Exam notes sheet

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1 Circular motion

Angular velocity, units: $\frac{rad}{sec}$

$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{2\pi}{T}$$

Exercise: $\frac{33rev}{min}$ find ω

$$\omega = \frac{33rev}{min} * \frac{1min}{60sec} * \frac{2\pi rad}{1rev} = \frac{33 * 2\pi rad}{60sec} = 3.46\frac{rad}{sec}$$

Exercise: $\omega = 3.46rad/sec$

How fast is the object traveling if it's moving in a circle of 5cm radius?

$$\frac{3.46rad}{sec} * \frac{2\pi * (.05)m}{2\pi rad} = \frac{3.46 * (.05)m}{sec} = 1.73m/s = v$$

The speed of the object travelling the circle is:

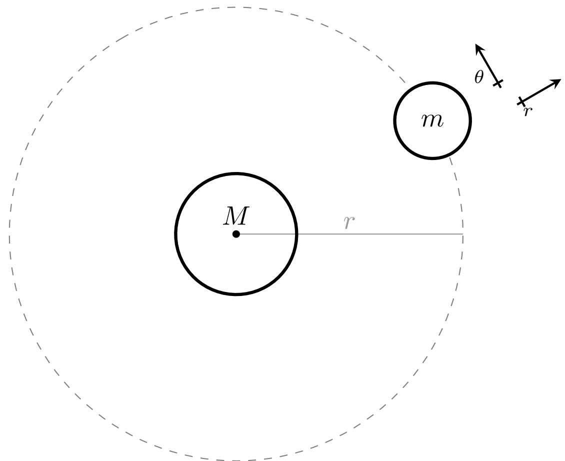
$$v = \frac{2\pi r}{T} = \omega r$$

Centripetal (center seeking) acceleration, specify "towards the center":

$$a = \frac{v^2}{r} = \omega^2 r$$

The force applied by a string causing centripetal acceleration is called tension.

2 Exam 1



$$F_g = \frac{mMG}{r^2}$$

Description	Symbol	Quantity
Gravitational Constant	G	$6.67 \times 10^{-11} \mathrm{N{\cdot}m^2/kg^2}$
Mass of Earth	m_{earth}	5.98×10^{24}kg
Mass of Moon	m_{moon}	7.36×10^{22}kg
Radius of Earth	R_{earth}	6.38×10^{6}m
Radius of Moon	R_{moon}	1.74×10^{6}m
Orbital Radius of Earth	r_{earth}	1.50×10^{11}m
Orbital Radius of Moon	r_{moon}	3.84×10^{8}m
Period of Earth's Orbit	T_{earth}	365.24 days
Period of Moon's Orbit	T_{moon}	27.3 days

Table 1: A list of physical quantities.

1) Consider the earth moving around the sun.

a. Determine the orbital angular velocity of the earth.

$$\omega = \frac{\Delta\theta}{\Delta t}$$

$$\omega = \frac{2\pi}{T_{earth}}$$

$$\omega = \frac{2\pi}{365.24 * 24 * 60 * 60}$$

$$\omega = 1.99 \times 10^{-7} \frac{\text{rad}}{\text{sec}}$$

b. Determine the speed of the earth relative to the sun.

$$v = \frac{2\pi r}{T}$$

$$v = \omega r_{earth}$$

$$v = 1.99 \times 10^{-7} * 1.5 \times 10^{11}$$

$$v = 3.0 \times 10^{4} \frac{\text{m}}{\text{s}}$$

c. Determine centripetal acceleration of the earth relative to the sun.

$$a_{cent} = \frac{v^2}{r_{earth}}$$

$$a_{cent} = \frac{(3 \times 10^4)^2}{1.5 \times 10^{11}}$$

$$a_{cent} = 6.0 \times 10^{-3} \frac{\text{m}}{\text{s}^2}$$

d. Determine the net force on the earth considering this acceleration.

$$F_{net} = m_{earth} a$$

$$F_{net} = 5.98 \times 10^{24} * 6.0 \times 10^{-3}$$

$$F_{net} = 3.6 \times 10^{22} \text{N}$$

e. Determine the mass of the sun from the above.

$$M = \frac{F_g r^2}{mG}$$

$$M = \frac{(3.6 \times 10^{22})(1.5 \times 10^{11})^2}{5.98 \times 10^{24} * 6.67 \times 10^{-11}}$$

$$M = 2.0 \times 10^{30} \text{kg}$$

2) Consider gravitation at the surface of the moon.

a. Determine the acceleration due to gravity on the surface of the moon.

$$F_g = \frac{\cancel{m}MG}{r^2} = \cancel{m}a$$

$$F_g = \frac{M_{moon}G}{R_{moon}^2} = a$$

$$F_g = \frac{(7.36 \times 10^{22})(6.67 \times 10^{-11})}{(1.74 \times 10^6)^2} = a$$

$$a = 1.62\frac{\text{m}}{\text{s}^2}$$

b. Determine the launch velocity for circular orbit.

$$a = a_{cent} = \frac{v^2}{R_{moon}}$$

$$1.62 = \frac{v^2}{R_{moon}}$$

$$v = \sqrt{1.62 * 1.74 \times 10^6}$$

$$v = 1680\frac{\text{m}}{\text{s}}$$

c. Determine the launch velocity for escape from the moon's gravity.

$$E = 0$$

$$KE + PE = 0$$

$$\frac{1}{2}\cancel{m}v^2 - \frac{\cancel{m}M_{moon}G}{R_{moon}} = 0$$

$$v = \sqrt{\frac{2M_{moon}G}{R_{moon}}}$$

$$v = \sqrt{\frac{2 * 7.36 \times 10^{22} * 6.67 \times 10^{-11}}{1.74 \times 10^6}}$$

$$v = 2370\frac{\text{m}}{\text{s}}$$

d. Determine the result of launching an object at 2000 m/s into the moon's horizon.

An elliptical orbit, since that velocity is in between the launch velocity and the escape velocity.

3) Consider a capacitor. Two very large parallel conducting plates are connected to the leads of a 9 Volt battery.

a. Determine the separation between the plates to generate a 30.0 $\frac{\mathrm{N}}{\mathrm{C}}$ electric field.

$$E = \frac{-\Delta V}{x}$$
$$x = \frac{-\Delta V}{E}$$
$$x = \frac{9}{30}$$
$$x = 0.3\mathrm{m}$$

b. Determine the force of this electric field on a 0.012 Coulomb charge.

$$F = qE$$
$$F = (0.012)(30)$$
$$F = 0.36\mathrm{N}$$

c. Determine the change in potential energy for the 0.012 C charge moving from the 9V plate to the 0V plate.

$$PE = qV$$
$$PE_{9V} = qV = (0.012)(9) = 0.108$$
$$PE_{0V} = qV = (0.012)(0) = 0$$
$$\Delta PE = -0.108 \text{ Joules}$$

d. Draw the parallel plates and the electric field between them.

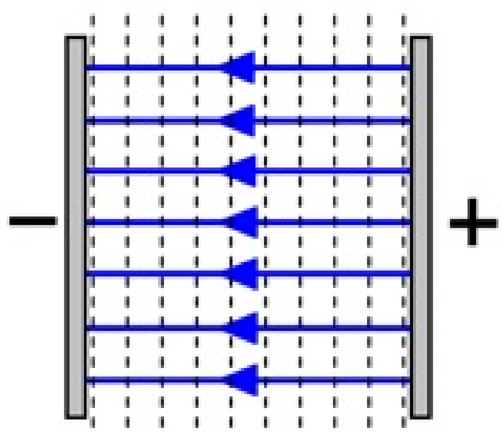


Figure 1: Electric field between 0V and 9V parallel plates

3 Exam 2

$$E = -\frac{\Delta V}{\Delta x}$$

$$C = \frac{Q}{V}$$

$$I = \frac{\Delta Q}{\Delta t}$$

$$V = IR$$

$$P = IV$$

$$\text{Parallel:} \qquad \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\text{Series:} \qquad R_{eq} = R_1 + R_2$$

$$\overrightarrow{F}_B = q\overrightarrow{v} \times \overrightarrow{B}$$

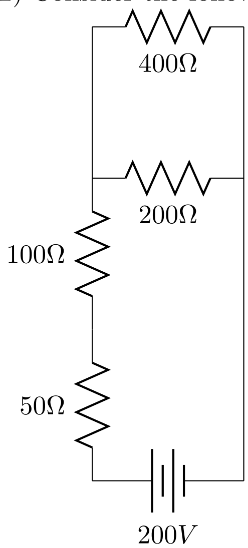
$$\overrightarrow{F}_B = I\overrightarrow{L} \times \overrightarrow{B}$$

$$B_{wire} = \frac{\mu_0 I}{2\pi r}$$

Description	Symbol	Quantity
Gravitational Constant	G	$6.67 \times 10^{-11} \mathrm{N \cdot m^2/kg^2}$
Electrostatic Constant	k_e	$8.99 \times 10^{9} \mathrm{N \cdot m^2/C^2}$
Boltzmann's Constant	k_B	$1.38 \times 10^{-23} \mathrm{J/K}$
Avogado's Number	N_A	6.02×10^{23}
Plank's Constant	h	$6.63 \times 10^{-34} \mathrm{J \cdot s}$
Speed of Light	c	$3.0 \times 10^{8} \mathrm{m/s}$
Fundamental Charge	e	$1.6 \times 10^{-19} \mathrm{C}$
Mass of the Electron	m_e	$9.1 \times 10^{-31} \mathrm{kg}$
Mass of Proton	m_p	$1.7 \times 10^{-27} \mathrm{kg}$
Gas Constant	R	$8.31 \ \mathrm{J/mole \cdot K}$
Vacuum Permativity	ε_0	$8.85 \times 10^{-12} \mathrm{F/m}$
Vacuum Permeablity	μ_0	$4\pi \times 10^{-7} \mathrm{T \cdot m/A}$
Bohr Radius	a_0	$0.53 \times 10^{-10} \mathrm{m}$
Fine Structure Constant	α	$1/137$

Table 2: A list of physical quantities with SI units and dimensions.

1) Consider the following circuit



Description: current, i, moving clockwise, from high to low. Solve by first determining each sections' resistance and then determining the circuit's total current by using its total resistance (just calculated) and its voltage drop (from the battery's capacity). Then, use this current to determine each sections' voltage drop, using that section's resistance (for resistors in parallel the voltage drop is the same, and the resistance used is their total resistance (not the one of each resistor), for the resistors in series it's their own). Then, use each individual resistor's voltage drop and resistance to determine its individual current. Power for each individual resistor is calculated using this (their individual) current and its voltage drop.

a. Determine the equivalent resistance of the circuit.

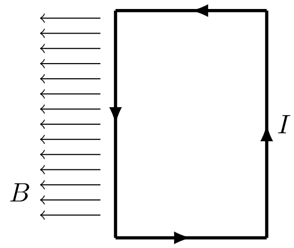
b. Determine the current through the 50Ω resistor.

c. Determine the current through the 200Ω resistor.

d. Determine the voltage drop across the 100Ω resistor.

e. Determine the power dissipated by the 400Ω resistor.

2) Consider a magnetic field interacting with a loop of current. The loop is a 4x6 cm rectangle. The wire contains 10^{18} free moving electrons. The magnetic field is $B = 0.050$ Tesla. The current is $I = 1.6$ Amperes.



a. Determine the direction of magnetic force on each section of the loop.

No F B on neither the top or bottom section because they are parallel to the B field. It's coming out on the right and going in on the left.

b. Determine the magnitude of force on each section of the loop.

F B=qvB

q=(0.06 [length of the section in meters!])/(0.2 [total length in meters])*(0.16 [electron charge times the amount of electrons, 10 to the 18]) * (2 [velocity given by distance over time, time given by rearrangement of formula into t = Q / I which is the previous found charge, 0.16 over the current, 1.6, resulting in .1 sec. Distance given by adding up the sections into the total length, .2m] * (0.050, the B field)

=0.0048 N (on the 6cm sections), Since the 4cm sections (non perpendicular components) are parallel to the B field they have no magnetic force!

c. Describe the structure of the magnetic field created by the loop.

It is spinning around the loop

d. Determine the subsequent motion of the loop if it is free to move.

It would rotate to the right as if it was coming at us. The B field would also make it shrink together.

3) Consider a charged capacitor that holds 60×10^{-3} Coulombs with 12 Volts of potential. The capacitor is connected in series with a 300 Ω resistor. The capacitor begins discharging at $t = 0$.

a. Draw the circuit described above.

Capacitors: Positive charged is so accumulated on one side that the negative charge on the other side pulls it over, generating an electric field which at the same time creates a new charge and flowing current (it's not that the charge just jumped over). The current generated is known as displacement current, happening as the capacitor charges up.

Once the capacitor is charged up then no more current can flow because there because the field cannot continue to be generated.

An increasing electric field, in time, will cause a displacement current.

At time=0 the charge Q in the capacitor is 0 and there is no current flowing. As time increases charge and current do so too. At an infinite time the charge Q is at is max. and there is no more current. Plotting I against time as a capacitor is being charged up will result in an exponential decay graph, while plotting charge against time will result in an exponential growth. Plotting the voltage of the resistor against time and the electric field of the wire against time result in exponential decay graphs, while plotting the voltage of the capacitor and the electric field of the capacitor against time result in exponential growth graphs.

b. Draw a graph of the current as a function of time, $I(t)$. Include the value of the initial current.

The initial current is 12/300=0.04 Amps.

c. Explain how the capacitor functions as a battery in this system.

*Battery discharges as time passes while capacitor charges up, making the current flow.

4) Two long straight wires, separated by 50 cm, run parallel and carry current in opposite directions.

Describe the magnetic force between the wires.

The wires are being repelled by their opposing magnetic fields. This happens if they carry current in the opposite directions. They would bend out over time as in a circle.

If two wires carry current in the same direction they will experience an attractive force that will make them bend inwards towards each other. If their magnetic fields attract they will eventually join one atop the other.

Explain how these wires could be used to define the Ampere.

Ampère's force law states that there is an attractive or repulsive force between two parallel wires carrying an electric current. This force is used in the formal definition of the ampere, which states that the ampere is the constant current that will produce an attractive force of 2×10^7 newtons per metre of length between two straight, parallel conductors of infinite length and negligible circular cross section placed one metre apart in a vacuum.

*If we get a changing electric field we'll generate a constant magnetic field.

The SI unit of charge, the coulomb, "is the quantity of electricity carried in 1 second by a current of 1 ampere". Conversely, a current of one ampere is one coulomb of charge going past a given point per second: $1\ \mathrm{A} = 1\frac{\mathrm{C}}{\mathrm{s}}$

4 Orbits from lab

4.1 Definitions

Law of Universal Gravitation The law of universal gravitation states the force of gravity between two point masses is directly proportional to each mass and inversely proportional to the distance between them. This is also true for masses outside of spherically symmetric mass distributions.

$$F_g = \frac{mMG}{r^2}$$

Hookean Forces Inside a uniformly dense sphere of mass the force is Hookean, with an attractive force proportional to the displacement from equilibrium. The effective spring constant is $K = \frac{mMG}{R^3}$.

$$F_g = \frac{mMG}{R^3}r$$

Gravitational Constant The universal gravitation constant G determines the strength of the gravity force from a given mass. It may also be considered as the force that 1 kg exerts on another 1 kg mass separated by 1 meter.

$$G = 6.67 \times 10^{-11}\frac{Nm^2}{kg^2}$$

Escape Velocity Escape velocity is the initial velocity required to escape gravitational attraction. An object launched at the escape velocity will never come back (escape).

$$v_{escape} = \sqrt{\frac{2MG}{r}}$$

Kinetic Energy Kinetic energy is the energy associated with motion.

$$KE = \frac{mv^2}{2}$$

Potential Energy The potential associated with the universal gravitation force is written as follows.

$$PE = -\frac{mMG}{r}$$

Circular Orbit A circular orbit is an orbit with a constant radius r.

Elliptic Orbit An elliptic orbit is a closed orbit with changing radius r.

5 Mass Spectroscopy

Spectroscopy is the branch of science that deals with measurements of electromagnetic radiation. Mass spectrometry is an analytical technique that involves analyzing fragmented particles' patterns to reconstruct them and find out their chemical compositions, principally by analyzing their mass to charge ratio. Originally, the technique used to analyze the fragments required them to be recorded on plate through electromagnetic radiation, thus the name *mass spectroscopy*. However, nowadays, the equipment used to execute the task doesn't employ electromagnetism, making it an archaic term. Now it is, technically, referred to as *mass spectrometry*.

Mass spectrometry is carried out by using a mass spectrometer. This instrument can measure the masses and relative concentrations of atoms and molecules by a process of ionizing and accelerating particles to later select (deflect) them. Selected single velocity particles go into the instrument's generated magnetic field in a circular path. "This is because the ions are deflected by the magnetic field according to their masses; the lighter they are, the more they are deflected" (Clark). The machine can measure the radius of the particles' followed path through detectors and, comparing the position of the impacts on them, identify the mass of the particle. The position of the impact of the particle in the detector is then a function of the particle's mass.

Deflection can be deconstructed by the following analysis. When charged particles enter the magnetic field their direction is perpendicular to the field, causing the circular path. As the magnetic force is perpendicular to the velocity, the force that occurs is centripetal. This can be illustrated in the following way:

$$F_{net}$$

$$F_B = F_{centripetal}$$

$$F = qv \times B = \frac{mv^2}{r}$$

To find the path's radius:

$$qv \times B = \frac{mv^2}{r}$$

$$r = \frac{mv^2}{qv \times B}$$

$$r = \frac{mv}{qB}$$

The obtained equation gives the mass to charge ratio $\frac{m}{q}$, a physical quantity –property quantified by measurement– relevant for its proof that "two particles with the same ratio move in the same path in a vacuum when subjected to the same electric and magnetic fields".

The previous equation could be modified to exemplify the ratio (where v is known, B is set and r is being measured):

$$r = \frac{mv}{qB}$$

$$\frac{m}{q} = \frac{rB}{v}$$

6 Specific Heat Lab

6.1 Definitions

Heat Heat is the measure of the internal kinetic energy of a substance.

Temperature Temperature is a measure of the kinetic energy of a particle. It is the degree or intensity of heat in a substance. Celcius is a unit of temperature. One degree Celcius represents the temperature change of one gram of water when 2.39×10^{-5}Joules of heat is added to it.

Specific Heat Capacity The specific heat capacity is the energy transferred to one kilogram of substance causing its temperature to increase by one degree Celcius.

Thermal Equilibrium Thermal equilibrium is a condition where two substances in physical contact with each other exchange no net heat energy. Substances in thermal equilibrium are at the same temperature.

6.2 Theory

The change in the internal energy of an object or substance is equal to the product of the mass and the specific heat capacity and the change in temperature.

$$\Delta U = mC_p \Delta T$$

When water and the metal samples are in thermal equilibrium the change in heat of the water is equal in magnitude to the change in heat of the metal.

$$\Delta U_{metal} = \Delta U_{water}$$

From this relationship we may derive a formula for the specific heat capacity of the metal sample given the mass of metal, mass of water, change in temperature of the water, change in temperature of the metal and the specific heat capacity of water.

$$m_{metal} C_{metal} \Delta T_{metal} = m_{water} C_{water} \Delta T_{water}$$

$$\boxed{C_{metal} = \frac{m_{water}}{m_{metal}} \frac{\Delta T_{water}}{\Delta T_{metal}} C_{water}}$$

7 Further notes

1. Polar coordinates:
$v_{->hat} = \frac{\Delta r_{->hat}}{\Delta t} = \frac{\Delta(r * r_{->hat})}{\Delta t} = (\frac{\Delta r}{\Delta t} * r_{->hat}) + (r * \frac{\Delta r_{->hat}}{\Delta t})$
$\frac{\Delta r}{\Delta t} = radialspeed$ and $\frac{\Delta r_{->hat}}{\Delta t} = \frac{\Delta \theta}{\Delta t} * \theta_{->hat}$ from which $\frac{\Delta \theta}{\Delta t} = angularvelocity, \omega$

so, $v_{->hat} = (v)(rad)(r_{->hat}) + (r)(\omega)(\theta_{->hat})$

$(\frac{\Delta r}{\Delta t} * r_{->hat}) = radialvelocity(sameasspeedbutthistimewithr- > hat; direction)$ and $(r)(\omega)(\theta_{->hat}) = tangentialvelocity$

circular motion implies a constant (same) radius, so tangential velocity, v hat = rw0hat, is used, at a constant speed (w)

2. Magnetic field lines are infinite
3. A normal force's direction is always away from (perpendicular to) a surface. It causes a perpendicular force

4.1 Linear-
- position: x
- velocity: v= delta x / delta t
-acceleration: a = delta v / delta t
-mass: m
-1st Law (a=0): Fnet = 0
-2nd Law: Fnet=ma
-Force: F
-momentum: p=mv
-kinetic energy: $KE_l in = mv^2/2$
4.2 Rotation-
-angle: 0
-angular velocity: w
-angular acceleration: alpha
-moment of inertia: I=SUMmr^2
-1st Law (a=0): TorqueNet=0
-2nd Law: Tnet=I proportional to
-torque = T
-angular momentum: l=Iw
-angular kinematic energy: $KE_r ot = Iw^2/2$

5. Fg = mg (gravity)