**Physics: 12. Static Electricity**

***Please remember to photocopy 4 pages onto one sheet by going A3→A4 and using back to back on the photocopier***

**Questions to make you think**

1. Why do you sometimes get goose-pimples in cold weather?
2. Why does your hair stand up when you get a fright?
3. What do you think is the evolutionary purpose behind this (hint: it also happens when you get an electrical shock)?
4. Why is it that socks which are dried in a tumble-dryer come out lovely and soft while those which are dried on a clothesline outside are often hard/abrasive?

 **Syllabus**

**OP48** Use simple materials to generate static electricity; demonstrate the force between charged objects and the effects of earthing.

**Student Notes**

**A conductor is a substance that allows charge to flow through it easily (metals are conductors)**

**An insulator is a substance that does not allow charge to flow through it (plastics are insulators)**

When one object is rubbed against another, charges (electrons) often get transferred from one object to the other.

Remember that electrons have a negative charge.

An object becomes positively charged if it loses electrons, and negatively charged if it gains electrons.



**Demonstration: using simple materials to generate static electricity**

Option 1: Rub a biro (a balloon is even better) with a cloth to charge it and then use it to attract pieces of tissue paper.

Option 2: A charged balloon can attract an empty coke can which is lying on a table.

Conclusion: Neutral objects are attracted to charged objects



**Similar charges repel; opposite charges attract**

**To demonstrate the force between charged objects**

1. Charge a plastic rod by rubbing it with a cloth and then hang it from a retort stand.
2. Rub another rod with the same cloth (so that it will have the same charge) and bring it up to the first rod.

**Result**:

The first rod will be repelled by the second rod.

**Conclusion**:

Similar charges repel.

Now bring up a different type of charged rod (which has an opposite charge).

**Result**:

The first rod will move towards the second rod.

**Conclusion**

Opposite charges attract.

**Earthing**

Earthing means connecting a charged object to the earth by means of a conductor, so that most of the charge which was on the object flows to the earth.

If a rod is charged then all the charges on the rod are repelled from each other and will try to escape from the material if they can. If the material is an insulator like plastic then the charges are not able to move and so remain on the material.

However if you touch the material with your fingers then the points of contact become ‘earthed’ because the charges get transferred to earth via your body. When an object loses charge in this manner we say it gets ‘earthed’.

Similarly the charges can transfer into the air if there is a lot of moisture in the air because water is a conductor.

**Useful effects of static electricity**

1. Removing soot from chimneys
2. Spray-painting

**Nuisance effects of static electricity**

1. Television screens attracting dust
2. Lightning

**Exam Questions**

1. ****[2006 OL]

A student set up the circuit drawn on the right to investigate different materials to see which were electrical conductors and which were electrical insulators.

1. What would you expect to observe when an electrical conductor is connected between the contact points A and B? Give a reason for your answer.
2. What would you expect to observe when an electrical insulator is connected between the contact points A and B? Give a reason for your answer.
3. [2008]

Two rods A and B, made from different plastics, were given the static electrical charges shown in the diagram.

How could you have charged the rods as shown?

1. [2008]

Describe with the help of a labelled diagram how the force between the two charged rods A and B could be investigated.

What result would you expect from this investigation?

1. [2011 OL]

The diagram shows a freely suspended charged rod.

1. What happens when a similarly charged rod is brought close to the suspended rod?
2. What does this tell us about like charges?
3. [2008]

In dry weather you can sometimes get an electric shock from a supermarket trolley.

This is caused by the build-up of static electricity on the trolley.

Explain clearly why this only happens in dry weather.

1. [2009][2012]

A plastic pen when rubbed with a dry cloth can attract small pieces of paper which ‘stick’ to it.

1. Why does this happen?
2. Explain why the pieces of paper fall from the pen after some time.

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1. [2011]

The boy in the photo is touching a charged globe that is at high voltage.

He is insulated from the earth.

What property of electric charge causes the boy’s hair to stand on end and apart?

1. [2006 OL]
2. What type of energy generates lightning?
3. The flash of lightning is seen before the thunder is heard.

What does this tell us about the speed of light?

**Exam Solutions**

* 1. The bulb lights because there is a complete (closed) circuit.
	2. The bulb doesn’t light because the circuit is still broken (the material doesn’t conduct)’
1. By rubbing them with a cloth
2. Suspend the rods as shown

Bring the rods close together

Result: The rods attract each other

*OR*

Balance one rod on a clock glass and bring the other rod up close to it.

Result: The rod balanced on the glass rotates towards the hand-held rod.

1. The suspended rod moves away from the other rod
2. Similar charged objects repel each other.
3. In wet weather moisture allows electric charge to escape.
4. Because the pen has charge
5. The pen loses its charge
6. Similar charges repel
	1. Static electricity
	2. Light travels faster than sound

**Other Test Questions**

1. What is the difference between a conductor and an insulator?
2. Write out the following sentence, filling in the missing words:

Similarly-charged objects \_\_\_\_\_\_\_\_\_\_\_\_\_\_ while oppositely-charged objects \_\_\_\_\_\_\_\_\_\_\_\_\_\_.

1. Describe briefly how you would investigate the relationship between two similarly charged objects.
2. Give one example of when static electricity is useful and one example of when static electricity can be a nuisance (apart from getting a shock)?
3. When a Perspex rod is rubbed with a cloth it becomes positively charged. Explain in terms of electron transfer how this occurs.

**Teaching *Static Electricity***

**Syllabus**

**OP48** Use simple materials to generate static electricity; demonstrate the force between charged objects and the effects of earthing.

**Introduction**

* There is a central concept here which is just plain wrong and which must at least be understood by the teacher in order to answer the question if it does arise, namely that both positive and negative charges are capable of movement. We know from our knowledge of the atom that only electrons move, so why do we invoke the concept of moving positive charges?
The answer is twofold;
1. The phenomena were studied long before we had any knowledge of what was happening at an atomic level.
2. Whether we say that an object becomes positively charged because positive charges are put on it, or because negative charges left it, the end result is the same, so the convention is to maintain the historically (inaccurate) explanation, and hope that it doesn’t cause (too) much confusion.

This can get a little trickier for the concept of earthing a positively-charged rod – it means that negative charges must come from the earth to the rod to neutralise it.

* The central concept here is that by rubbing an insulating material you can charge it either positively or negatively.

Somewhat counter-intuitively, a positively-charged object is a result of the object *losing* electrons while a negatively-charged charged object is a result of the object *gaining* electrons.

The effect is only noticeable with insulators because charge (i.e. electrons) can’t flow along the surface and so can’t escape, whereas they can if the object is a conductor.

* Students are not expected to know which plastics become positively charged when rubbed, and which become negatively charged.
* If an object is neutral or uncharged, it does not mean that the object has no charge - merely that it has an equal amount of positive and negative charge, and they cancel each other out.

**Static electricity and the weather**

All static electricity experiments are affected by humidity – try to pick a dry day. It may seem surprising but cold dry days (e.g. in the middle of winter) are actually better than warm dry days because cold air contains less moisture than warm air.

**OP48: Use simple materials to generate static electricity; demonstrate the force between charged objects and the effects of earthing.**

**1.1** **Use simple materials to generate static electricity**

I don’t know what is meant by the phrase “to generate static electricity” - it makes no sense. I presume it should read; *use simple materials to charge an object* (as per the exam question above).

A variety of rods and cloths are available in the resource box. Balloons also work very well (buy your own set!)

**1.2 Demonstrate the force between charged objects**

* **Hanging the rods – don’t**

You could try to use a stirrup which has little contact area like the text-books suggest. The disadvantage associated with hanging the rods is that they can easily be discharged due to contact with the students’ hands while setting it up.

I find it much better to instead delicately balance the rod on an upturned clock-glass.

* **Remember – the rods are not magnets**

The single greatest reason for non-results is the assumption that this experiment will be similar to investigating the force between magnets. In principle this is correct, but because the forces involved with static electricity are very much weaker, we must be much more careful in our effort to control other variables.

For example when bringing one plastic close to another, don’t just point one end close to the other – use as much overlap area as possible without actually going beyond half-way.

* **Stall the ball**

Watch that you don’t confuse the plastic’s display of repulsion or attraction with its natural swinging motion due to having been touched, or from not having had adequate time to come to rest after having been hung. This confusion is most likely to occur when the rod is changing direction.

* **Unintentional earthing**

Remember that whenever and wherever you hold one plastic you discharge the area of contact (the charges in this area can travel through you to earth). This is because, while you may think that your body is an insulator, the surface of your skin actually contains moisture and therefore can conduct electricity.

* **Why does a charged object attract an uncharged object?**

You may find that one rod attracts another rod even though they are both from the same material (and therefore should be similarly charged and should repel each other). The most likely reason for this is that the first object was either not charged properly or lost its charge while being hung.

While most textbooks show a photograph of a biro being used to pick up small pieces of paper (tissue-paper works best), they don’t explain *why* this is happening.

I think it’s because the electrons in the material re-orientate themselves such that the electrons are either on the side facing the biro if the biro was positively charged, or on the side facing away from the biro if it was negatively charged.

The attractive forces are now closer to the biro than the repulsive forces, and so the material gets attracted to the biro.

* 1. **Demonstrate the effects of earthing**

As good an excuse as any to bring out the Van der Graff generator.

Apart from the standard routine try the following extras:

1. Place a bunch of disposable aluminium dishes on the dome and watch as they rise up and float away as they become charged.
2. Pour some rice-crispies into one aluminium dish and watch them dance.
3. Blow bubbles at the dome and watch them become attracted and then fly away.
4. Hold a fluorescent light-bulb beside the dome and watch as it glows mysteriously – you’re Harry Potter!

Note that you don’t have to know the physics behind the last two; sometimes they’re just fun to do.

**Other Demonstrations**

Note that you don’t have to use a rod; a charged polystyrene cup or balloon would work just as well.

* Deflect a stream of water by bringing a charged object close to it. I’m not sure why this happens; I suspect it is because although the water is uncharged the molecules have a ‘polarity’, i.e. they can alter their orientation so that the net effect is that the water acts as though it were charged.
* Attract a coke can or even an empty two litre bottle (lying on its side).
* Textbooks sometimes show two hanging balloons being repelled from each other; three balloons is even better – it can also act as a model for chemical arrangement of electrons for leaving cert chemistry.
* Balance a metre stick on an upturned clock glass and get it to rotate by holding a charged rod close to one end. Any other rigid insulator should also work – the moment of a force also comes into play here. The most impressive object I’ve tried was a ten foot length of ‘2 by 4’ timber!

**Everyday Effects of Static Electricity**

* Dust on Television Screens
* Static on Clothes
* Getting a shock from a car door after getting out following a long journey

The following is a wonderful article written by the late Brendan McWilliams, who used to write a column every day on weather-related issues in *The Irish Times*.

Among other things, this article explains why we feel refreshed after a shower.

**Putting the ion under the microscope**

Molecules of air comprise of atoms in many combinations. Moreover, atoms, as we all know, contain tiny negatively-charged particles called electrons, and sometimes, for a variety of reasons, an electron may be dislodged from its parent atom and from the molecule family to which it properly belongs.

The departure brings a sense of loss. The molecule, deprived of some of its negative charge, is no longer electrically neutral and is left holding a net positive charge: we call it a *positive ion.*

But the vagrant electron soon finds a new home; it adheres to an adjacent molecule, which then has a surfeit of negative charge and becomes a *negative ion*.

Either way, because they carry an electrical charge, ions are strongly by any electrical activity nearby and are highly mobile. It was for this reason that the English physicist Michael Faraday called them after the ancient Greek Ionians who were, apparently, great travellers.

Now, the reason we bother ourselves at all with these miniscule dots of electricity is that there is evidence to suggest that ions affect our well-being. Most of the time, negative and positive ions are present in the air in roughly equal quantities, but sometimes one or the other may predominate. The air becomes rich in positive ions, for example, during a thunderstorm, and also in the vicinity of fire. According to those who claim to know, a preponderance of positive ions produces irritability and anxiety in the 30 per cent of the population who find themselves susceptible, and may induce nausea and headaches.

It is alleged that the *Minstral* of southern France, the *Santa Ana* wind which blows in California, and Italy’s *Sirocco* wind are all laden with positive ions, and that this accounts for the unpleasant psychological effects that they are known to cause.

Negative ions, on the other hand, have quite the opposite effect and induce, we are told, a sense of physical and mental well-being. There is normally a high concentration of negative ions near the seashore, and in the rarefied air at the summits of very high mountains; negative ions are also present in abundance in the vicinity of waterfalls, created by the breaking up of water droplets into a fine spray. Negative ions are also created in the domestic shower and this is said to be why a shower produces a feeling of freshness and invigoration superior to the traditional bath.

Pollution, on the other hand, rapidly destroys negative ions so concentrations are normally low in urban areas. In dull, smoggy conditions there are very few of them indeed.

**The triboelectric series**

It is not obvious whether a material will lose or gain electrons when rubbed by another material.

The tribolelectric series is a table which lists a variety of materials in the order of which they lose or gain electrons. Students do not have to know the names of different plastics which go positive or negative.

Not only that, but if wool is rubbed against two different types of plastic (let’s call them A and B) it may make both of them negative. However if A is more negative than B, then A can be said to be positive relative to B and so both plastics can attract each other.