- perform an investigation to model the behaviour of semiconductors, including the creation of a hole or positive charge on the atom that has lost the electron and the movement of electrons and holes in opposite directions when an electric field is applied across the semiconductor

First-Hand Investigation: Modeling of Semiconductors

Aim: To model the behaviour of semiconductors.

Materials:

- Marbles
- 2 Petri dishes

Method:

1) Fill one Petri dish completely with one layer of marbles and leave the other empty.

2) Remove ONE marble from the filled dish and place it into the empty dish.

3) Tilt the Petri dishes in one direction.

Results:

- What occurred when the Petri dish was tilted?

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- What was the relative motion of the marbles and the gap in the filled dish?

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Discussion:

- Outline how this set-up modeled the behaviour of semiconductors.

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- Describe how we could model metal conductors using the same concept of marbles and a Petri dish.

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- describe how 'doping' a semiconductor can change its electrical properties

Doping Semiconductors

- Doping is the process of adding a GROUP 3 OR 5 ELEMENT in trace amounts as an impurity to a SEMI-CONDUCTOR to DRAMATICALLY INCREASE ITS CONDUCTIVITY.

- Silicon is commonly used as a semiconductor.

  - How many valence electrons does a silicon atom have?

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  - Identify the bonding and structure of silicon.

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- If a group 3 element is added, then because it has one less electron in its valence shell to complete the bonding, a hole would be produced in the lattice structure.

- If a group 5 element is added, there will be an extra, free electron in the lattice structure.

- Effectively, doping changes the number of free electrons or holes present and hence the conductivity of a semiconductor.

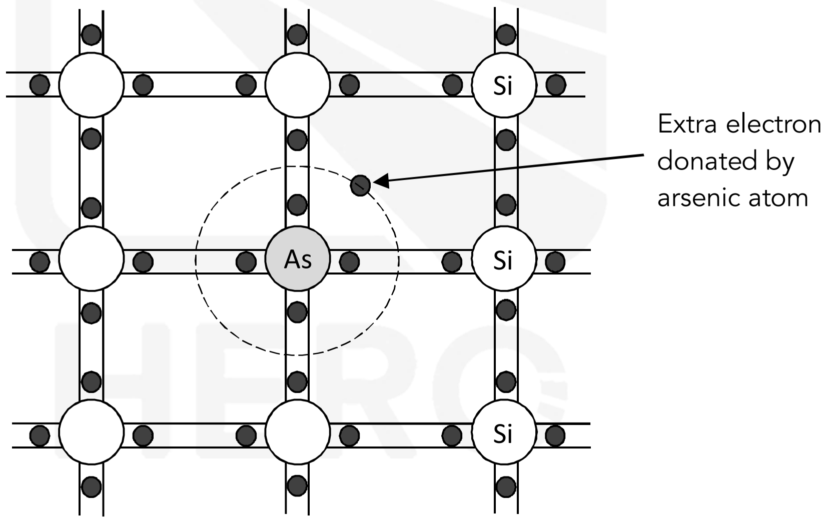
- There are two different types of doped semiconductors:

  - n-type
  - p-type

- identify differences in p and n-type semiconductors in terms of the relative number of negative charge carriers and positive holes

N-type Semiconductors

- N-type semiconductors are ones that have been doped with DONOR atoms from group 5 of the periodic table.
- Since semiconducting materials such as silicon have 4 valence electrons for bonding, only 4 of the available 5 electrons from the donor atom are used for covalent bonding.
- The remaining electron is thus, available for conduction.
- Arsenic is a commonly used example of a group 5 impurity used in doping.



- What is the charge of a n-type semiconductor? Explain.

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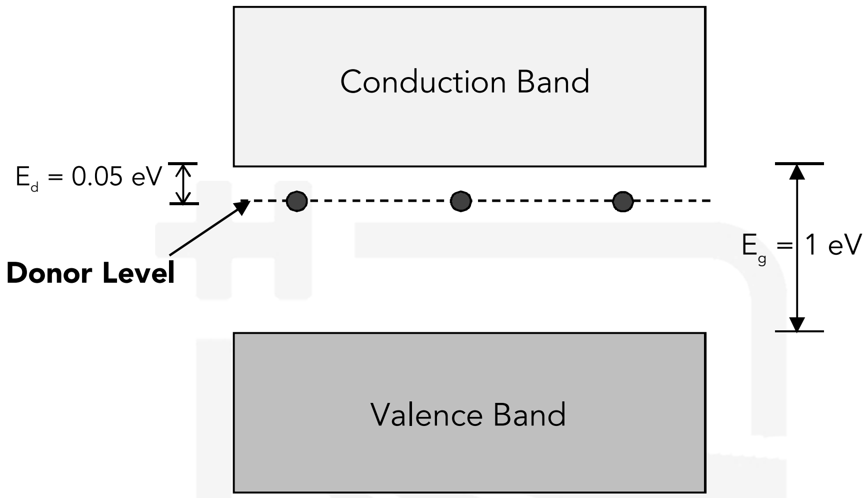
- The fifth excess electron from the arsenic atom cannot fit into the valence band as it is full. Therefore, it exists at an energy level called the DONOR LEVEL that lies just below the conduction band, within the energy gap.



- How does the presence of the donor atom affect the conductivity of silicon?

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- Outline the relative number of electrons in the conduction band and holes in the valence band for a n-type semiconductor.

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- At 0K would the donor level be full or empty of electrons?

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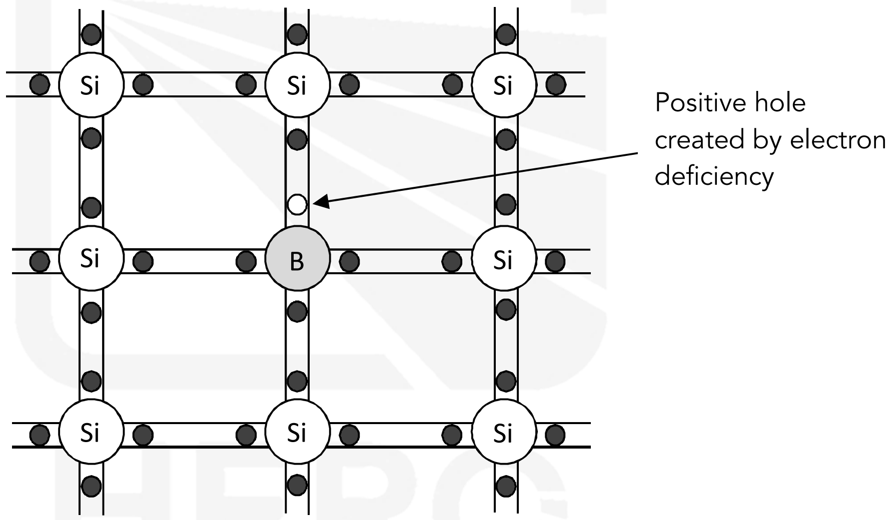
P-type Semiconductors

- P-type semiconductors are ones that have been doped with ACCEPTOR atoms from group 3 of the periodic table.
- Since semiconducting materials such as silicon have 4 valence electrons for bonding, acceptor atoms which have only 3 valence electrons represent an electron deficiency.
- Thus, only three covalent bonds are formed and a hole is produced which is available for conduction.
- Boron is a commonly used example of a group 3 impurity used in doping.



- What is the charge of a p-type semiconductor? Explain.

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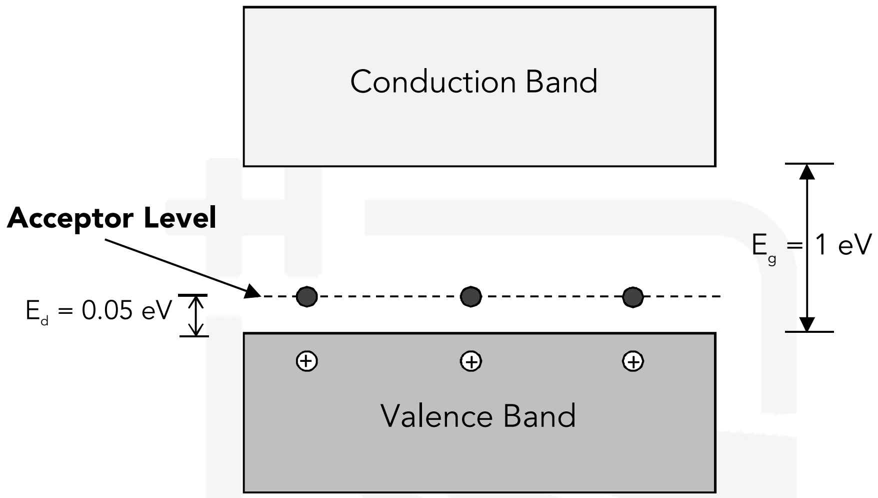
- The positive hole created by the Boron atom exists at an energy level called the ACCEPTOR LEVEL that lies just above the valence band, within the energy gap.



- How does the presence of the acceptor atom affect the conductivity of silicon?

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- Outline the relative number of electrons in the conduction band and holes in the valence band for a p-type semiconductor.

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- At 0K would the acceptor level be full or empty of electrons?

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- identify that the use of germanium in early transistors is related to lack of ability to produce other materials of suitable purity

Germanium VS. Silicon

- Early transistors used GERMANIUM as the semiconducting material.

- This was because during the 1940's at the start of semiconductor research, suitable purification methods were only developed for germanium.

  - Why must materials used for semiconductor devices be very pure?

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- Germanium however, did not retain its semiconducting properties at high temperatures which is a problem since the transistor would contain too many free electrons and stop functioning.

- By the 1960's purification methods were developed for SILICON which allowed it to quickly replace germanium in solid state devices.

- This is due to its advantages over germanium:

  - Silicon retains its semiconducting properties at higher temperatures.
  - Silicon is much more abundant than germanium and hence is cheaper.
  - Silicon forms an oxide layer with very good insulating properties when heated which is critical in the manufacture of integrated circuits.

- Thus, early transistors used germanium as it was the only really pure semiconductor available at the time but was quickly replaced by silicon once purification methods were developed.

Concept Check 3.4:

(i) What is 'doping'? **1**

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(ii) Explain how doping affects the conducting properties of a semiconductor using the band theory of solids with reference to the two types of extrinsic semiconductors. **4**

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Concept Check 3.5:

Compare the electrical conduction in n-type and p-type semiconductors.

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