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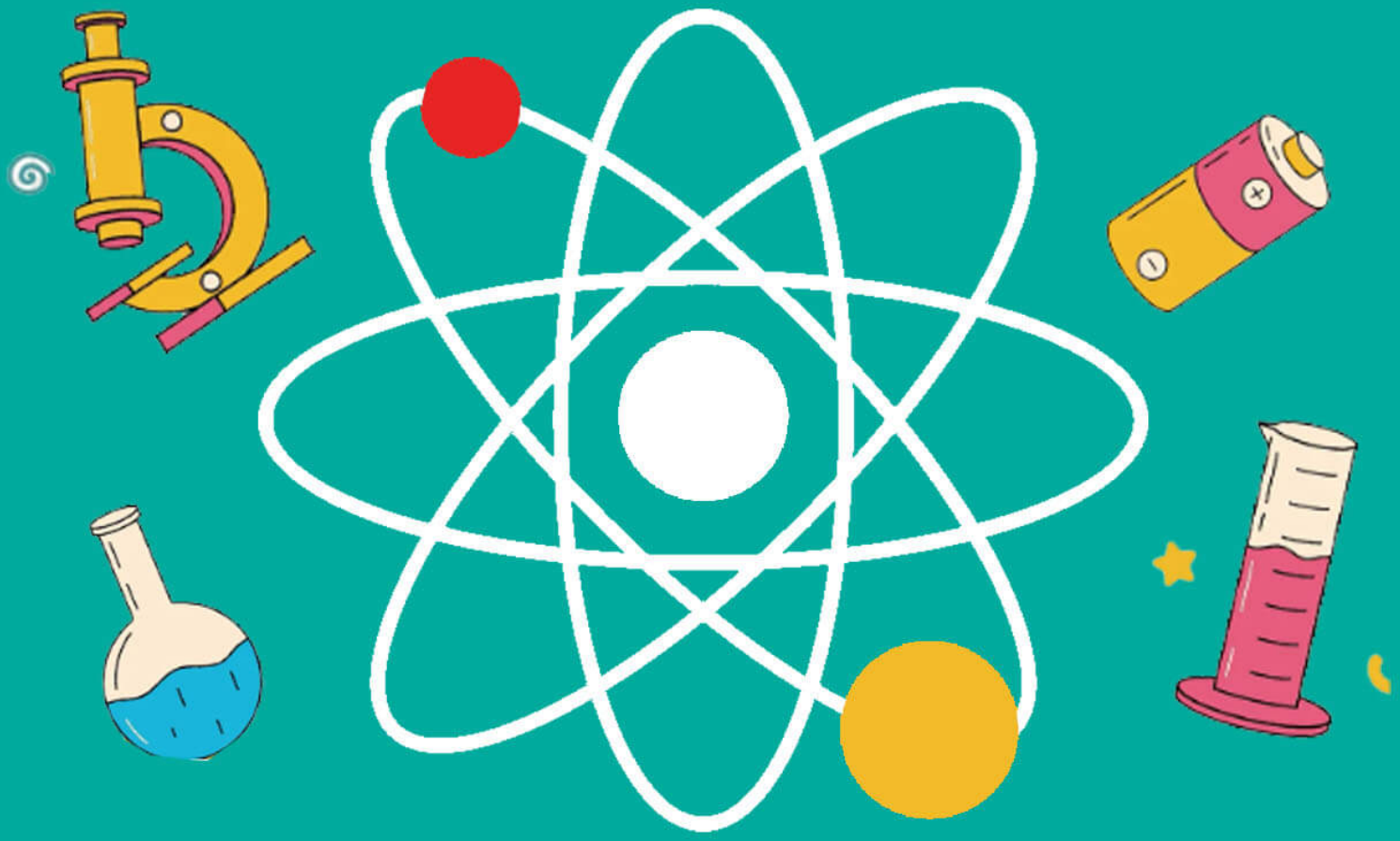
10.3 Biological Measurement



AQA A Level Physics Revision Notes

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10.3.1 ECG Machines

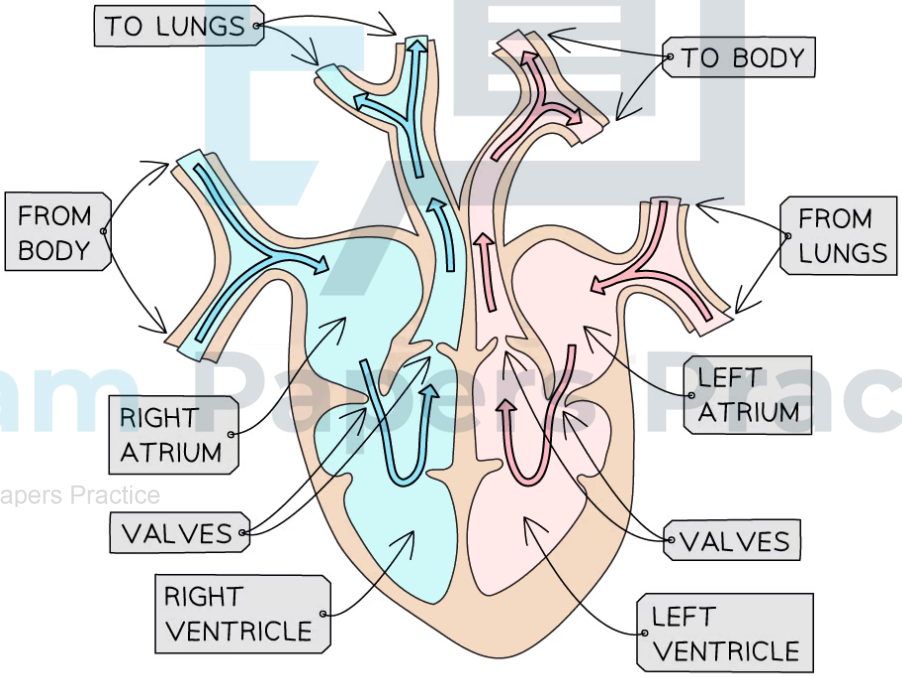
Simple ECG Machines

- Electrocardiography can be used to monitor and investigate the electrical activity of the heart
- **Electrodes** that are capable of detecting electric signals are placed on the skin
- These electrodes produce an **electrocardiogram** (ECG)
- An ECG shows several distinctive electrical waves produced by the activity of the heart
- A healthy heart produces a distinctive shape in an ECG

The Structure of the Heart

- The heart is controlled by **electrical impulses** in nerve cells
- These can be measured as weak electrical signals by detectors on the surface of the skin
- The heart consists of four chambers with two chambers on both the left and right sides:
  - **Atria** in the upper parts
  - **Ventricles** in the lower parts
- The left side of the heart is the right side of the diagram

A Diagram of the Structure of the Heart



The diagram shows the left and right sides of the heart with the atrium and ventricle on each side

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Electrical Signals of the Heart

- During a heartbeat, the four chambers of the heart **contract** (this is depolarisation) and **relax** (this is repolarisation) in a sequence controlled by electrical signals
  - First, the **atria contract** (depolarise), forcing blood into the **ventricles**
  - This causes the **ventricles** to **contract** (depolarise) and the **atria** to **relax** (repolarise)

- Blood is pumped into the lungs and body
- The **ventricles** then **relax** (repolarise) to complete one heartbeat

Obtaining an ECG Trace

- Electrodes must be positioned to obtain the maximum electrical signal possible from the heart
- The reading measured by the ECG machine is the **potential difference** between pairs of electrodes
- To obtain a good trace, the following factors must be considered:
  - The optimum positioning of the electrodes
  - Minimising contact resistance
  - Improving the quality of the received signals

Positioning the electrodes

- Electrodes are placed strategically **in pairs** on the body to obtain the largest potential difference, these are:
  - In six standard chest positions
  - One on each limb (close to the arteries)

Reducing contact resistance

- The point where the **electrodes** are attached to the skin is called a **contact**
- The contacts must be:
  - Good conductors of electricity
  - Provide a low resistance to the electrical signal
  - Non-irritant
  - Non-reactive to skin chemicals
  - All securely stuck in place
- As such, the contacts are:
  - Made from a non-reactive material
  - Secured in place with a **conductive gel**
  - Attached after **removing hairs** and dead **skin cells** (with sandpaper or a razor)

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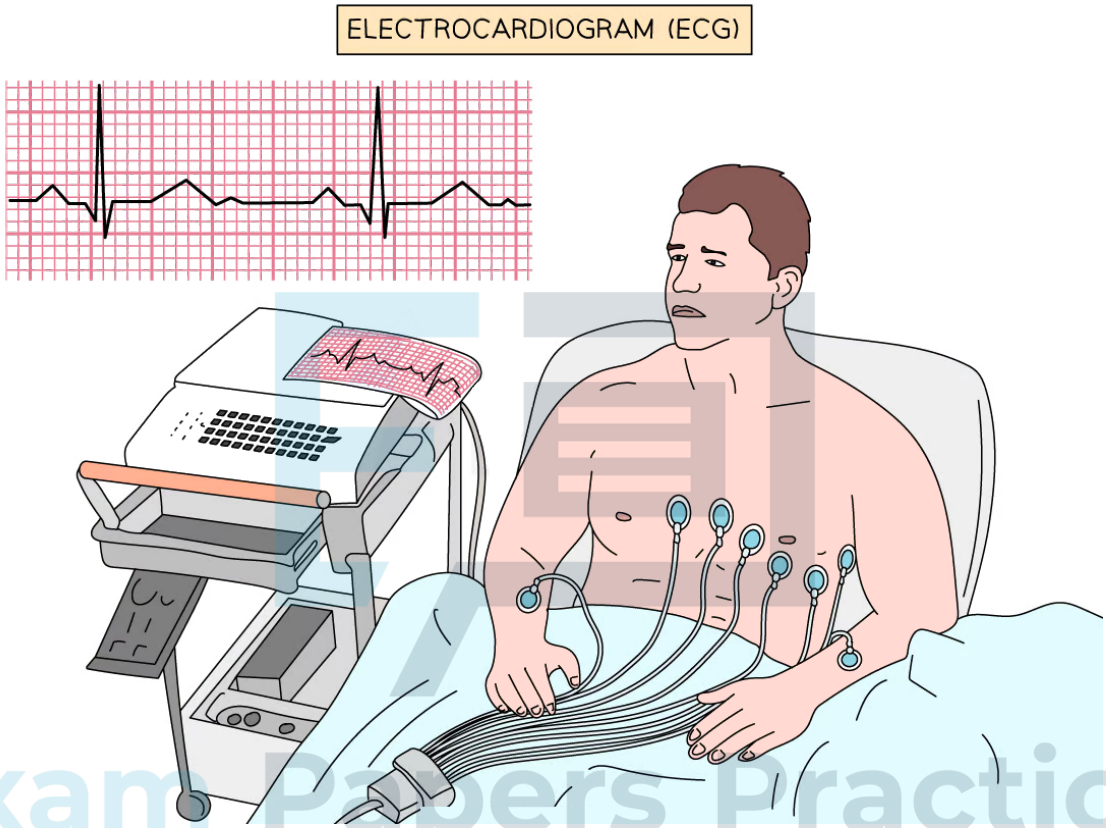
Improving the Signal

- The electrical signal detected by the ECG is relatively small because it is easily **absorbed** by the body
- To improve the received signals:
  - The patient should remain **relaxed** and still
  - The machine and leads should be **shielded** from the electrical interference of other AC sources
  - The signal needs to be **amplified**
- The signal needs to be amplified by a high-gain, low-noise, high-impedance amplifier
  - **High gain** means the amplifier can increase the electrical signal without increasing the **noise**
  - **Low noise** means the amplifier does not reduce the quality of the electrical signal during the amplification process

- **High impedance** means the amplifier increases the input signal enough so it can be interpreted by the machine

Patient undergoing an ECG



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Electrodes are attached in pairs to a patient's chest in the six positions shown and all four limbs. The variation in potential difference between them is detected

Worked example

Electrodes are attached to the chest of a healthy person and a normal ECG waveform is obtained.

(a) State two ways of ensuring good electrical contact between the electrodes and the patient.

(b) State two properties needed by the amplifier to amplify the signal from the electrodes.

Answer:

(a) Two ways of ensuring good electrical contact between the electrodes and the patient

Any **two** from:

- Hair and dead skin must be removed from the surface of the patient (using sandpaper)
- The electrodes must be coated with a conducting gel
- The electrodes must be made from a material that does not react with the skin

(b) Two properties needed by the amplifier to amplify the signal from the electrodes

Any **two** from:

- High gain
- Low noise
- High input impedance

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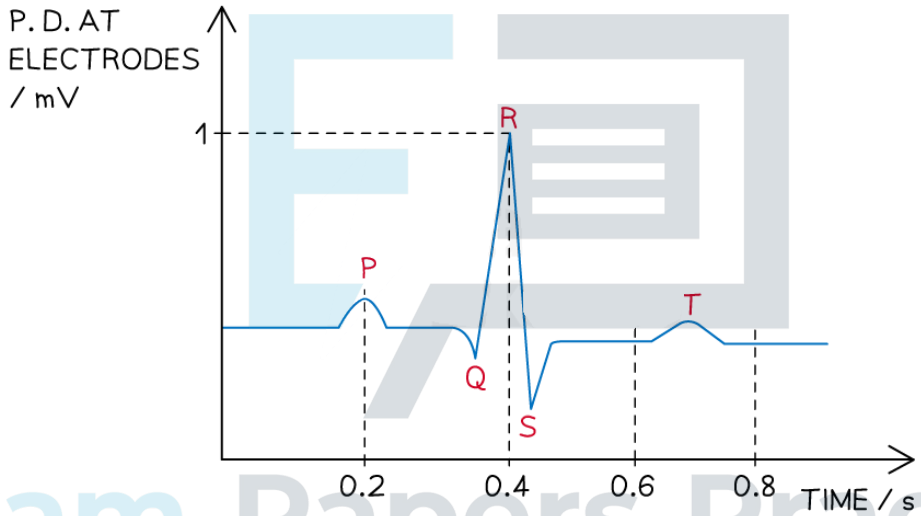
Exam Tip

It is common practice to be asked about increasing electrical contact and properties about the amplifier. You do not go into a lot of detail in this unit, so just learn these key facts.

Normal ECG Waveform

- ECG stands for **electrocardiogram**
- It is a graph of the potential difference between the electrodes (in mV) against time (in s)
- A normal ECG, covering a single heartbeat, has three separate parts:
  - A **P wave**
  - A **QRS wave**
  - A **T wave**
- The **heartbeat** can be determined from the number of contractions (number of waveforms) present on the ECG in 1 minute

A Normal ECG Waveform



A normal electrocardiogram (ECG) waveform contains P, QRS and T components

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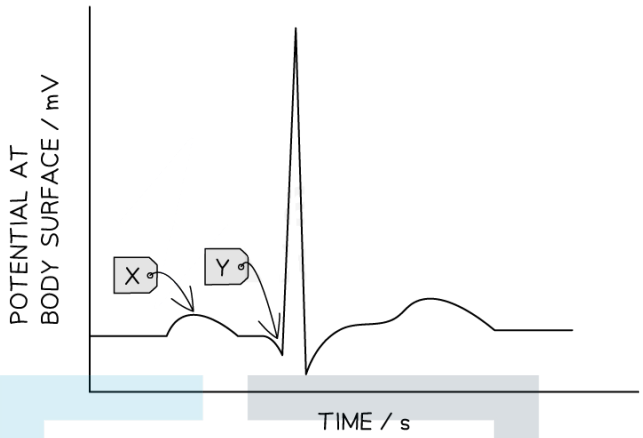
- **The P wave**
  - Caused by the **contraction** (depolarisation) of the **atria**
- **The QRS wave**
  - Corresponds to the **contraction** (depolarisation) of the **ventricles**
  - It occurs 0.2 seconds after the **P wave**
  - The signal is much greater than the **P wave**
  - It reaches its maximum at 1 mV
- **The T wave**
  - Corresponds to the **relaxation** (repolarisation) of the **ventricles**
  - It occurs 0.2 seconds after the **QRS wave**

Worked example

Electrodes are placed on the surface of a body to record an ECG trace for a healthy person.

The trace obtained for one heartbeat is shown below.



(a) Label the approximate scales on each axis.

(b) State the name of the wave part at points X and Y and the physical change that takes place.

Answer:

(a) Label the approximate scales on each axis

- Draw dotted lines from each key property of the graph to the correct axis
- Label the maximum potential difference (in mV) of the QRS wave as 1
- Label the time in seconds every 0.2 seconds (0.2, 0.4, 0.6 and 0.8)

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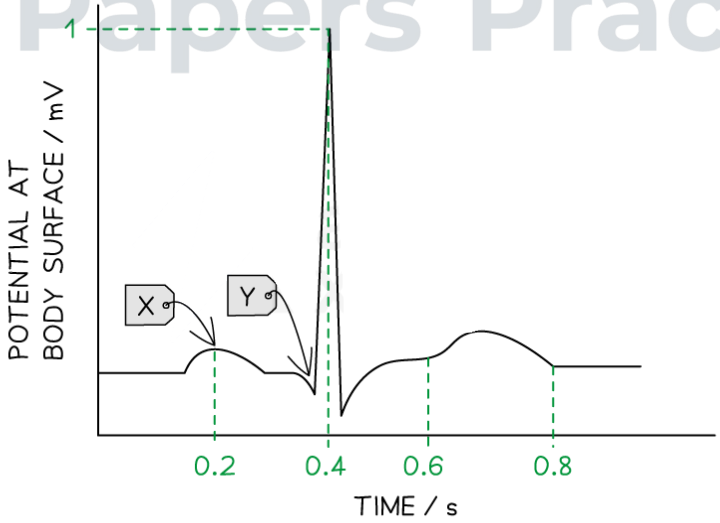

(b) State the wave part at points X and Y and the physical change that takes place

Point X:

- Wave part: P wave
- Physical change: atria contract

Point Y:

- Wave part: QRS wave
- Physical change: ventricles contract

Exam Tip

You only need to know what an ECG looks like for a healthy person and not for someone with a heart problem. You need to remember the ECG graph very carefully, as you may be asked to sketch it on an axis or label the axis of a pre-drawn waveform.

Remember that the plural of atrium is atria and **not** atriums.

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