Gravitational Fields

Consider the gravity force of the earth. A recent idea in physics is the concept of a field. A ***uniform*** *field is drawn as parallel field lines drawn straight down. On a small scale, like the school lab, the model works. It's how things fall.*

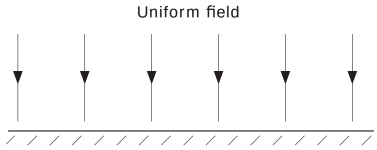
But on a larger scale, like from outer space, we see the field lines as forming a ***radial*** *pattern. A large mass like our planet earth sets up a gravitational field in the space around itself. The field lines show the direction of the gravitational force.*

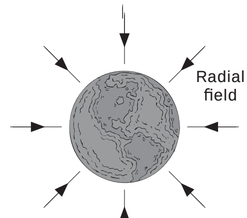
The strength of the earth's gravitational field can be measured. At ground zero it can be stated as 9.8 Newtons per kg. This means that each kg of mass feels a weight force of 9.8 N.

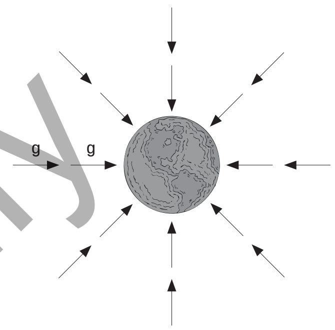
The weight force, W, of a mass, m, is given by $W = mg$
The gravitational force, F, is given by $F = GMm/r^2$
But W is the same as F. Hence $mg = \mathbf{GMm/r^2} \rightarrow \mathbf{g = GM/r^2}$

The symbol ***g*** *represents the strength of a gravitational field. It is not a constant. The field strength, g, will become weaker as we move away from the surface the earth. In fact the field strength varies with distance by the inverse square law.*

The diagram opposite shows how the size and direction of g varies in the space around the earth.







1. The gravitational field strength on the moon is g = 1.6 Nkg^{-1}.

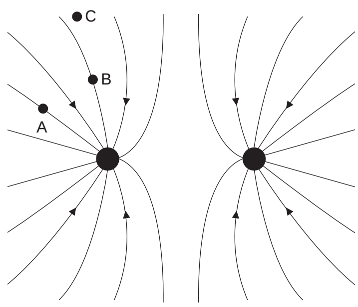
   a. How would you explain what this value means to another student?

   b. Calculate the weight of an 85 kg astronaut on the moon.

   c. Calculate the weight of the astronaut on the earth.

   d. How much would the astronaut weigh on mars where the gravitational field strength is 3.8 Nkg^{-1}?

2. Binary stars are quite common throughout the galaxy. The diagram opposite shows the gravitational field pattern around a binary star system.



   a. Where is the gravitational field strength a minimum?

   b. A spaceship travels from A to B and then later it travels from B to C. Which of the two journeys needs the smaller amount of fuel?

   c. Sketch the field pattern below for a binary system where one star is considerably larger than the other.

   d. Sketch the field pattern for a binary system where one star is composed of 'antigrav' matter which repels ordinary matter instead of attracting.

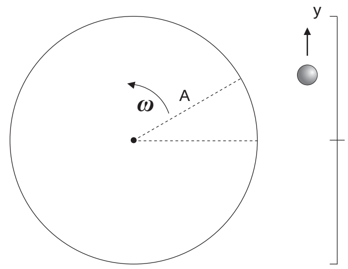
Maximum Values

In simple harmonic motion, the maximum displacement is, $y_{max} = A$
The maximum velocity is, $v_{max} = A\omega$
The maximum acceleration is $a_{max} = A\omega^2$

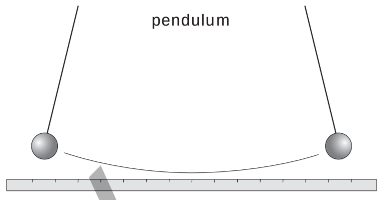
These maximum values occur at different phases of the motion.

Using F = ma, the maximum force is, $F_{max} = mA\omega^2$

During simple harmonic motion, the energy changes continuously from purely potential energy (at each end of the motion) to purely kinetic (in the central position).



1. The diagram shows a pendulum swinging with simple harmonic motion. A student records a total time of 4.83 s over five swings. The pendulum is observed to swing between the 25 cm and 65 cm marks on the ruler.



   a. Calculate the angular frequency of the motion.

   ____

   b. What is the amplitude of the motion in metres?

   ____

   c. Calculate the maximum speed and the maximum acceleration.

   ____

   ____

   d. Where do these maximum values occur in the motion?

   ____

   e. Where does the maximum kinetic energy occur?

   ____

   f. Where does the maximum potential energy occur?

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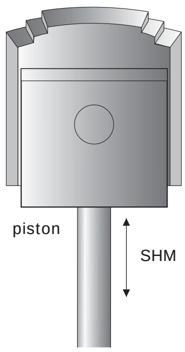
2. The piston inside a car cylinder oscillates up and down in simple harmonic motion, as shown, at 5 400 cycles per minute. It travels upwards through a distance of 24 cm and downwards through 24 cm each cycle.



   a. What is the amplitude of the piston's motion?

   ____

   b. Calculate the motion's angular frequency.

   ____

   c. At which position does the piston have maximum acceleration?

   ____

   d. Calculate the maximum velocity of the piston.

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Charging a Capacitor

Consider the circuit opposite. When the switch is closed, electrons from the negative battery terminal travel to the upper plate. These electrons repel free electrons from the lower plate.

So the capacitor charges up. It charges quickly to start with and the surge of electrons lights up the bulb for a while.

However after a time, the charging process starts to slow down. Electrons from the battery now have to work against the electrons that are already on the upper plate.

The new electrons are repelled a little by the electrons already there. So the charging current starts to decrease and the bulb gets dimmer. The current gets progressively smaller as the capacitor charges up.

The graph opposite shows how the current varies with time. The general shape of the graph is controlled by the value of resistor, R. A large resistor slows down the whole process. A large capacitor is also slow to charge up.

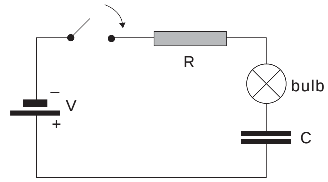
The shape of the graph is an example of ***exponential decay****.*

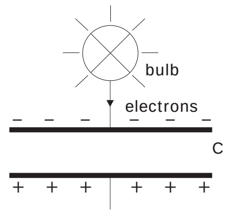
The initial high current, I_0, is given by Ohm's Law $I_{max} = V_{supply} / R$

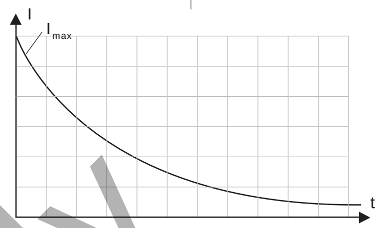
The current then decreases asymptotically.

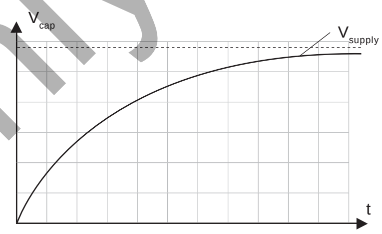
The second graph shows the voltage across the capacitor, V_{cap}. The shape of the graph shows ***exponential growth****. The voltage is zero to start with, and increases rapidly as the electrons are soaked up.*

But the increasing voltage across the capacitor repels the later electrons. So the capacitor voltage starts to slow down asymptotically.



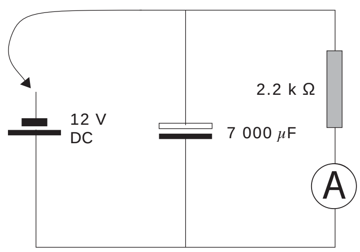






Practical: To Investigate Current When a Capacitor Discharges

1. Study the circuit opposite. When you connect the flying lead, the capacitor charges up. When you disconnect the lead, the capacitor discharges through the ammeter and the resistor. You need the resistor to slow down the current (as an ammeter is a low resistance device).
2. Set up the circuit. Connect the flying lead to charge up the capacitor. Remove the lead and start timing. Record values of the current, I_{cap}, at five second intervals as the capacitor discharges.
3. Plot a graph of I_{cap} versus time, t, for the discharge process.



Practical: To Investigate the Charging and Discharging of a Capacitor

1. Study the circuit opposite. Instead of the flying lead, the frequency generator switches the circuit on and off.
2. The square wave input acts as a rapidly switching high/low supply voltage. The capacitor is repeatedly charged and then discharged. The oscilloscope monitors the capacitor voltage.
3. Set up the circuit. Try frequencies from 200 Hz to 800 Hz. Sketch the voltage waveform across the capacitor.