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Van de Graaff Generator with Accessories Code: L1000

General Description

The IPC Irwin Van de Graaff Generator is designed to be operated by either a hand crank or electric motor.

Hand operation confirms that the charge generated is independent of mains electricity to make it clear that the charge is generated mechanically, independent of mains electricity. It can then be changed to the motor driven option. The Van de Graaff provides demonstrations that will inspire students to intuitively ask searching questions which aides understanding and leads to other projects in electrostatics. In this document we set out to show that the Van de Graaff Generator is not simply a machine that makes one's hair stand on end but is a hub of fascinating and learning in the field of electrostatics and how it can be integrated into STEAM programmes.

Science: A huge number of experiments and investigations into electrostatics.

Technology: A demonstration of how the design process achieved the results of a machine to perform a required task.

Engineering: The mechanics of how the Van de Graaff works provides the means to investigate the various engineering methods used in its production

Art: The way in which different materials react to electrostatic charge has created fascinating abstract art – please visit our website for more information.

Maths: As Physics depends on an understanding of Maths, the equations used will beautifully integrate to STEAM programmes in Maths

The variable speed generator will develop potentials as high as 350,000 volts making it possible to perform many electrostatic experiments on a large and spectacular scale! With sparks of 8 cm to as high as 12 to 15 cm, yet a maximum continuous current of just 10 microamps, it's quite safe for classroom use. The unit requires minimal assembly when shipped and is supplied with a spare silicon belt.

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The Van de Graaff generator is designed for schools and is the triboelectric type (*see notes on the Triboelectric Series*). The transfer of charge is achieved by a Silicon rubber belt driven by a plastic pulley, over metal combs (*sometimes referred to a collector plates*) at either end of the belt. Charge is transferred to a metal sphere (*a capacitor)* and very high voltages are achieved between the sphere and ground (*Earth*)

OPERATING INSTRUCTIONS

To operate by hand simply fit the crank handle to the base using the two fixing screws (already fitted to the base) and tighten the screw. Then attach the rubber drive belt (already fitted to the crank) to the pulley on base of the lower roller. **Note:** if the electric motor drive belt is fitted simply remove first.

To operate using the electric motor simply attach the rubber drive belt (supplied already fitted) to the motor drive pulley and the pulley on base of the lower roller. Once the belt is fitted plug the mains cable to the mains supply and switch on the motor drive on using the green rocker switch located on the top of the motor drive enclosure, the motor with then turn. To increase the motor speed (and Dome voltage generated) rotate the speed control clockwise. **Note:** if the crank handle belt is fitted simply remove first.

To use the discharge sphere simply attach the 4mm plug/lead from the sphere to the 4mm socket (red) on the base of the unit. The sphere can then be held (using the handle only) close to the Dome (approx. 8cm) to create a spark when the unit is running. The sphere can also be used to discharge the Dome once the demonstration is over, to do this simply touch the sphere against the Dome.

Features

- Discharge sphere
- Neon indicator
- Electron Windmill and holder (with protective cover)
- Head of hair
- Silicon belt (spare)

Dimensions

- Sphere diameter 280mm
- Discharge sphere diameter 80mm
- Overall height 760mm
- Base length 380mm
- Base depth 230mm
- Weight 7kg max. fully packaged

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ELECTRICAL SAFETY

IMPORTANT

Although the Van de Graaff can produce extremely high voltages, the current is low, so it is safe even if inadvertently touched before discharging. However, it is designed for demonstration purposes and always only to be used or supervised by a qualified and experienced Teacher or Technician.

The following electrical safety check should be carried out routinely and regularly:

Check the fuse rating of the Van de Graaff (located at the rear of the motor drive enclosure next to the mains lead entry), ensure it is a correctly rated 250mA 'fast blow' fuse. Check that the mains cable is in good condition, check the plug fuse rating is 3 Amp. Test the mains cable in accordance with current electrical safety regulations and LEA guidelines. Carry out a Portable Appliance Test in accordance with current electrical regulations and LEA Guidelines, this unit is classified as a CLASS II appliance.

Please see The IPC Irwin Portable Appliance checker: https://www.ipcirwin.com/portable-appliance-tester-checker.

Note: All PAT Testers must be calibrated regularly, please contact us to arrange calibration, tel: **01539 558555**

WARNING:

Only replace the silicon belt with the exact belt for this unit (a spare is provided). Should a different material be used, it could affect the production of a higher current.

Do not modify the Dome - increasing the size of the dome will increase its capacitance.

It is advisable when conducting practical work with students or adults to check if anyone has heart conditions, or a pacemaker, or other electronic medical equipment fitted. If so they should not come into close proximity to the Van de Graaff and should be kept at least 1 meter away.

The electrostatic field from a Van de Graaff generator can affect electronic circuits, so equipment that does not have protection such as older computers and instrumentation with electronic circuits should be isolated.

In England Northern Ireland and Wales: Follow CLEAPSS guidelines - https://www.cleapss.org.uk

In Scotland: Refer to SSSERC - https://www.sserc.org.uk

Republic of Ireland: Suggested contact for support is the ISTA - https://www.ista.ie

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Care and Maintenance

The function of the Van de Graaff causes surfaces to become charged; this attracts air-borne dust and dirt to build up on the Dome, Discharge Sphere and can affect the Combs. This can interrupt the conducting path to Earth.

Therefore, it is important to keep all surfaces clean and free from moisture. We recommend using Methylated Spirit on a lint free cloth. Clean the dome, and the Discharge Sphere. After prolonged use the belt will become dirty, simply wash the belt in washing up liquid and then dry it thoroughly before use.

If not used for a long time and it has been stored in a damp atmosphere, most likely in the autumn and winter when condensation appears, it is best to allow it to dry our before demonstrating to the students. The simplest way of doing this is to use a hair drier. Just blow warm air over the unit for about five minutes whilst it is not switched on or running.

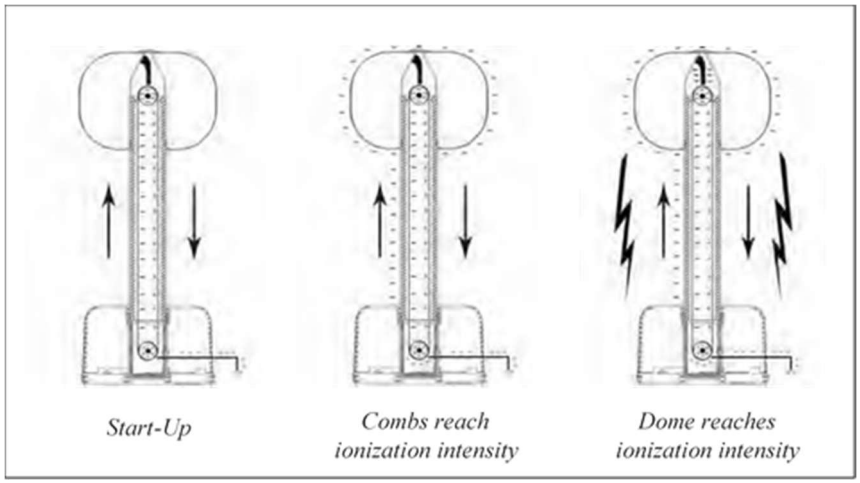
You can check that the Van de Graaff is charging; use the Neon Indicator (*supplied in the pack*) held near the Dome.

We recommend that if the Van de Graaff is not to be used for a long time to remove the Belt so it is not under tension and will reduce stretch stress, then store in dry place out of sunlight this will prolong the life of the Belt.

Basic Guide to Experiments and Investigations

The Basic Principals

The Van de Graaff transfers electrons from its base (*the* earth) to the upper dome, which acts as a capacitor where they accumulate. You can estimate the potential difference (*voltage*) between the dome and earth knowing that it takes about 30 kV per centimetre to produce a spark in air (this figure depends on humidity etc.). A 4 cm spark requires 120 kV. This is the insulating factor of air.



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As mentioned, the voltage is extremely high, but the charge is low, so if inadvertently making contact it will give you a jolt but should be harmless for healthy people, however, should there be people with heart conditions or pacemakers fitted it is advisable to keep them at least 1 metre away from the apparatus - see **the safety notes above.**

The process is like the charging which occurs when one material is rubbed against another, the standard rubbing a balloon against your jumper and then sticking it to the wall. However, the Van de Graaff Generator, substitutes this by moving the belt over the rollers which are different materials.

Note: The triboelectric series; this can be additional investigation for the students to discover which materials will become positively charged when they are rubbed together:

Good Practice

Make a habit of discharging the Van de Graaff after each time it is switched on and at the end of each experiment. Simply bring the Discharge sphere which is connected to the Earth towards the Dome and touch them together. Alternatively, use the bare male end of the 4mm connecting lead which is plugged into the functional Earth on the front of the Van de Graaff and touch the Dome with it.

Always have the Discharge Sphere connect to the functional Earth on the front of the unit via a long green 4mm lead when possible, during experiments.

1. The Electron Windmill

Ionisation of the air occurs at the tips of the electrostatic windmill due to the accumulated charge at the points. This ionisation causes a stream of ions to be emitted away from the tips of the windmill. The tips of the windmill emit ions and as like charges repel, due to the conservation of momentum, results in a rotation of the windmill.

- **i)** Make sure the Van de Graaff is switched off and discharged.
- **ii)** Plug the holder into the 4mm socket on the top of the Dome and removed the protective cover.
- **iii)** Place the Electron Windmill into the holder on the top of the Dome.
- **iv)** Switch on and observe that as the charge builds the windmill will start to rotate.

You can bring the Discharge Sphere towards the Dome and see that as the charge leaks away from the Windmill it slows down.

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2. Standing Hair on End

Before engaging students in this demonstration, you can show the principals using the Head of Hair unit supplied in the pack.

v) Make sure the Van de Graaff is switched off and discharged.
vi) Plug the Head of Hair unit into the 4mm socket on top of the Dome.
vii) Switch on and observe that as the charge builds the strands of hair begin to separate and stand on end.

You can bring the Discharge Sphere towards the Dome and see that as the charge leaks away from the Windmill is slows down.

Make sure the Van de Graaff Generator is switched off and discharged.

i) Ask a volunteer with fineish, medium length hair to stand on the insulating pad or box, a Gratnells tray is a good insulator for this experiment.
ii) Ask the student to put both hands on the Dome towards the top.
iii) Tell the student not to remove their hands.
iv) To avoid an electric shock, it is important that the volunteer does not let go of the generator or come into close contact with an object at Earth potential.
v) Switch on the Van de Graaff generator on and observe the volunteer's hair stand up on end. The volunteer can make a most impressive effect by gently shaking their head.
vi) Switch off the generator and discharge it using the earthed sphere.

After the demonstration, to avoid a sudden discharge, the person should take their hand off the sphere and touch the surface of a wood bench top (avoiding metal fittings such as gas taps). Alternatively, hand the charged person a wooden metre rule. After a few moments, they will be discharged.

Explanation

The hairs on the volunteer's body become charged and repel each other. On the head they move as far as possible from each other by standing on end. In fact, they follow the electric field lines.

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Further Experiments and Investigations

The Van de Graaff Generator is a huge source of practical experiments, and it should be used more often than just for these basic experiments.

Here is list of ideas for other experiments and investigation.

1. **Measuring the Electrostatic Field**: use the Neon indicator from the pack to move toward the Dome until it lights and measure the distance.

2. **Cake Tins:** Pile cake tins on top of the Dome and switch on to see them separate and fly away.

3. **Polystyrene Packing Chips:** take a small plastic bucket and drill a hole in the centre and fit a 4mm plug. Position the bucket on top of the Dome and hold in place by plugging the 4 mm plug in to the socket on top of the Dome. Fill with polystyrene packing chips, switch on and watch them fly away as they repel.

4. **Parallel Capacitor Plates:** Fix a polystyrene ball to a line of thread and hang between two capacitor plates from a Retort Rod, Stand, Boss Head and Clamp. Connect one of the capacitor plates to the top of the Dome and the other to the earth. Switch on and observe that the ball acts like a pendulum.

5. **Capacitor:** Make a capacitor by cutting out two large squares from a bin bag and two from a roll of aluminium baking Foil.

   i) Place the one square of bin bag on the bench (*the binbag acts as the dielectric*).
   ii) Then place the aluminium foil on top (*the plates*).
   iii) Now place the other square of bin bag on top of that.
   iv) Then the final square of aluminium on top of the second square of bin bag.
   v) Flatten the top square of bin bag to remove any air pockets.
   vi) Attach a 4mm lead via crocodile clip to the corner of lower sheet of aluminium.
   vii) Attach another 4mm lead via crocodile clip to the opposite corner of the top aluminium sheet.
   viii) Make sure the Van de Graaff is switched off and discharged.
   ix) Connect the crocodile clips to the Van de Graaff, one to the top of the Dome and the other to the Earth.
   x) Switch on the Van de Graaff and observe as the charged builds, the capacitor is energised, and the dielectric breaks down sparking across the top plate (aluminium square).
   xi) Note: remember to discharge the Van de Graaff before touching the plates.

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Note: Look out for the IPC CPD Science Video about this experiment. The video uses an IPC Irwin EHT, 5kV Power Supply sometimes referred to as an EHT unit (*Extra High Tension*) instead of the Van de Graaff Generator.

https://www.ipcirwin.com/power-supplies/5kv-eht-power-supply

6. **Brownian Motion:** An alternative to using a smoke cell to show Brownian Motion is to use a clear plastic vessel with a 4mm plug through the bottom so it can be fixed to the socket on top of the Van de Graaff. Place small polystyrene balls coated with graphite into the vessel and switch on to observer random motion.

7. **Faraday's Cage:** using an aluminium can with a 4mm plug through the bottom so it can be fixed to the socket on top of the Van de Graaff. Switch on and using the neon indicator supplied with the kit or an electrician's screwdriver first detect the charge on the outside of the can and then point the end of the neon indicator or electrician's screwdriver inside the can to show that there is no charge detected.

8. **Lightening Conductor (using a Model House with a Model Thunder Cloud):**

This experiment shows the effect and function of a lightning conductor on a house.
The model house has a translucent front (ie. windows) and a fluorescent tube is simply placed inside the house to indicate the presence of a lighting strike charge.
A second fluorescent tube is fixed to the outside of the house with a lightening conductor connected from the roof of the house to the top of the tube, while the bottom of the tube is connected to an earth socket at the base of the house.
Initially set the test up without the lightening conductor attached.
Attach the thunder cloud (polystyrene covered with tin foil) to the top of the Van de Graaff via a long 4mm lead, then attach the earth on the house to the earth socket on the Van de Graaff via a 4mm lead. As you move the cloud over the house a spark will discharges from the cloud to the house. The fluorescent tube inside the house will energise showing the lightening has struck the house itself.
Now repeat the test with the lightening conductor connected to the house and the tube connected to the side of the house will then show that the path of the strike has been safely takes to ground via the lightening conductor.

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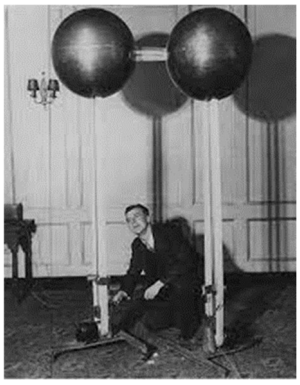
Background

The Van de Graaff Generator was developed by Robert Jameson Van de Graaff an American Physicist at the Massachusetts Institute of Technology (*MIT*) in 1929.

Robert Jameson Van de Graaff.

It was a part of research into generating extra high voltage to facilitate Xray development.



One of the next generation developments with twin mechanisms.

Further development Van de Graaff generators on railway trucks, to understand the scale of these units see the figures of people in the background.

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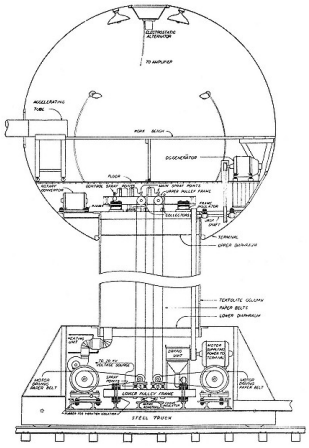

Drawing of a Van de Graaff with a laboratory in the Dome

Faraday Cage

Useful Contacts:

1. Institute of Physics:
   https://spark.iop.org/collections/van-de-Graaff-generator#gref
2. **CLEAPSS:**
   https://www.cleapss.org.uk
3. **Association of Science Educators (*ASE*)**
4. **ASE, Northern Ireland:**
   https://www.ase.org.uk/event-region/northern-ireland
   https://www.ase.org.uk/
5. SSERC:
   https://www.sserc.org.uk/
6. STEM:
   https://www.stem.org.uk/
   ISTA:
   https://www.ista.ie/
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Useful Links:

Oxford Reference:
https://www.oxfordreference.com/view/10.1093/oi/authority.20110803115149187
Institute of Physics: *(IOP*)
https://spark.iop.org/collections/van-de-Graaff-generator#gref
The Massachusetts institute of Technology (*MIT*)
https://www.mit.edu/
Education.com:
https://www.education.com/science-fair/article/making-lightning-van-de-Graaff/
How stuff Works:
https://science.howstuffworks.com/transport/engines-equipment/vdg7.htm

Thank you for purchasing the IPC Irwin Van de Graaff Generator. We hope that this document helps you develop more exciting and inspirational experiments and investigations.
We strive to support our colleagues in science education, Teachers and Technicians and we continue to develop our support material. Should you have any observations about this document or ideas you would like to pass on we will happily incorporate them into our review of instructions and experimental notes, please contact us at: info@ipcirwin.com.

Also, please visit our website for more information, news and blogs, follow us on Facebook, Twitter and linked in.

IPC Irwin is a UK designer, developer and manufacturer of science equipment with a long heritage and excellent reputation for quality, service and reliability. We supplement our manufactured lines with equipment from associate manufacturers who reach the same quality standards we set ourselves.
All our equipment meets or exceeds all regulations on safety, quality, performance, reliability and educational value. We expect our equipment to give you many years of service and should you need any help support or advice, please do not hesitate to contact us on 015395 58555.

To register your guarantee go online at www.ipcirwin.com

Electromagnetic Compatibility
The use of this apparatus outside the classroom, laboratory, study area or similar such place invalidates the conformity with the protection requirements of the Electromagnetic Conformity Directive (89/336/EEC) and could lead to prosecution.