PART I: Heat and Thermodynamics

1. Suppose you have 1 Kg water at 50 °C and you want to heat it to 300 °C. The specific heat capacity of liquid water is 4186 joule/kg°C, its latent heat of melting is 334 kJ/kg, Latent heat of evaporation is 2,270,000 J/kg, and the specific heat capacity water vapor is 1996 J/kg °C
   A) How much heat energy is required to increase the temperature of 1 kg of water from 50 °C to 300 °C (Show all the steps)

   B) Suppose 1 kg of liquid water at 20 °C comes into contact with 2 kg of an unknown liquid at 8 °C. If the final temperature is 16 °C, what was the specific heat capacity of the unknown liquid?

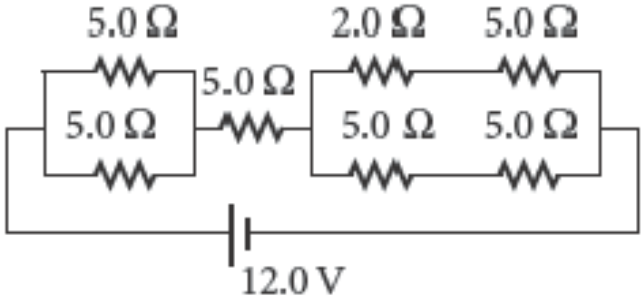
2. The air in a research balloon does 1.06×10^6 J of work to raise the balloon to an altitude of 35 km. The balloon inflates from $2.8 \times 10^3\ m^3$ to $8.5 \times 10^5\ m^3$. How much must be the net pressure of the air be inside the balloon?

3. A system's initial internal energy is 39 J. Then 114 J of energy is transferred to the system as heat. If the final internal energy is 163 J, how much work is done on or by the system?

4. Find the efficiency of a gasoline engine that, during one cycle, receives 365 J of energy from combustion and loses 223 J as heat to the exhaust.

PART II: Electricity

1. Consider the following figure:



A) Draw a VOLTMETER and an AMMETER around any of the resistors you like; then indicate what the resistance of your voltmeter and ammeter should be in order for them to be ideal

B) Find voltage drop AND current across each of the resistors in the diagram:

C) If all of the resistors were to be replaced with capacitors, what would be the equivalent capacitance?

2. Consider three point charges on the corners of a triangle, where *q1* = –4.0 mC at the origin; *q2* = –8.0 mC at (2.0 m, 0 m); and *q3* = 2.0 mC at (0 m, 2.0 m). Calculate the magnitude and direction of the resultant force on *q1*.

3. Millikan's experiment measures the charge of an electron by suspending charged oil droplets in an electric field. If an oil droplet with a mass of 3.35×10^{-15} kg has the same charge as an electron,
   A) What electric force is required to balance the weight of the oil droplet?

   B) What is the electric field strength felt by the charged oil droplet?

   C) ***EC:*** An electron in an electron gun is accelerated by a voltage of 20 000 V. (a) What kinetic energy in joules does it acquire? (b) Assuming that the mass of the electron is 9.1×10^{-31} kg, what is its velocity?

4. Answer ONLY ONE of the following two questions and the other one would be EC
   1) The Eiffel Tower has a height of 0.30 km. Suppose the atmospheric electric field of the Earth at the Eiffel Tower is 95 N/C directed downward. What is the electric potential difference between the ground and the tip of the Eiffel Tower?
   2) An electron ($q = -1.6 \times 10^{-19}$ C) has an electrical potential energy of 1.1×10^{-18} J in an electric field.What is the electric potential at that point in the field?
   3) How far from a charge of 94 nC is the electric potential 9.0 V?

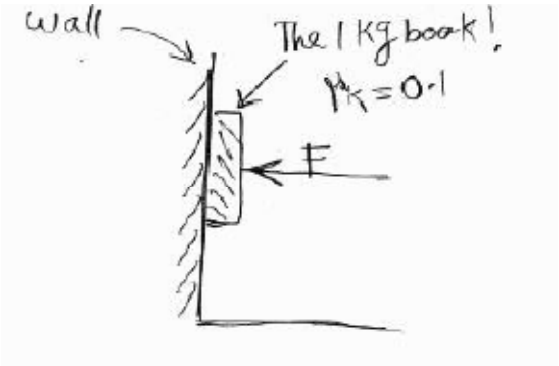
5. Answer ONLY ONE of the following two questions and the other one would be EC
   1) An electric kettle requires 370 W of power to boil water. If the kettle I plugged into a 120 V outlet, what is the resistance in the kettle's circuit?
   2) A blender requires 350 W to power the rotating blades that chop food. If the blender has a resistance of 75 Ω, how much current passes through the blender's circuit?
   3) A generator at a central electric power plant produces electricity with potential difference of 2.5×10^4 V across power lines which carry a current of 20.0 A. How much power does the generator produce?

6. Answer ONLY ONE of the following two questions and the other one would be EC
   1) Suppose a transmitter uses a 4550 pF parallel-plate capacitor in a vacuum. Each plate has an area of 6.4 × 10–3 m2. The capacitor is placed across a potential difference of 36 kV. What is the distance between the plates?
   2) A bread machine requires 1200 W to bake bread. How much time is required for it to use 1.512×10^{10} J of energy?

7. Some glass capacitors can store as much as 1000pF when placed across a potential difference as high as 600V.
   A) What is the maximum amount of charge?

   B) What electrical potential energy can a glass capacitor store?

8. What force do you need to prevent the 1 kg book from sliding? Which of the four fundamental forces of nature are you using to prevent the book from sliding?



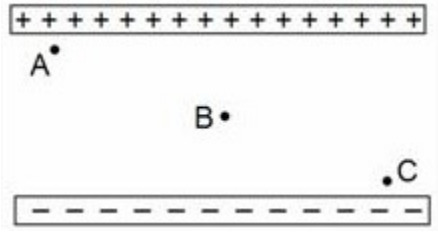
PART III: Magnetism

1. Suppose an electron moves to the right at a velocity of 6×10^6 m/s at an angle of 45° to a uniform magnetic field. If the magnetic field is 3×10^{-4}T upward, what is the magnitude and direction of the magnetic force exerted on the electron?

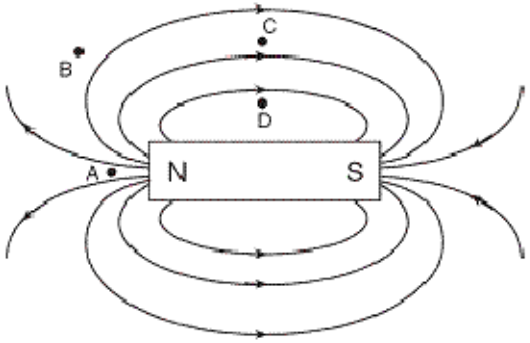
2. Suppose a coil has 785 turns of wire and an area of $7.3 \times 10^{-2}\ m^2$. If the magnetic field changes by 6.9×10^{-3}T. Each time the magnet oscillates (moves up and down), it induces an potential difference of 2.8 V.
   A) What is the time interval for each oscillation?

   B) If there were a total of 120 oscillations during an earthquake, how long did the earthquake last?

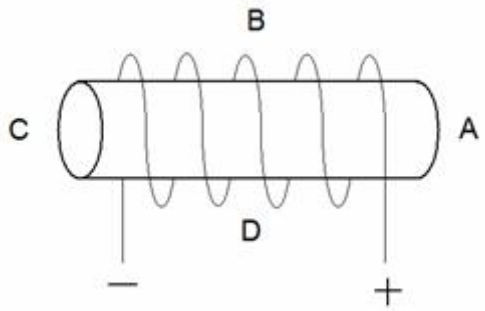
3. Answer the following questions:
   A) The diagram below shows two large parallel metal plates separated by a short distance. Draw the electric field lines between the plates; in which position, A, B or C is the electric field strength the greatest? Explain.



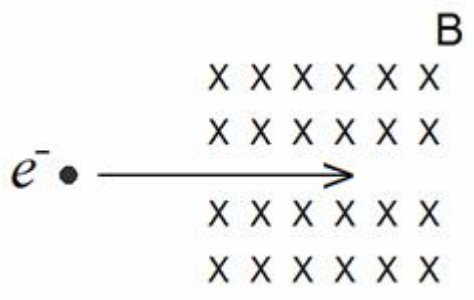
B) At which point is the magnetic field strength the greatest in the diagram below?



C) Base your answers to the following questions on the diagram below showing a solenoid Which point is closest to the north pole of the solenoid? If a compass needle is placed at point B, then in which direction will it point (make sure you label the north and south poles of the compass needle)?



D) An electron is moving through a magnetic field as shown below.

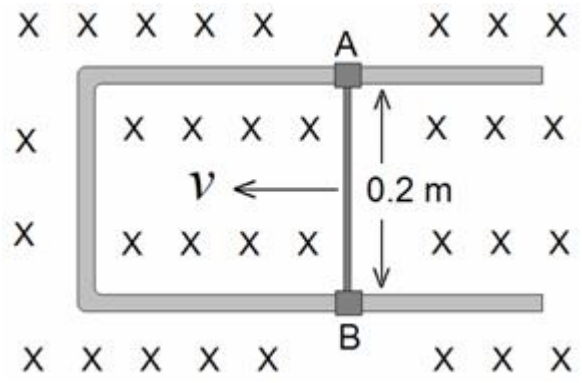


1) In what direction is the magnetic force on the electron acting?

2) If the electron of the previous problem were replaced by a proton, then what would happen to the magnitude and direction of the magnetic force on it?

3) What if a neutron was to pass through the magnetic field?

E) Base your answers to all of the following questions, on the diagram below, which shows a 0.2 meter long wire segment, AB sliding without friction to the left at a constant speed of 9 m/s along a U shaped wire in a uniform magnetic field of strength 0.6 T.



1) What is the potential difference induced across wire segment AB?

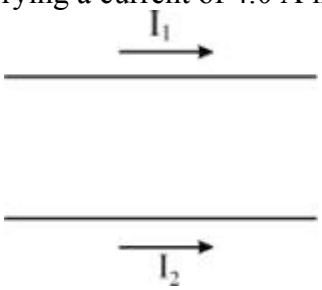
2) What is the direction of the induced electron current in wire AB?

3) If the resistance of wire AB is 3 ohms, then what will the magnitude of the induced current be?

4) What is the change in magnetic flux in 2 seconds?

5) ***EC:*** If the resistance of the wire were increased, then what would happen to the magnitudes of the induced voltage, and the induced current?

4. Suppose there are two 1 meter long parallel wires 1 meter apart as shown, one carrying a current of 2.0A and the other carrying a current of 4.0 A in the same direction:



A) Will the wires attract each other or repel each other?

B) Use the right/left hand rule to show the direction of magnetic field between the wires:

C) Find the magnetic field that each of the wires produces

D) Find the force on wire 1 and the force on wire 2

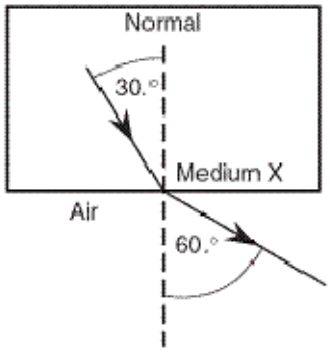
E) What is the relationship between the two forces you found in part D and why should that be the case?

F) ***EC*** What is the magnetic flux if the magnetic field strength is 2T in a cross sectional area of space that is 2 square meters?

PART IV: Light and Optics

1. ***EC:*** Monochromatic light passes through two slits 0.030 cm apart and falls on a screen 120 cm away. The first-order bright band is 0.16 cm from the middle of the center band. What is the wavelength of the light?

2. The diagram below shows a ray of light passing from medium X into air. What is the absolute index of refraction of medium X?



3. Find the critical angle for light rays passing from (a) crown glass (n = 1.52) into air

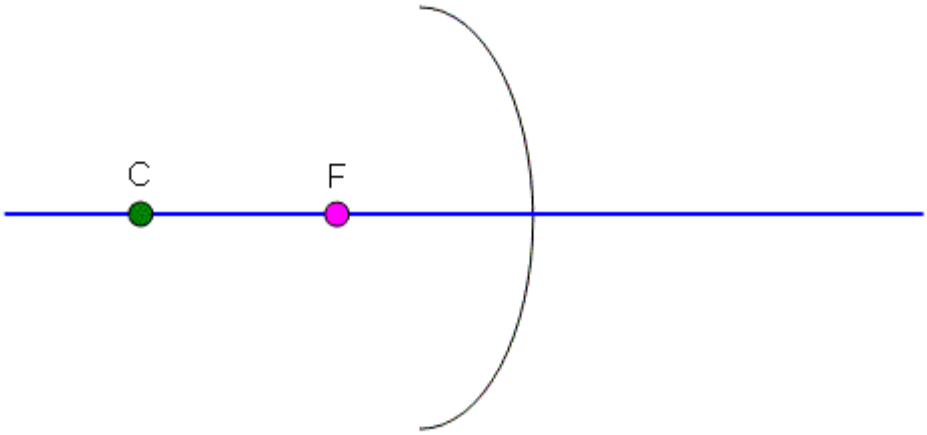
4. What is the speed of light when it goes through the glass crown?

5. Suppose you bend a sheet of aluminized Mylar™ to form a reflective surface that resembles a concave mirror when the axis is vertical. The bent reflective sheet has a focal length of 17 cm.
   A) Where must you stand so that the image of your eye appears at 23 cm?

   B) If your eye is 2.7 cm tall, how tall will the image be?

   C) Describe the image:

   D) Draw the ray diagram to support your answer:



6. An object that is 15 cm tall is placed 44 cm in front of a diverging lens. A virtual image appears 14 cm in front of the lens. Determine the focal length of the lens and the height of the image.

PART V: Waves and Sound

1. Suppose a person weighing 669 N sits in a hanging chair, causing a giant spring suspending the load to expands 6.5 cm.
   A) What is the spring constant?

   B) If the chair oscillates, what would be the frequency of its oscillation?

   C) What is the maximum potential energy in the spring?

   D) What is the maximum speed, with which the chair moves (use conservation of energy)

2. Suppose the speed of sound in air is 345 m/s; if a police car is moving away from you at a speed of 10 m/s, its siren producing a sound waves of frequency 60Hz, and you are moving away from the police car with a velocity of 5 m/s, what frequency of sound will you hear?

3. ***EC:*** The power output of heavy street traffic is 1.57×10^{-3}W. At what distance is the sound intensity of the traffic 5.20×10^{-3}W/m2?

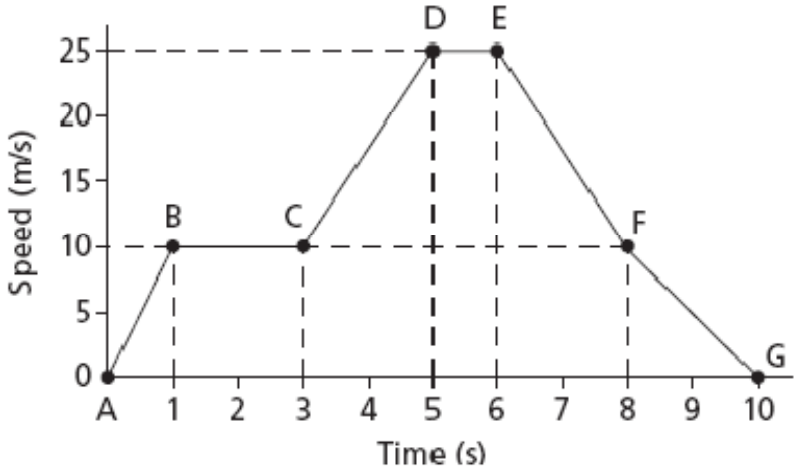
4. An organ pipe that is open at both ends has a fundamental frequency of 370.0 Hz when the speed of sound in air is 331 m/s.
   A) What is the length of this pipe?

   B) What are the first 3 harmonic frequencies AND their wavelengths?

   C) What would be the first 3 harmonic frequencies if the pipe was open only at one end?

PART VI: Mechanics and Conservation of Energy

1. Refer to the diagram to answer the following questions:



A) What is the acceleration of the object during the time interval t = 6 s to t = 8 s?

B) What is the average speed of the object during the time interval t = 3 s to t = 5 s?

C) What is the total distance traveled by the object during the first 3 seconds?

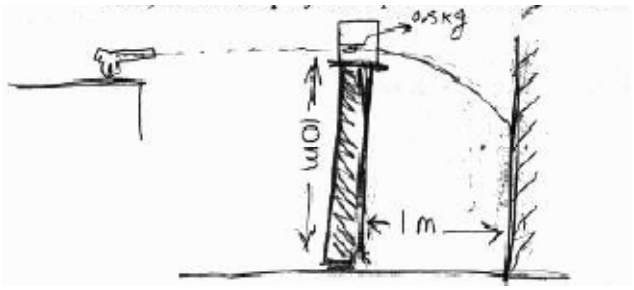
D) ***EC:*** What is the displacement from t = 3 s to t = 10?

E) During which interval is the object's acceleration the greatest?

F) During the interval t_8 s to t_10 s, the speed of the object is

G) What is the maximum speed reached by the object during the 10 seconds of travel?

2. Suppose a 2-gram bullet is fired from a 1 kilogram gun and strikes a 0.5 kilogram wooden block on a pole that is 10 meters high and gets stuck in the block; the block, in turn, follows a projectile path and hits a wall on the opposite direction



A) If the recoil velocity of the gun is 2 meters per second, what is the velocity of the bullet as it leaves the gun?

B) What is the horizontal velocity of the "wooden block + bullet" after the bullet gets stuck in the wood?

C) If the wall is 1 meter away from the pole, how long will it take for the "wooden block + bullet" to strike the wall?

D) How far has the "wooden block + bullet" DROPED by that time?

E) What is the final speed and angle by which the "wooden block + bullet" strikes the wall?

3. The Magellan space probe was placed into orbit around the planet Venus in 1992. Its mission was to map the surface of Venus using radar. For optimum results the probe was to orbit at an altitude of 4370 km. The mass of Venus is 4.87×10^{24} kg and its radius is 6100 km.
   (a) In order to place it into this orbit what speed was required?

   (b) ***EC:*** What was the orbital period in seconds?

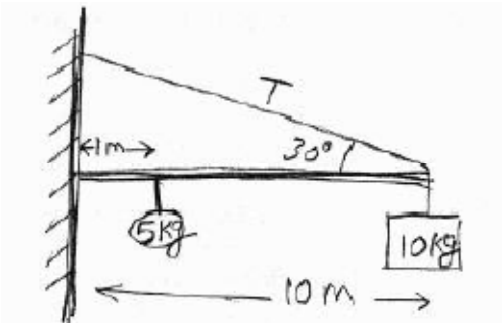
   (c) What is the escape velocity of Venus?

   (d) What is the gravitational acceleration on the "surface" of Venus?

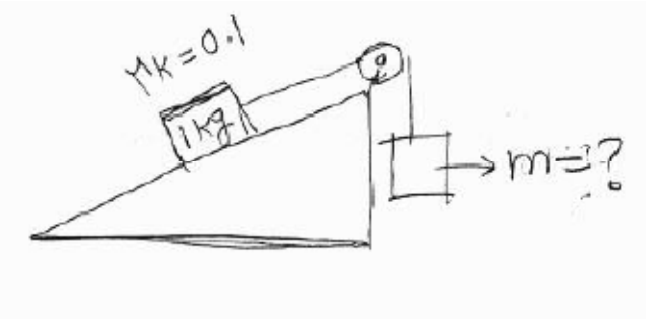
   (e) If a weightlifter lifts a mass of 100 kg with an upward acceleration of 2 meters per square seconds on the surface of Venus, what force does he encounter?

4. Based on your answers to question 3, if we hang a pendulum bob with a 2 meter rope on the surface of Venus, what would be the frequency and period of its oscillation?

5. Find the tension in the cable if the mass of the rod is 50 kg:



6. Find the mass of the box on the right if the system is to accelerate 2 meters per square seconds to the right (For extra credit, find out what mass should we place on the box on the left side to have the system go with constant velocity)



7. Suppose an electron is turning with a velocity of 5000000 m/s in a magnetic field and around a radius of curvature of 1 meter. What must be the magnetic field?

8. ***<u>EC:</u>*** A bird flying at 20 m/s drops a ball from 100 meters above the ground. If 10% of the mechanical energy converts to heat, then how many Joules of heat are used and how high will the ball bounce?

PART VII: Nuclear Physics

1. Calculate the frequency of ultraviolet (UV) light, having the energy of 20.7 eV.

2. Answer ONLY ONE of the following 2 questions:
   A) Light shines on a photoelectric metal and the maximum kinetic energy is measured to be 0.6 eV. What is the speed of the photoelectrons?
   B) Light of wavelength 519 nm shines on a rubidium surface. Rubidium has a work function of 2.16 eV. What is the maximum kinetic energy of the photoelectrons?

3. Calculate the de Broglie wavelength of an electron orbiting the hydrogen atom at a velocity of 2.19 × 106 m/s.

4. Answer ONLY TWO of the following:
   A) Calculate the binding energy of $^{39}_{19}K$
   B) If an electron drops from the *E4* energy level to *E1* in Helium, what is the energy of the emitted photon?
      E4 E = –3.27 eV
      E3 E = –5.92 eV
      E2 E = –13.50 eV
      E1 E = –54.42 eV
   C) Complete the following nuclear reaction.

$$^{22}_{10}\text{Ne} + {}^{4}_{2}\text{He} \rightarrow \_\_\_\_\_ + 2\ {}^{1}_{0}\text{n}$$

PART VIII: Definitions

Answer the 7 of the following 14 questions:

1. What is nuclear fission (give an example)
2. What is the difference between heat and temperature?
3. Show how mixing blue color and yellow color results in green:
4. What color do you get if you mix red and blue light?
5. What are the uncharged Leptons called?
6. Describe different types of waves:
7. What is the force carrying particle for electromagnetic force?
8. What are Hadrons made of?
9. Electrons belong to what category of matter?
10. What quarks make up protons and neutrons?
11. Name the four fundamental forces in nature:
12. Define refraction, diffraction and interference
13. Define dispersion, reflection and polarization
14. What is the difference between accuracy and precision?

TABLE OF INFORMATION FOR 2006 and 2007

CONSTANTS AND CONVERSION FACTORS

1 unified atomic mass unit,	$1\ \text{u} = 1.66 \times 10^{-27}\ \text{kg}$
	$= 931\ \text{MeV}/c^2$
Proton mass,	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
Neutron mass,	$m_n = 1.67 \times 10^{-27}\ \text{kg}$
Electron mass,	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
Electron charge magnitude,	$e = 1.60 \times 10^{-19}\ \text{C}$
Avogadro's number,	$N_0 = 6.02 \times 10^{23}\ \text{mol}^{-1}$
Universal gas constant,	$R = 8.31\ \text{J/(mol·K)}$
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23}\ \text{J/K}$
Speed of light,	$c = 3.00 \times 10^8\ \text{m/s}$
Planck's constant,	$h = 6.63 \times 10^{-34}\ \text{J·s}$
	$= 4.14 \times 10^{-15}\ \text{eV·s}$
	$hc = 1.99 \times 10^{-25}\ \text{J·m}$
	$= 1.24 \times 10^3\ \text{eV·nm}$
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N·m}^2$
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^9\ \text{N·m}^2/\text{C}^2$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}\ \text{(T·m)/A}$
Magnetic constant,	$k' = \mu_0/4\pi = 10^{-7}\ \text{(T·m)/A}$
Universal gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{m}^3/\text{kg·s}^2$
Acceleration due to gravity at Earth's surface,	$g = 9.8\ \text{m/s}^2$
1 atmosphere pressure,	$1\ \text{atm} = 1.0 \times 10^5\ \text{N/m}^2$
	$= 1.0 \times 10^5\ \text{Pa}$
1 electron volt,	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$

UNITS

Name	Symbol
meter	m
kilogram	kg
second	s
ampere	A
kelvin	K
mole	mol
hertz	Hz
newton	N
pascal	Pa
joule	J
watt	W
coulomb	C
volt	V
ohm	Ω
henry	H
farad	F
tesla	T
degree Celsius	°C
electron-volt	eV

PREFIXES

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	sin θ	cos θ	tan θ
0°	0	1	0
30°	1/2	$\sqrt{3}/2$	$\sqrt{3}/3$
37°	3/5	4/5	3/4
45°	$\sqrt{2}/2$	$\sqrt{2}/2$	1
53°	4/5	3/5	4/3
60°	$\sqrt{3}/2$	1/2	$\sqrt{3}$
90°	1	0	∞

The following conventions are used in this exam.

I. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.

II. The direction of any electric current is the direction of flow of positive charge (conventional current).

III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.

*IV. For mechanics and thermodynamics equations, W represents the work done on a system.

*Not on the Table of Information for Physics C, since Thermodynamics is not a Physics C topic.

Reference:

$$v_i = \sqrt{\frac{-g\Delta x}{2\sin\theta\cos\theta}}$$

$$r = \sqrt[3]{\frac{T^2GM}{4\pi^2}}$$

$$F_c = \frac{4m\pi^2r^2}{rT^2}$$

$$C = \frac{\varepsilon A}{d}$$

$$R = \frac{\rho l}{A}$$

$$B = \frac{\mu I}{2\pi r}$$

$$X = \frac{\lambda L}{d}$$

$$V = BLv$$

$$f_o = f_s\frac{v + v_o}{v - v_s}$$

$$\Delta U = Q - W$$