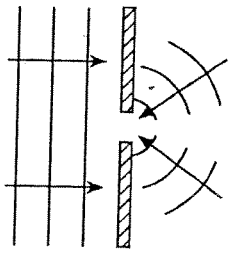
A) diffraction C) refraction
B) resonance D) reflection

403) Which diagram *best* represents the shape and direction of a series of wave fronts after they have passed through a small opening in a barrier?

A) 

B) 

C) 

D) 

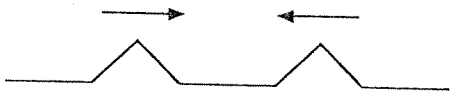
404) Two waves having the same frequency and amplitude are traveling in the same medium. Maximum constructive interference occurs at points where the phase difference between the two superposed waves is

A) 0° C) 180°
B) 90° D) 270°

405) Two waves having the same amplitude and frequency are traveling in the same medium. Maximum destructive interference will occur when the phase difference between the waves is

A) 180° C) 90°
B) 0° D) 270°

406) Two pulses traveling in the same uniform medium approach each other, as shown in the diagram below.



Which diagram *best* represents the superposition of the two pulses?

A) 

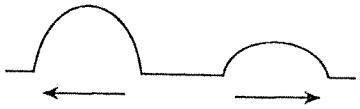
B)

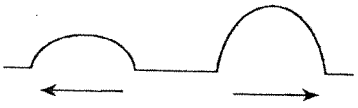
C) 

D) 

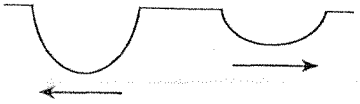
407) The diagram below represents two pulses approaching each other from opposite directions in the same medium.

Which diagram *best* represents the medium after the pulses have passed through each other?

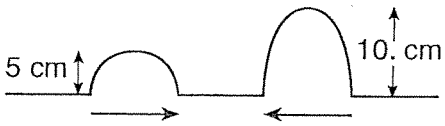
A) 

B) 

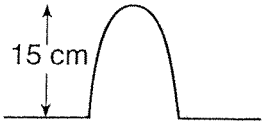
C) 

D) 

408) The diagram below shows two pulses approaching each other in a uniform medium.



Which diagram *best* represents the superposition of the two pulses?

A) 

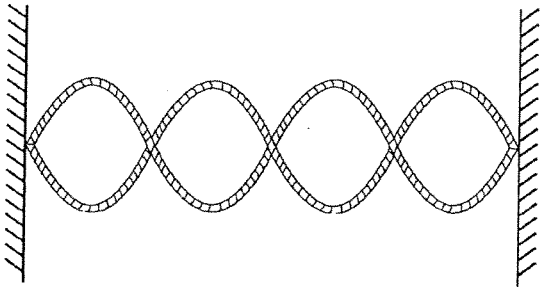
B) 

C) 

D) 

◆ PRODUCTION OF STANDING WAVES

409) The diagram below shows a standing wave in a string clamped at each end.



What is the total number of nodes and antinodes in the standing wave?

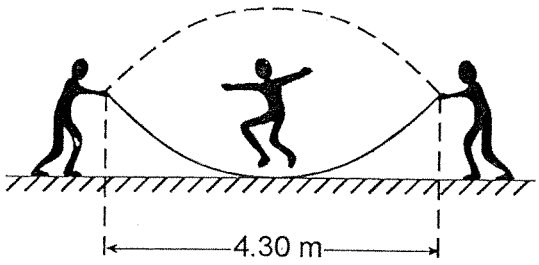
A) 5 nodes and 4 antinodes
B) 3 nodes and 2 antinodes
C) 2 nodes and 3 antinodes
D) 4 nodes and 5 antinodes

410) The diagram below represents a standing wave.

The number of nodes and antinodes shown in the diagram is

A) 6 nodes and 5 antinodes
B) 4 nodes and 5 antinodes
C) 5 nodes and 6 antinodes
D) 6 nodes and 10 antinodes

411) While playing, two children create a standing wave in a rope, as shown in the diagram below. A third child participates by jumping the rope.



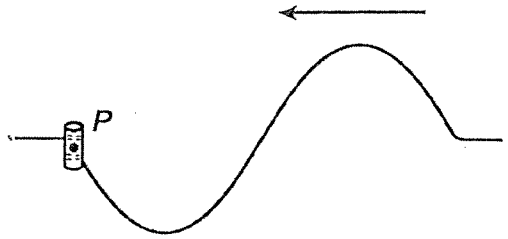
What is the wavelength of this standing wave?

A) 8.60 m
B) 2.15 m
C) 4.30 m
D) 6.45 m

412) Wave *X* travels eastward with frequency *f* and amplitude *A*. Wave *Y*, traveling in the same medium, interacts with wave *X* and produces a standing wave. Which statement about wave *Y* is correct?

A) Wave *Y* must have a frequency of *f*, an amplitude of *A*, and be traveling westward.
B) Wave *Y* must have a frequency of *f*, an amplitude of *A*, and be traveling eastward.
C) Wave *Y* must have a frequency of 2*f*, an amplitude of 3*A*, and be traveling eastward.
D) Wave *Y* must have a frequency of 3*f*, an amplitude of 2*A*, and be traveling westward.

413) The diagram below represents a transverse water wave propagating toward the left. A cork is floating on the water's surface at point *P*.



In which direction will the cork move as the wave passes point *P*?

A) down, then up, then down
B) up, then down, then up
C) left, then right, then left
D) right, then left, then right

PART 5: RESONANCE

414) What type of wave phenomenon occurs when vibrations in one object cause vibrations in a second object?

A) resonance
B) reflection
C) intensity
D) tuning

415) A 256-hertz vibrating tuning fork is brought near a non-vibrating 256-hertz tuning fork. The second tuning fork begins to vibrate. What phenomenon causes the non-vibrating tuning fork to begin to vibrate?

A) resonance
B) resistance
C) refraction
D) reflection

416) A dampened fingertip rubbed around the rim of a crystal stemware glass causes the glass to vibrate and produce a musical note. This effect is due to

A) resonance
B) refraction
C) reflection
D) rarefaction

417) Playing a certain musical note on a trumpet causes the spring on the bottom of a nearby snare drum to vibrate. This phenomenon is an example of

A) resonance
B) refraction
C) reflection
D) diffraction

418) Sound waves strike a glass and cause it to shatter. This phenomenon illustrates

A) resonance
B) refraction
C) reflection
D) diffraction

419) A car traveling at 70 kilometers per hour accelerates to pass a truck. When the car reaches a speed of 90 kilometers per hour the driver hears the glove compartment door start to vibrate. By the time the speed of the car is 100 kilometers per hour, the glove compartment door has stopped vibrating. This vibrating phenomenon is an example of

A) resonance
B) the Doppler effect
C) diffraction
D) destructive interference

420) Resonance occurs when one vibrating object transfers energy to a second object causing it to vibrate. The energy transfer is *most* efficient when, compared to the first object, the second object has the same natural

A) frequency
B) loudness
C) amplitude
D) speed

TOPIC C: *Light*

❶ PART 1: Speed of Light

421) Which of the following characteristics is the same for every color of light in a vacuum?

A) speed
B) energy
C) frequency
D) period

422) In a vacuum, all electromagnetic waves have the same

A) speed
B) phase
C) frequency
D) wavelength

423) What is the speed of a radio wave in a vacuum?

A) 3.00×10^8 m/s
B) 0 m/s
C) 3.31×10^2 m/s
D) 1.13×10^3 m/s

424) As viewed from Earth, the light from a star has lower frequencies than the light emitted by the star because the star is

A) moving away from Earth
B) moving toward Earth
C) stationary

425) Approximately how much time does it take light to travel from the Sun to Earth?

A) 5.00×10^2 s
B) 1.28×10^0 s
C) 2.00×10^{-3} s
D) 4.50×10^{19} s

426) What is the speed of light ($f = 5.09 \times 10^{14}$ Hz) in flint glass?

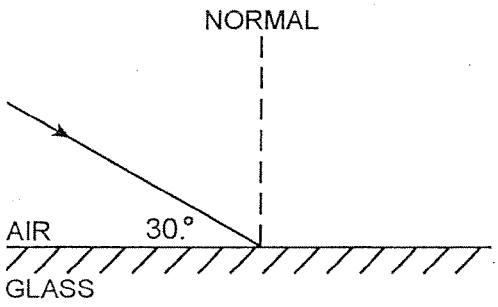
A) 1.81×10^8 m/s
B) 1.97×10^8 m/s
C) 3.00×10^8 m/s
D) 4.98×10^8 m/s

427) What is the wavelength of a light ray with frequency 5.09×10^{14} hertz as it travels through Lucite?

A) 3.93×10^{-7} m
B) 5.89×10^{-7} m
C) 3.39×10^{14} m
D) 7.64×10^{14} m

❷ PART 2: Reflection

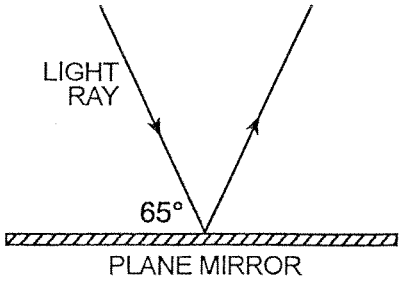
428) The diagram below represents a light ray striking the boundary between air and glass.



What would be the angle between this light ray and its reflected ray?

A) 120.°
B) 30.°
C) 60.°
D) 150.°

429) The diagram below represents a light ray reflecting from a plane mirror.

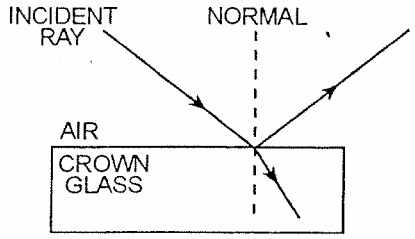


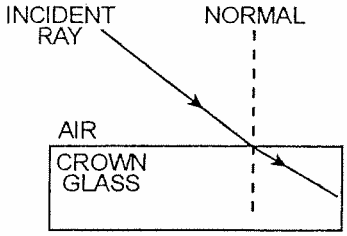
What is the angle of reflection for the light ray?

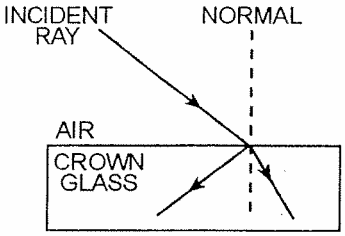
A) 25°
B) 35°
C) 50.°
D) 65°

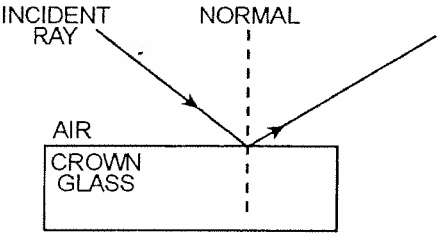
❸ PART 3: REFRACTION

430) Which diagram *best* represents the behavior of a ray of monochromatic light in air incident on a block of crown glass?

A)


B)


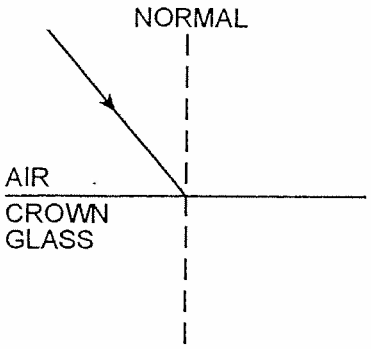
C)


D)


431) A ray of light ($f = 5.09 \times 10^{14}$ Hz) traveling in air strikes a block of sodium chloride at an angle of incidence of 30.°. What is the angle of refraction for the light ray in the sodium chloride?

A) 19° C) 40.°
B) 25° D) 49°

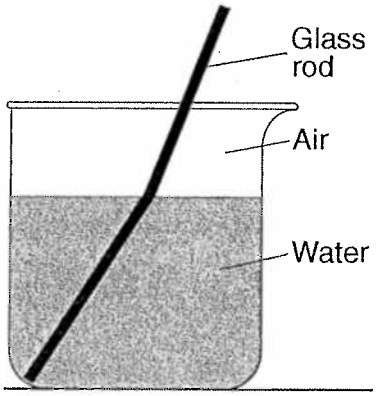
432) A ray of light ($f = 5.09 \times 10^{14}$ Hz) traveling in air is incident at an angle of 40.° on an air-crown glass interface as shown below.



What is the angle of refraction for this light ray?

A) 25° C) 40°
B) 37° D) 78°

433) A straight glass rod appears to bend when placed in a beaker of water, as shown in the diagram below.



What is the *best* explanation for this phenomenon?

A) Light is refracted as it crosses the air-water interface.
B) The water is warmer than the air.
C) Light travels faster in water than in air.
D) Light is reflected at the air-water interface.

PART 4: Absolute Index of Refraction

434) When a light wave enters a new medium and is refracted, there must be a change in the light wave's

A) speed
B) color
C) frequency
D) period

435) As yellow light ($f = 5.09 \times 10^{14}$ Hz) travels from zircon into diamond, the speed of the light

A) decreases
B) increases
C) remains the same

436) In which way does blue light change as it travels from diamond into crown glass?

A) Its speed increases.
B) Its frequency decreases.
C) Its frequency increases.
D) Its speed decreases.

437) What happens to the speed and frequency of a light ray when it passes from air into water?

A) The speed decreases and the frequency remains the same.
B) The speed decreases and the frequency increases.
C) The speed increases and the frequency increases.
D) The speed increases and the frequency remains the same.

438) What is the speed of a ray of light traveling through a substance having an absolute index of refraction of 1.1?

A) 2.7×10^8 m/s
B) 1.1×10^8 m/s
C) 3.0×10^8 m/s
D) 3.3×10^8 m/s

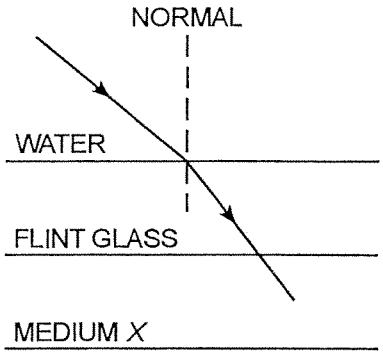
439) A light ray traveling in air enters a second medium and its speed slows to 1.71×10^8 meters per second. What is the absolute index of refraction of the second medium?

A) 1.75
B) 1.00
C) 0.570
D) 1.94

440) The speed of light in a piece of plastic is 2.00×10^8 meters per second. What is the absolute index of refraction of this plastic?

A) 1.50
B) 1.00
C) 0.670
D) 1.33

441) A ray of monochromatic yellow light ($f = 5.09 \times 10^{14}$ Hz) passes from water through flint glass and into medium X, as shown below.



The absolute index of refraction of medium X is

A) equal to 1.66
B) less than 1.33
C) greater than 1.33 and less than 1.52
D) greater than 1.52 and less than 1.66

PART 5: Wave Nature of Light (Diffraction)

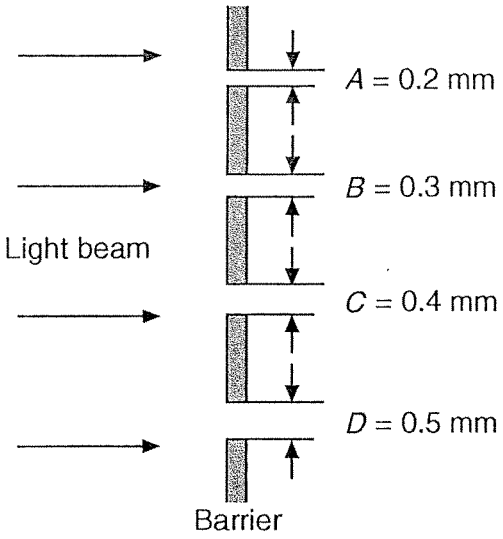
442) Parallel wave fronts incident on an opening in a barrier are diffracted. For which combination of wavelength and size of opening will diffraction effects be *greatest*?

A) long wavelength and narrow opening
B) short wavelength and narrow opening
C) short wavelength and wide opening
D) long wavelength and wide opening

443) A wave of constant wavelength diffracts as it passes through an opening in a barrier. As the size of the opening is increased, the diffraction effects

A) decrease
B) increase
C) remain the same

444) A beam of monochromatic light approaches a barrier having four openings, *A*, *B*, *C*, and *D*, of different sizes as shown below.



Which opening will cause the *greatest* diffraction?

A) *A* C) *C*
B) *B* D) *D*

PART 6: Electromagnetic Spectrum

Questions 445 and 446 refer to the following:

The spectrum of visible light emitted during transitions in excited hydrogen atoms is composed of blue, green, red, and violet lines.

445) What characteristic of light determines the amount of energy carried by a photon of the light?

A) frequency C) phase
B) amplitude D) velocity

446) Which color of light in the visible hydrogen spectrum described has photons of the *shortest* wavelength?

A) violet C) green
B) blue D) red

447) A microwave and an x-ray are traveling in a vacuum. Compared to the wavelength and period of the microwave, the x-ray has a wavelength that is

A) shorter and a period that is shorter
B) longer and a period that is shorter
C) longer and a period that is longer
D) shorter and a period that is longer

448) What color of light has a wavelength of 5.0×10^{-7} meter in air?

A) green C) orange
B) blue D) violet

449) Which of the following wavelengths is in the infrared range of the electromagnetic spectrum?

A) 100 μm C) 100 mm
B) 100 nm D) 100 m

450) An electromagnetic AM-band radio wave could have a wavelength of

A) 500 m
B) 5 m
C) 0.005 m
D) 5,000,000 m

451) A photon of light traveling through space with a wavelength of 6.0×10^{-7} meter has an energy of

A) 3.3×10^{-19} J
B) 4.0 10-40 J
C) 5.4×10^{10} J
D) 5.0×10^{14} J

452) A television remote control is used to direct pulses of electromagnetic radiation to a receiver on a television. This communication from the remote control to the television illustrates that electromagnetic radiation

A) transfers energy without transferring mass
B) is a longitudinal wave
C) possesses energy inversely proportional to its frequency
D) diffracts and accelerates in air

TOPIC D: *Constructed Response Questions*

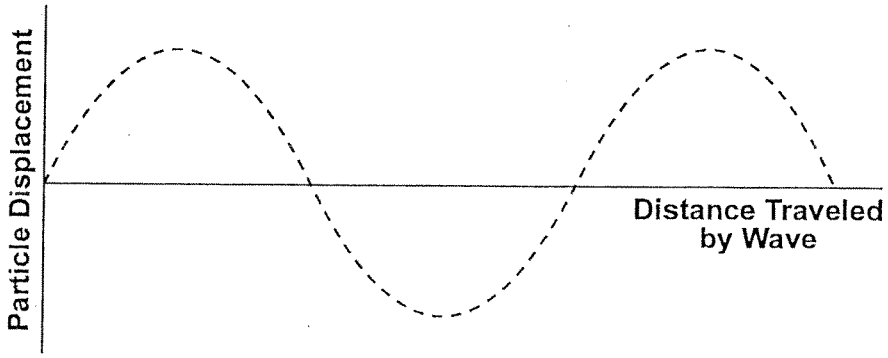
❶ PART 1: Introduction to Waves

453) A student and a physics teacher hold opposite ends of a horizontal spring stretched from west to east along a tabletop. Identify the directions in which the student should vibrate the end of the spring to produce transverse periodic waves.

❷ PART 2: Properties of Waves

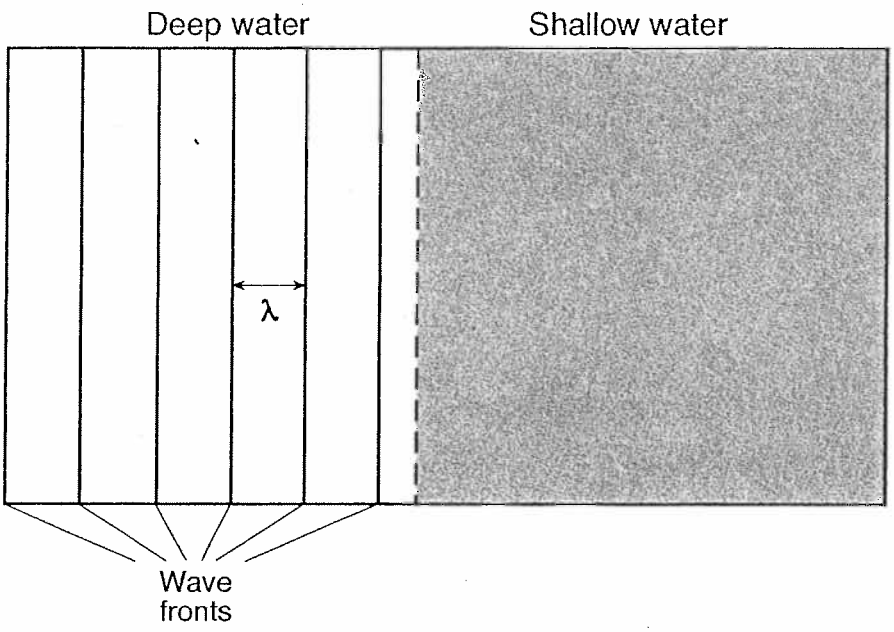
◆ *Characteristics of Waves*

454) The diagram below represents a periodic transverse wave traveling in a uniform medium.



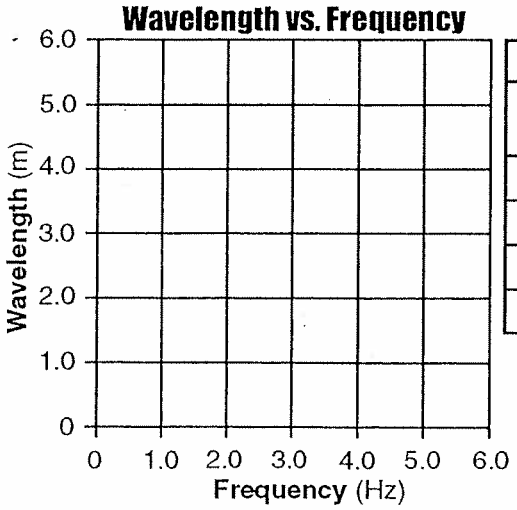
On the diagram provided, draw a wave having *both* a smaller amplitude and the same wavelength as the given wave.

455) A wave generator having a constant frequency produces parallel wave fronts in a tank of water of two different depths. The diagram below represents the wave fronts in the deep water.



As the wave travels from the deep water into the shallow water, the speed of the waves decreases. On the diagram provided, use a straightedge to draw at least three lines to represent the wave fronts, with appropriate spacing, in the shallow water.

456) A student generates a series of transverse waves of varying frequency by shaking one end of a loose spring. All the waves move along the spring at a speed of 6.0 meters per second.



Data Table

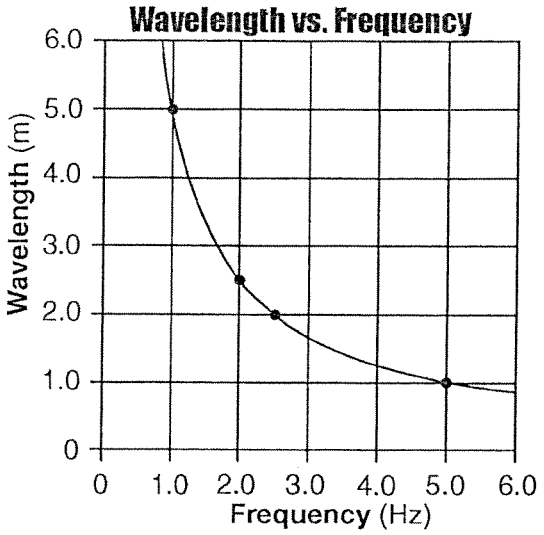
Frequency (Hz)	Wavelength (m)
1.0	
2.0	
3.0	
6.0	

(a) Complete the data table by determining the wavelengths for the frequencies given.

(b) On the grid provided, plot the data points for wavelength versus frequency.

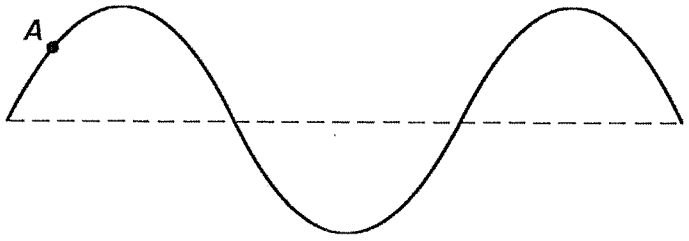
(c) Draw the best-fit line or curve.

457) The graph below represents the relationship between wavelength and frequency of waves created by two students shaking the ends of a loose spring.

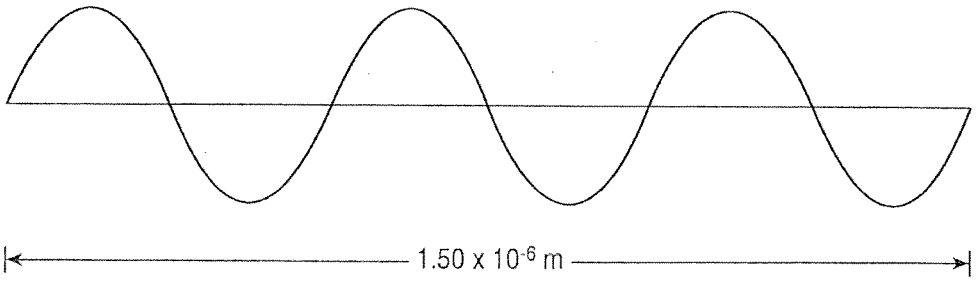


Calculate the speed of the waves generated in the spring. [*Show all work, including the equation and substitution with units.*]

458) The diagram below represents a transverse wave moving on a uniform rope with point *A* labeled as shown. On the diagram provided, mark an **X** at the point on the wave that is 180° out of phase with point *A*.



459) A 1.50×10^{-6} meter-long segment of an electromagnetic wave having a frequency of 6.00×10^{14} hertz is represented below.



On the diagram provided, mark *two* points on the wave that are in phase with each other. Label each point with the letter *P*.

460) A stationary research ship uses sonar to send a 1.18×10^3-hertz sound wave down through the ocean water. The reflected sound wave from the flat ocean bottom 324 meters below the ship is detected 0.425 second after it was sent from the ship.

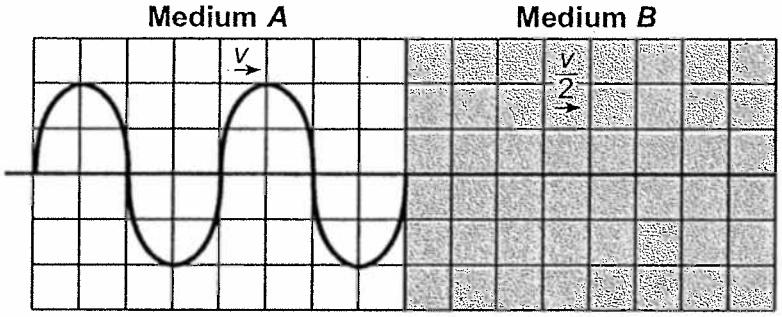
(a) Using the given information, calculate the speed of the sound wave in the ocean water. [*Show all work, including the equation and substitution with units.*]

(b) Calculate the wavelength of the sound wave in the ocean water. [*Show all work, including the equation and substitution with units.*]

(c) Determine the period of the sound wave in the ocean water.

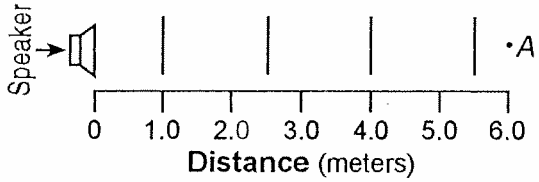
◆ Movement of Waves Traveling Between Mediums

461) A periodic wave travels at speed v through medium A. The wave passes with all its energy into medium B. The speed of the wave through medium B is $\frac{v}{2}$. On the diagram provided below, draw the wave as it travels through medium B. [*Show at least one full wave.*]



◆ Doppler Effect

462) The vertical lines in the diagram below represent compressions in a sound wave of constant frequency propagating to the right from a speaker toward an observer at point A.

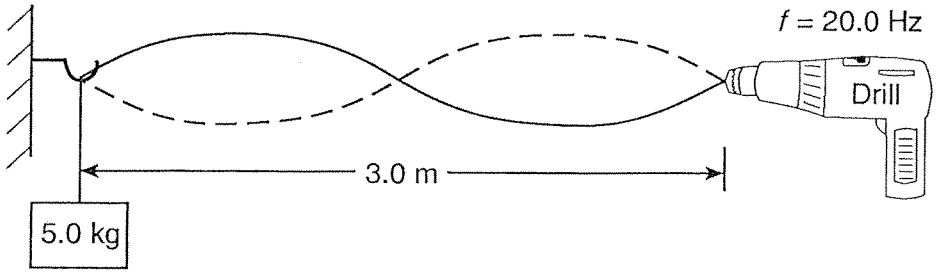


(a) Determine the wavelength of the sound wave.

(b) The speaker is then moved at constant speed toward the observer at A. Compare the wavelength of the sound wave received by the observer while the speaker is moving to the wavelength observed when the speaker was at rest.

◆ *Interference*

463) One end of a rope is attached to a variable speed drill and the other end is attached to a 5.0-kilogram mass. The rope is draped over a hook on a wall opposite the drill. When the drill rotates at a frequency of 20.0 Hz, standing waves of the same frequency are set up in the rope. The diagram below shows such a wave pattern.



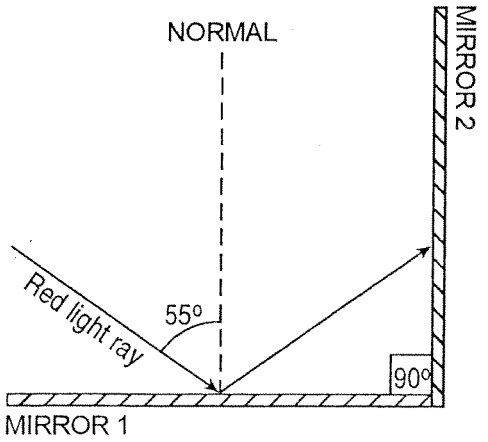
(a) Determine the wavelength of the waves producing the standing wave pattern.

(b) Calculate the speed of the wave in the rope. [*Show all work, including the equation and substitution with units.*]

❸ PART 3: Light

◆ *Reflection*

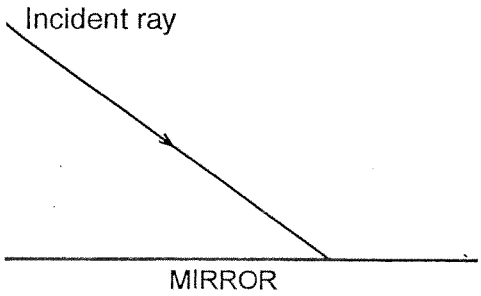
464) Two plane mirrors are positioned perpendicular to each other as shown below. A ray of monochromatic red light is incident on mirror 1 at an angle of 55°. This ray is reflected from mirror 1 and then strikes mirror 2.



(a) Determine the angle at which the given ray is incident on mirror 2.

(b) On the diagram above, use a protractor and a straightedge to draw the ray of light as it is reflected from mirror 2.

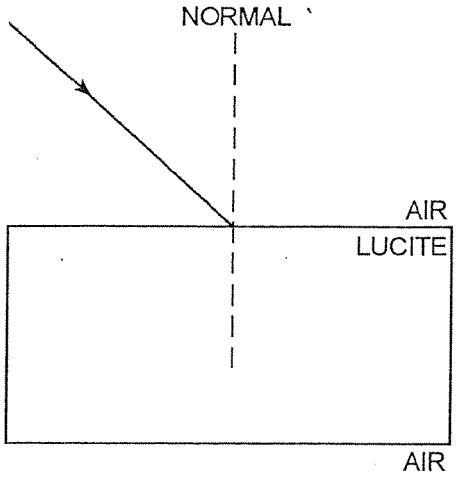
465) The diagram below represents a ray of light incident on a plane mirror.



Using a protractor and straightedge, on the diagram provided, construct the reflected ray for the incident ray shown.

◆ Refraction

466) A monochromatic light ray ($f = 5.09 \times 10^{14}$ Hz) traveling in air is incident on the surface of a rectangular block of Lucite.

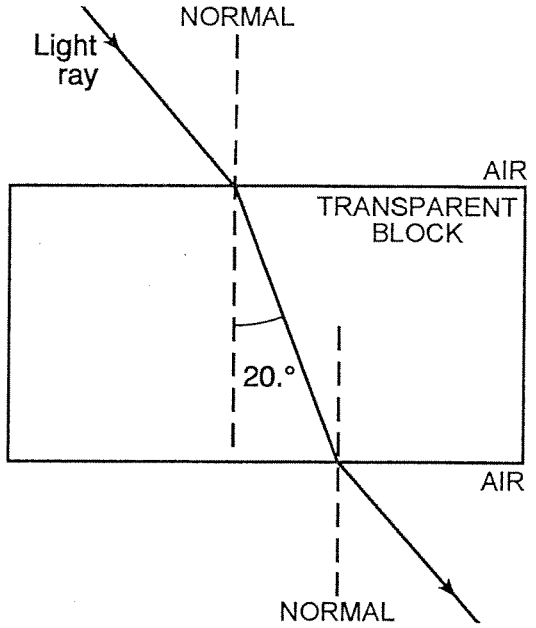


(a) Measure the angle of incidence for the light ray to the nearest degree.

(b) Calculate the angle of refraction of the light ray when it enters the Lucite block. [*Show all work, including the equation and substitution with units.*]

(c) What is the angle of refraction of the light ray as it emerges from the Lucite block back into air?

467) A ray of monochromatic light ($f = 5.09 \times 10^{14}$ Hz) passes through air and a rectangular transparent block, as shown in the diagram below.



(a) Using a protractor, determine the angle of incidence of the light ray as it enters the transparent block from air.

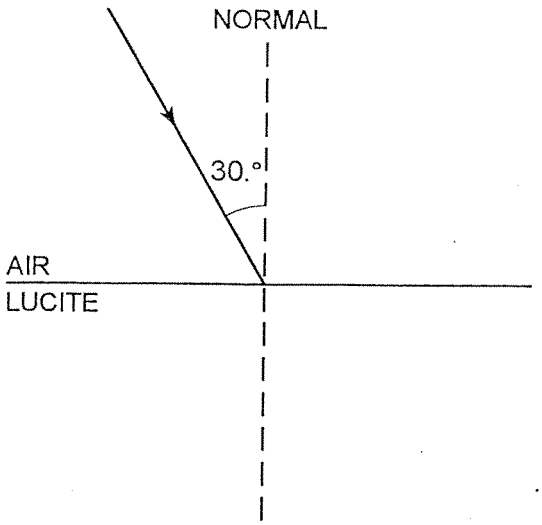
(b) Calculate the absolute index of refraction for the medium of the transparent block. [*Show all work, including the equation and substitution with units.*]

(c) Calculate the speed of the light ray in the transparent block. [*Show all work, including the equation and substitution with units.*]

468) A ray of monochromatic light ($f = 5.09 \times 10^{14}$ Hz) passes from air into Lucite at an angle of incidence of 30.°.

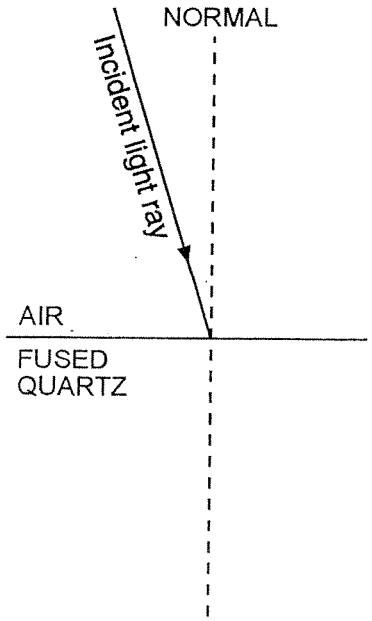
(a) Calculate the angle of refraction of the ray in the Lucite. [*Show all work, including the equation and substitution with units.*]

(b) Using a protractor and straightedge, draw the refracted ray in the Lucite on the diagram below.



Questions 469 through 472 refer to the following:

The diagram below shows a light ray ($f = 5.09 \times 10^{14}$ Hz) in air, incident on a boundary with fused quartz. At the boundary, part of the light is refracted and part of the light is reflected.



469) Using a protractor, measure the angle of incidence of the light ray in the diagram provided at the air-fused quartz boundary.

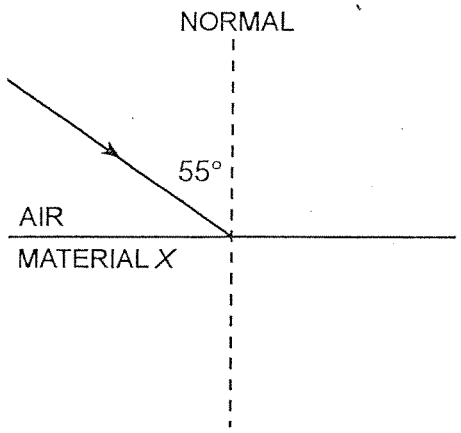
470) Calculate the angle of refraction of the incident light ray in the diagram. [*Show all work, including the equation and substitution with units.*]

471) Using a protractor and straightedge, construct the refracted light ray in the fused quartz on the diagram provided.

472) Using a protractor and straightedge, construct the reflected light ray on the diagram provided.

Questions 473 through 476 refer to the following:

A ray of light ($f = 5.09\ \ 10^{14}$ Hz) is incident on the boundary between air and an unknown material X at an angle of incidence of 55°, as shown below. The absolute index of refraction of material X is 1.66.



473) Using the given information, identify a substance of which material X may be composed.

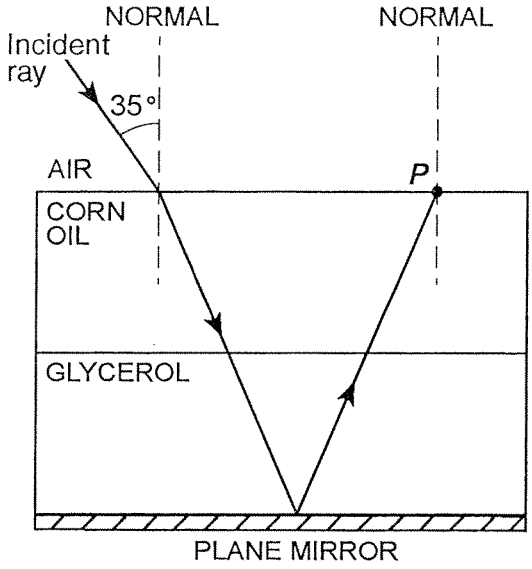
474) Using the given information, determine the speed of this ray of light in material X.

475) Using the given information, calculate the angle of refraction of the ray of light in material X. [*Show all work, including the equation and substitution with units.*]

476) On the diagram provided, use a straightedge and protractor to draw the refracted ray of light in material X.

Questions 477 through 479 refer to the following:

A ray of monochromatic light having a frequency of 5.09×10^{14} hertz is incident on an interface of air and corn oil at an angle of 35° as shown. The ray is transmitted through parallel layers of corn oil and glycerol and is then reflected from the surface of a plane mirror, located below and parallel to the glycerol layer. The ray then emerges from the corn oil back into the air at point P.



477) Calculate the angle of refraction of the light ray in the given diagram as it enters the corn oil from air. [*Show all work, including the equation and the substitution with units.*]

478) Explain why the ray in the given diagram does *not* bend at the corn oil-glycerol interface.

479) On the diagram provided, use a protractor and straight-edge to construct the refracted ray representing the light emerging at point P into air.

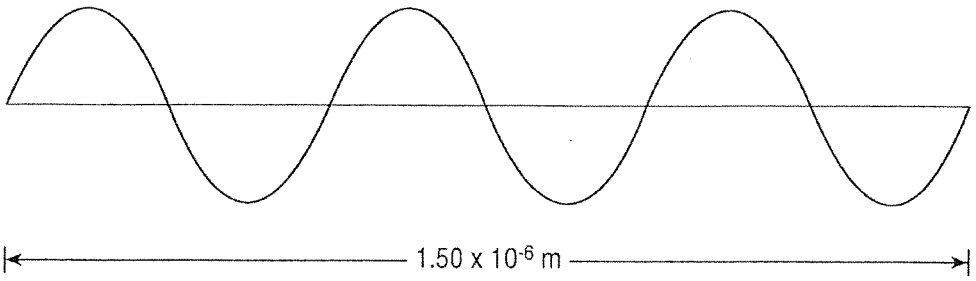
◆ Absolute Index of Refraction

480) A beam of monochromatic light has a wavelength of 5.89×10^{-7} meter in air. Calculate the wavelength of this light in diamond. [*Show all work, including the equation and substitution with units.*]

481) An electromagnetic wave of wavelength 5.89×10^{-7} meter traveling through air is incident on an interface with corn oil. Calculate the wavelength of the electromagnetic wave in corn oil. [*Show all work, including the equation and substitution with units.*]

◆ Electromagnetic Spectrum

482) A 1.50×10^{-6} meter-long segment of an electromagnetic wave having a frequency of 6.00×10^{14} hertz is represented below.



According to the *Reference Tables for Physical Setting/Physics*, which type of electromagnetic wave does the segment in the given diagram represent?

MODERN PHYSICS

TOPIC A: *Dual Nature of Light*

483) Light demonstrates the characteristics of
- A) both particles and waves
- B) particles, only
- C) waves, only
- D) neither particles nor waves

484) Which of the following phenomenons provides evidence that light has a wave nature?
- A) diffraction of light passing through a narrow opening
- B) emission of light from an energy-level transition in a hydrogen atom
- C) absorption of light by a black sheet of paper
- D) reflection of light from a mirror

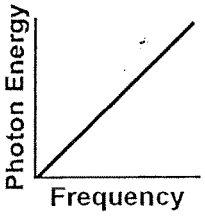
485) Moving electrons are found to exhibit properties of
- A) both particles and waves
- B) particles, only
- C) waves, only
- D) neither particles nor waves

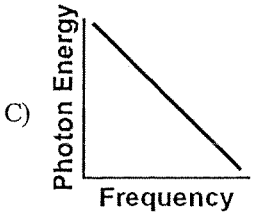
486) On the atomic level, energy and matter exhibit the characteristics of
- A) both particles and waves
- B) particles, only
- C) waves, only
- D) neither particles nor waves

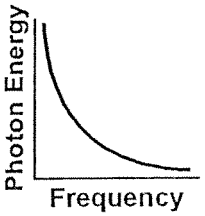
TOPIC B: *Quantum Theory*

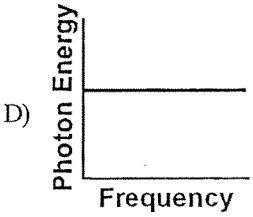
PART 1: Energy of Photons (Quanta)

487) Which graph *best* represents the relationship between photon energy and photon frequency?

A)


C)


B)


D)


488) The slope of a graph of photon energy versus photon frequency represents

A) Planck's constant
B) the mass of a photon
C) the speed of light
D) the speed of light squared

489) A variable-frequency light source emits a series of photons. As the frequency of the photon increases, what happens to the energy and wavelength of the photon?

A) The energy increases and the wavelength decreases.
B) The energy decreases and the wavelength decreases.
C) The energy decreases and the wavelength increases.
D) The energy increases and the wavelength increases.

❷ PART 2: PHOTOELECTRIC EQUATION

490) An electron in a mercury atom drops from energy level *f* to energy level *c* by emitting a photon having an energy of

A) 2.84 eV
B) 8.20 eV
C) 5.52 eV
D) 2.68 eV

491) A mercury atom in the ground state absorbs 20.00 electronvolts of energy and is ionized by losing an electron. How much kinetic energy does this electron have after the ionization?

A) 9.62 eV
B) 6.40 eV
C) 10.38 eV
D) 13.60 eV

492) An electron in the *c* level of a mercury atom returns to the ground state. Which of the following photon energies could *not* be emitted by the atom during this process?

A) 5.43 eV
B) 0.22 eV
C) 4.64 eV
D) 4.86 eV

❸ PART 3: PHOTON-PARTICLE COLLISION

493) A photon having an energy of 9.40 electronvolts strikes a hydrogen atom in the ground state. Why is the photon *not* absorbed by the hydrogen atom?

A) The photon's energy is too small.
B) The atom's orbital electron is moving too fast.
C) The photon striking the atom is moving too fast.
D) The photon is being repelled by electrostatic force.

494) What is the minimum total energy released when an electron and its antiparticle (positron) annihilate each other?

A) 1.64×10^{-13} J
B) 8.20×10^{-14} J
C) 5.47×10^{-22} J
D) 2.73×10^{-22} J

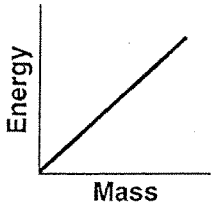
❹ PART 4: PHOTON MOMENTUM

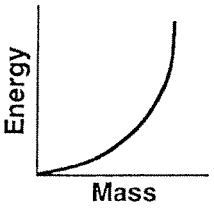
495) The momentum of a photon, p, is given by the equation $p = \frac{h}{\lambda}$ where h is Planck's constant and λ is the photon's wavelength. Which of the following equations correctly represents the energy of a photon in terms of its momentum?

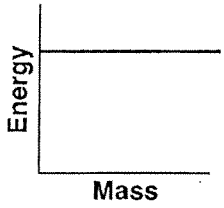
A) $E_{\text{photon}} = pc$
B) $E_{\text{photon}} = phc$
C) $E_{\text{photon}} = \frac{hp}{c}$
D) $E_{\text{photon}} = \frac{p}{c}$

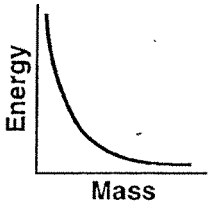
PART 5: MASS-ENERGY RELATIONSHIP

496) Which graph *best* represents the relationship between energy and mass when matter is converted into energy?

A)


B)


C)


D)


497) The energy produced by the complete conversion of 2.0×10^{-5} kilogram of mass into energy is

A) 1.8 TJ
B) 6.0 GJ
C) 1.8 MJ
D) 6.0 kJ

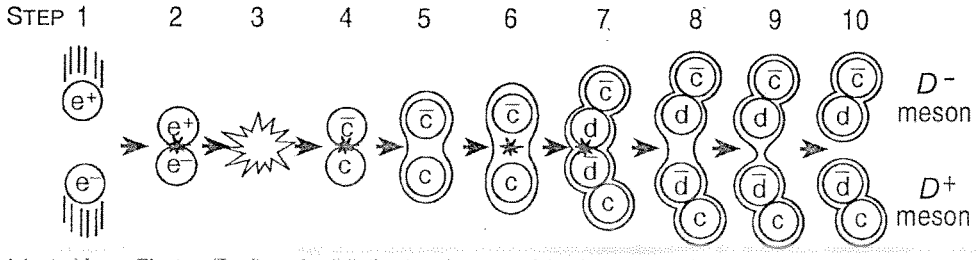
498) What total mass must be converted into energy to produce a gamma photon with an energy of 1.03×10^{-13} joule?

A) 1.14×10^{-30}
B) 3.43×10^{-22}
C) 3.09×10^{-5}
D) 8.75×10^{29}

499) The total conversion of 1.00 kilogram of the Sun's mass into energy yields

A) 9.00×10^{16} J
B) 9.31×10^{2} MeV
C) 8.38×10^{19} MeV
D) 3.00×10^{8} J

500) The diagram below represents the sequence of events (steps 1 through 10) resulting in the production of a D^- meson and a D^+ meson. An electron and a positron (antielectron) collide (step 1), annihilate each other (step 2), and become energy (step 3). This energy produces an anticharm quark and a charm quark (step 4), which then split apart (steps 5 through 7). As they split, a down quark and an antidown quark are formed, leading to the final production of a D^- meson and a D^+ meson (steps 8 through 10).



Adapted from: Electron/Positron Annihilation http:/www.particleadventure.org/frameless/eedd.html 7/23/2007

Which statement *best* describes the changes that occur in this sequence of events?

A) Matter is converted into energy and then energy is converted into matter.
B) Energy is converted into matter and then matter is converted into energy.
C) Isolated quarks are being formed from baryons.
D) Hadrons are being converted into leptons.

TOPIC D: *Particle Physics*

❶ PART 1: Fundamental Forces

501) The particles in a nucleus are held together primarily by the

A) strong force
B) gravitational force
C) electrostatic force
D) magnetic force

502) What fundamental force holds quarks together to form particles such as protons and neutrons?

A) strong force
B) electromagnetic force
C) gravitational force
D) weak force

503) Which particles are *not* affected by the strong force?

A) electrons
B) hadrons
C) protons
D) neutrons

504) A helium atom consists of two protons, two electrons, and two neutrons. In the helium atom, the strong force is a fundamental interaction between the

A) neutrons and protons
B) electrons, only
C) electrons and protons
D) neutrons and electrons

❷ PART 2: Subatomic Particles

505) A particle that is composed of two up quarks and one down quark is a

A) proton
B) meson
C) neutron
D) positron

506) A deuterium nucleus consists of one proton and one neutron. The quark composition of a deuterium nucleus is

A) 3 up quarks and 3 down quarks
B) 2 up quarks and 2 down quarks
C) 2 up quarks and 4 down quarks
D) 4 up quarks and 2 down quarks

507) What is the total number of quarks in a helium nucleus consisting of 2 protons and 2 neutrons?

A) 12
B) 16
C) 8
D) 4

508) A particle unaffected by an electric field could have a quark composition of

A) *css*
B) *bbb*
C) *udc*
D) *uud*

509) Compared to the mass and charge of a proton, an antiproton has

A) the same mass and the opposite charge
B) the same mass and the same charge
C) greater mass and the same charge
D) greater mass and the opposite charge

Questions 510 and 511 refer to the following:

The table below shows data about various subatomic particles.

Subatomic Particle Table

Symbol	Name	Quark Content	Electric Charge	Mass (GeV/c^2)
p	proton	uud	+1	0.938
$\bar{p}$	antiproton	$\bar{u}\bar{u}\bar{d}$	−1	0.938
n	neutron	udd	0	0.940
λ	lambda	uds	0	1.116
Ω^-	omega	sss	−1	1.672

510) Which particle listed on the given table has the opposite charge of, and is more massive than, a proton?

A) omega
B) antiproton
C) neutron
D) lambda

511) All the particles listed on the given table are classified as

A) hadrons
B) mesons
C) antimatter
D) leptons

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512) A subatomic particle could have a charge of

A) 3.2×10^{-19} C
B) 5.0×10^{-20} C
C) 8.0×10^{-20} C
D) 5.0×10^{-19} C

513) If an object has a net negative charge of 4.0 coulombs, the object possesses

A) 2.5×10^{19} more electrons than protons
B) 6.3×10^{18} more electrons than protons
C) 6.3×10^{18} more protons than electrons
D) 2.5×10^{19} more protons than electrons

514) Baryons may have charges of

A) -1e and +1e
B) +1e and $+\frac{4}{3}$e
C) +2e and +3e
D) -2e and $-\frac{2}{3}$e

515) An alpha particle consists of two protons and two neutrons. What is the charge of an alpha particle?

A) 3.20×10^{-19} C
B) 1.25×10^{19} C
C) 2.00 C
D) 6.40×10^{-19} C

516) The charge of an antistrange quark is approximately

A) $+5.33 \times 10^{-20}$ C
B) -5.33×10^{-20} C
C) $+5.33 \times 10^{20}$ C
D) -5.33×10^{20} C

TOPIC E: *Constructed Response Questions*

PART 2: Quantum Theory

517) The energy required to separate the 3 protons and 4 neutrons in the nucleus of a lithium atom is 39.3 megaelectronvolts. Determine the mass equivalent of this energy, in universal mass units.

518) A photon with a wavelength of 2.29×10^{-7} meter strikes a mercury atom in the ground state.

(a) Calculate the energy, in joules, of this photon. [*Show all work, including the equation and substitution with units.*]

(b) Determine the energy, in electronvolts, of this photon.

(c) Based on your answer to *part (b)*, state if this photon can be absorbed by the mercury atom. [*Explain your answer.*]

519) Calculate the wavelength of a photon having 3.26×10^{-19} joule of energy. [*Show all work, including the equation and substitution with units.*]

520) In a mercury atom, as an electron moves from energy level *i* to energy level *a*, a single photon is emitted.

(a) Determine the energy, in electronvolts, of the emitted photon.

(b) Determine the energy of the photon, in joules.

521) As a mercury atom absorbs a photon of energy, an electron in the atom changes from energy level *d* to energy level *e*.

(a) Determine the energy of the absorbed photon in electronvolts.

(b) Express the energy of the absorbed photon in joules.

(c) Calculate the frequency of the absorbed photon. [*Show all work, including the equation and substitution with units.*]

(d) Based on your calculated value of the frequency of the absorbed photon in *part (c)*, determine its classification in the electromagnetic spectrum.

Questions 522 through 524 refer to the following:

A photon with a frequency of 5.48×10^{14} hertz is emitted when an electron in a mercury atom falls to a lower energy level.

522) Identify the color of light associated with the photon described in the given passage.

523) Calculate the energy of the photon described in the given passage in joules. [*Show all work, including the equation and substitution with units.*]

524) Determine the energy of the photon described in the passage provided in electronvolts.

Questions 525 through 527 refer to the following:

A photon with a frequency of 5.02×10^{14} hertz is absorbed by an excited hydrogen atom. This causes the electron to be ejected from the atom, forming an ion.

525) Calculate the energy of the photon described in joules. [*Show all work, including the equation and substitution with units.*]

526) Determine the energy of the photon described in electronvolts.

527) What is the number of the lowest energy level (closest to the ground state) of a hydrogen atom that contains an electron that would be ejected by the absorption of the photon described?

528) In the first nuclear reaction using a particle accelerator, accelerated protons bombarded lithium atoms, producing alpha particles and energy. The energy resulted from the conversion of mass into energy. The reaction can be written as shown below.

$$^{1}_{1}H + {}^{7}_{3}Li \rightarrow {}^{4}_{2}He + {}^{4}_{2}He + \text{energy}$$

DATA TABLE:

Particle	Symbol	Mass (u)
proton	$^{1}_{1}H$	1.007 83
lithium atom	$^{7}_{3}Li$	7.016 00
alpha particle	$^{4}_{2}He$	4.002 60

(a) Determine the difference between the total mass of a proton plus a lithium atom, $^{1}_{1}H + {}^{7}_{3}Li$, and the total mass of two alpha particles, $^{4}_{2}He + {}^{4}_{2}He$, in universal mass units.

(b) Determine the energy in megaelectronvolts produced in the reaction of a proton with a lithium atom.

❹ PART 4: PARTICLE PHYSICS

Questions 529 through 532 refer to the following:

MORE SCI-THAN FI, PHYSICISTS CREATE ANTIMATTER

Physicists working in Europe announced yesterday that they had passed through nature's looking glass and had created atoms made of antimatter, or antiatoms, opening up the possibility of experiments in a realm once reserved for science fiction writers. Such experiments, theorists say, could test some of the basic tenets of modern physics and light the way to a deeper understanding of nature.

By corralling [holding together in groups] clouds of antimatter particles in a cylindrical chamber laced with detectors and electric and magnetic fields, the physicists assembled antihydrogen atoms, the looking glass equivalent of hydrogen, the most simple atom in nature. Whereas hydrogen consists of a positively charged proton circled by a negatively charged electron, in antihydrogen the proton's counterpart, a positively charged antiproton, is circled by an antielectron, otherwise known as a positron.

According to the standard theories of physics, the antimatter universe should look identical to our own. Antihydrogen and hydrogen atoms should have the same properties, emitting the exact same frequencies of light, for example....

Antimatter has been part of physics since 1927 when its existence was predicted by the British physicist Paul Dirac. The antielectron, or positron, was discovered in 1932. According to the theory, matter can only be created in particleantiparticle pairs. It is still a mystery, cosmologists say, why the universe seems to be overwhelmingly composed of normal matter.

—Dennis Overbye, "More Sci-Than Fi, Physicists Create Antimatter," *New York Times*, Sept. 19, 2002

529) The author of the reading passage incorrectly reported the findings of the experiment on antimatter. Which particle mentioned in the article has the charge incorrectly identified?

530) According to the reading passage, how should the emission spectrum of antihydrogen compare to the emission spectrum of hydrogen?

531) Based on the reading passage, identify *one* characteristic that antimatter particles must possess if clouds of them can be corralled by electric and magnetic fields.

532) According to the reading passage, why is it a mystery that "the universe seems to be overwhelmingly composed of normal matter"?

Questions 533 through 535 refer to the following:

For years, theoretical physicists have been refining a mathematical method called lattice quantum chromodynamics to enable them to predict the masses of particles consisting of various combinations of quarks and antiquarks. They recently used the theory to calculate the mass of the rare B_c particle, consisting of a charm quark and a bottom antiquark. The predicted mass of the B_c particle was about six times the mass of a proton.

Shortly after the prediction was made, physicists working at the *Fermi National Accelerator Laboratory, Fermilab*, were able to measure the mass of the B_c particle experimentally and found it to agree with the theoretical prediction to within a few tenths of a percent. In the experiment, the physicists sent beams of protons and antiprotons moving at 99.999% the speed of light in opposite directions around a ring 1.0 kilometer in radius. The protons and antiprotons were kept in their circular paths by powerful electromagnets. When the protons and antiprotons collided, their energy produced numerous new particles, including the elusive B_c.

These results indicate that lattice quantum chromodynamics is a powerful tool not only for confirming the masses of existing particles, but also for predicting the masses of particles that have yet to be discovered in the laboratory.

533) Identify the class of matter to which the B_c particle described in the reading passage belongs.

534) Determine *both* the sign and the magnitude of the charge of the B_c particle described in the reading passage (in elementary charges).

535) Explain how it is possible for a colliding proton and antiproton to produce a particle with six times the mass of either.