

I. INTRODUCTION

Willem Einthoven developed a “string galvanometer” in 1901 that could record the electrical activity of the heart. Although it was not the first such recorder, it was a breakthrough in that it was accurate enough to duplicate the results on the same patient. Einthoven’s work established a standard configuration for recording the ECG and won him the Nobel Prize in 1924. Since then, the ECG has become a powerful tool in diagnosing disorders of the heart. [It should be noted that the clinical interpretation of the ECG is quite empirical in practice, and has evolved from a long history of reference to and correlation with known cardiac disorders.]

About Willem Einthoven:

1860-1927
Born in Semarang, Java
Dutch physician
Professor, University of Leiden,
1885-1927
Nobel Prize: 1924

The electrical activity of each cardiac cycle begins with depolarization of the sinoatrial (SA) node, the primary pacemaker of the heart. The wave of depolarization spreads throughout the atria initiating contraction of atrial myocardium (see Lesson 5 ECG I for details.) Depolarization of the atria is recorded as the P wave of the ECG. Repolarization of the atria immediately follows the depolarization and occurs during the PR segment of the ECG. At the AV node, transmission of the electrical signal is slowed, allowing the atria sufficient time to complete their contraction, before the signal is conducted down the AV bundle, the left and right bundle branches, and the Purkinje fibers to ventricular myocardium. Depolarization of the ventricles is recorded as the QRS complex in the ECG, and repolarization of the ventricles is recorded as the T wave.

During the cardiac cycle, the current spreads along specialized pathways and depolarizes parts of the pathway in the specific sequence outlined above. Consequently, the electrical activity has directionality, that is, a spatial orientation represented by an electrical axis. The preponderant direction of current flow during the cardiac cycle is called the *mean electrical axis*. Typically, in an adult the mean electrical axis lies along a line extending from the base to the apex of the heart and to the left of the interventricular septum pointing toward the lower left rib cage.

The magnitude of the recorded voltage in the ECG is directly proportional to the amount of tissue being depolarized. Most of the mass of the heart is made up of ventricular myocardium. Therefore, the largest recorded waveform, the QRS complex, reflects the depolarization of the ventricles. Furthermore, since left ventricular mass is significantly greater than right ventricular mass, more of the QRS complex reflects the depolarization of the left ventricle, and orientation of the mean electrical axis is to the left of the interventricular septum.

The body contains fluids with ions that allow for electrical conduction. This makes it possible to measure electrical activity in and around the heart from the surface of the skin (assuming good electrical contact is made with the body fluids using electrodes.) This also allows the legs and arms to act as simple extensions of points in the torso. Measurements from the leg approximate those occurring in the groin, and measurements from the arms approximate those from the corresponding shoulder.

Ideally, electrodes are placed on the ankles and wrists for convenience to the subject undergoing the ECG evaluation. In order for the ECG recorder to work properly, a ground reference point on the body is required. This ground is obtained from an electrode placed on the right leg above the ankle. To represent the body in three dimensions, three planes are defined for electrocardiography (Fig. 6.1.) The bipolar limb leads record electrical activity of the cardiac cycle in the frontal plane and will be used in this lesson to introduce principles of vectorcardiography.

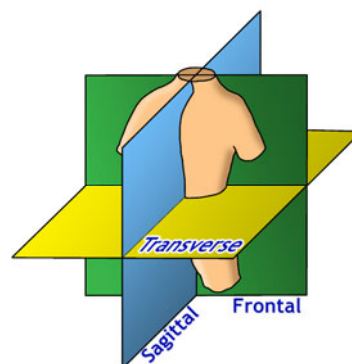


Fig. 6.1 ECG planes

A *bipolar lead* is composed of two discrete electrodes of opposite polarity, one positive and the other negative. A hypothetical line joining the poles of a lead is called the *lead axis*. The electrode placement defines the recording direction of the lead, when going *from the negative to the positive electrode*. The ECG recorder computes the difference (magnitude) between the positive and negative electrodes and displays the changes in voltage difference with time. A standard clinical electrocardiograph records 12 leads, three of which are called standard (bipolar) limb leads.

The standard bipolar limb leads, their polarity and axes are as follows:

| Lead | Polarity | Lead Axis |
|----------|-------------------------------|---------------------------|
| Lead I | right arm (-) to left arm (+) | $\pm 180^\circ - 0^\circ$ |
| Lead II | right arm (-) to left leg (+) | $-120^\circ - +60^\circ$ |
| Lead III | left arm (-) to left leg (+) | $-60^\circ - +120^\circ$ |

The relationships of the bipolar limb leads are such that the sum of the electrical currents recorded in leads I and III equal the sum of the electric current recorded in lead II. This relationship is called *Einthoven's law*, and is expressed mathematically as:

$$\text{Lead I} + \text{Lead III} = \text{Lead II}$$

It follows that if the values for any two of the leads are known, the value for the third lead can be calculated.

A good mathematical tool for representing the measurement of a lead is the vector. A *vector* is an entity that has both magnitude and direction, such as velocity. At any given moment during the cardiac cycle, a vector may represent the net electrical activity seen by a lead. An electrical vector has magnitude, direction, and polarity, and is commonly visualized graphically as an arrow:

- The length of the shaft represents the magnitude of the electrical current.
- The orientation of the arrow represents the direction of current flow.
- The tip of the arrow represents the positive pole of the electrical current.
- The tail of the arrow represents the negative pole of the electrical current.

The electric current of the cardiac cycle flowing toward the positive pole of a lead axis produces a positive deflection on the ECG record of that lead. An electric current flowing toward the negative pole produces a negative deflection. The amplitude of the deflection, negative or positive, is directly proportional to the magnitude of the current. If the current flow is perpendicular to the lead axis, no deflection is produced in the record of that lead. It follows that for a given magnitude of electrical current, the largest positive deflection will be produced by current flowing along the lead axis toward the positive pole, and the largest negative deflection produced by current flowing along the lead axis toward the negative pole (Fig.6.2) When the direction of current flow is between the lead axis and its perpendicular, the deflection is smaller. This is true for current flowing away from as well as toward the positive pole.

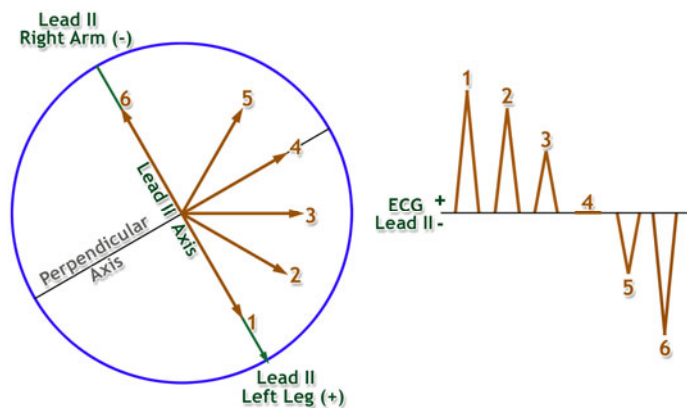


Fig. 6.2

Due to the anatomy of the heart and its conduction system, current flow during the electrical cardiac cycle is partly toward and partly away from the positive pole of the bipolar limb leads. This may produce a biphasic (partially +, partially -) deflection on ECG lead record. A good example is the coupled Q-R or R-S deflections of the QRS complex typically seen in Lead II. At any given moment, the bidirectional electric current can be represented by a single mean vector that is the average of all the negative and positive electrical vectors at that moment (Fig. 6.3.)

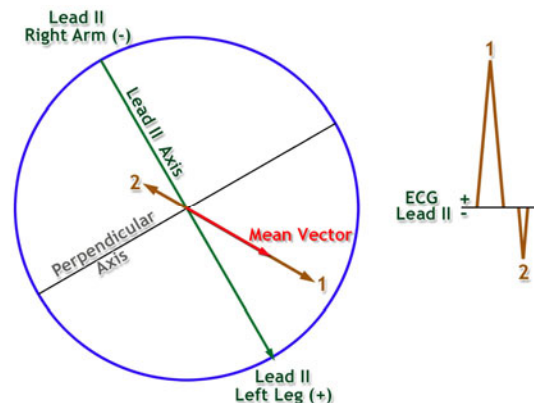


Fig. 6.3

The bipolar limb lead axes may be used to construct an equilateral triangle, called Einthoven’s triangle, at the center of which lies the heart (Fig. 6.4.) Each side of the triangle represents one of the bipolar limb leads. The positive electrodes of the three bipolar limb leads are electrically about the same distance from the zero reference point in the center of the heart. Thus, the three sides of the equilateral triangle can be shifted to the right, left, and down without changing the angle of their orientation until their midpoints intersect at the center of the heart (Fig. 6.4.) This creates a standard limb lead vectorgraph with each of the lead axes forming a 60-degree angle with its neighbors. The vectorgraph can be used to plot the vector representing the mean electrical axis of the heart in the frontal plane.

A vector can represent the electrical activity of the heart at any instant in time. The mean electrical axis of the heart is the summation of all the vectors occurring in a cardiac cycle.

Since the QRS interval caused by ventricular depolarization represents the majority of the electrical activity of the heart, you can approximate the mean electrical axis by looking only in this interval, first at the R wave amplitude, and then at the combined amplitudes of the Q, R, and S waves. The resultant vector, called the QRS axis, approximates the mean electrical axis of the heart.

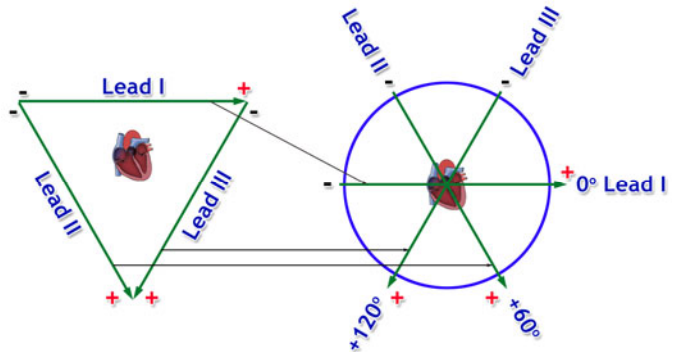


Fig. 6.4

An initial approximation of the mean electrical axis in the frontal plane can be made by plotting the magnitude of the R wave from Lead I and Lead III (Fig. 6.5.) To plot R wave magnitude:

1. Draw a perpendicular line from the ends of the vectors (right angles to the axis of the Lead.)
2. Determine the point of intersection of these two perpendicular lines.
3. Draw a new vector from point 0,0 to the point of intersection.

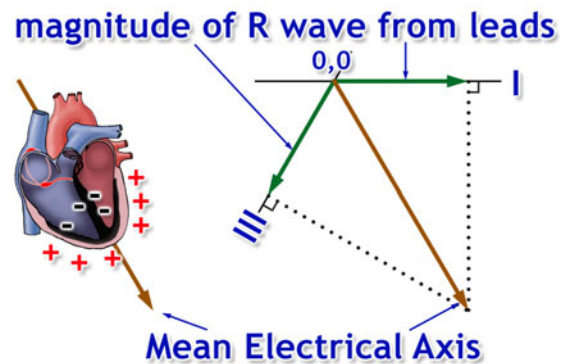


Fig. 6.5

The direction of the resulting vector approximates the mean electrical axis of the heart. The length of the vector approximates the mean potential of the heart.

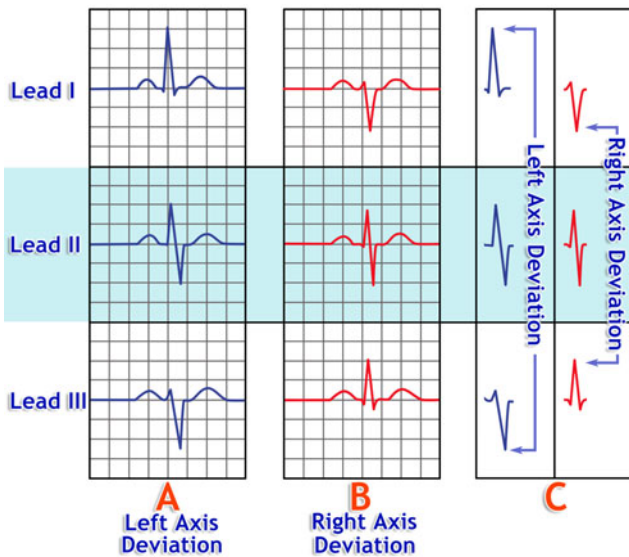


Fig. 6.6

A more accurate method of approximating the mean electrical axis is to algebraically add the Q, R, and S potentials for one lead, instead of using just the magnitude of the R wave. The rest of the procedure would be the same as outlined above.

The normal range of the mean electrical axis of the ventricles is approximately -30° to +90°. The axis may shift slightly with a change in body position (e.g., standing versus supine) and variation among individuals within the normal range occur as a result of individual differences in heart mass, orientation of the heart in the thorax, body mass index, and the anatomic distribution of the cardiac conduction system.

A shift in the direction of the QRS axis from normal to one between -30° and -90° is called left axis deviation (LAD.) Left axis deviation is abnormal and results from conditions that cause the left ventricle to take longer than normal to depolarize. One example is hypertrophy (enlargement, and hence a longer conduction pathway) of the left ventricle associated with systemic hypertension or stenosis (narrowing) of the aortic valve.

Left axis deviation may also occur when the conduction pathway or the left ventricular myocardium is damaged, creating blockage and slowing of the depolarization signal. Common causes of this include coronary occlusion (spasm, thrombosis, etc.) and injuries resulting from drug usage. Fig. 6.6A shows typical ECG patterns of Leads I, II, and III associated with LAD.

A shift in the direction of the QRS axis from normal to one between $+90^\circ$ and $+180^\circ$ is called right axis deviation (RAD.) In some cases right axis deviation may be normal, such as in young adults with long narrow chests and vertical hearts, but in the majority of adults, right axis deviation generally is associated with hypertrophy of the right ventricle or damage to the conduction system in the right ventricle. In both conditions, the right axis deviation results from a slowing or blockage of the depolarization signal for the right ventricle. Fig. 6.6B shows typical ECG patterns of Leads I, II, and III associated with RAD. A convenient method of differentiating LAD and RAD is to examine the QRS patterns of Leads I and III. A pattern where the apices of the QRS complexes go away from each other is left axis deviation (Fig. 6.6C.) A pattern where the apices approach one another is right axis deviation.

II. EXPERIMENTAL OBJECTIVES

- 1) Record ECG from Leads I and III in the following conditions: supine, seated, and breathing deeply while seated.
- 2) Compare the displayed calculated ECG Lead II to recorded ECG Leads I and III, and use the R wave amplitudes to confirm Einthoven's Law.
- 3) Approximate the mean electrical axis of the ventricles on the frontal plane using vectors derived from the amplitude and polarity of the QRS complex in ECG Leads I and III.
- 4) Approximate the mean electrical potential of the ventricles on the frontal plane using the resultant vector derived from the vectors of Leads I and III.

III. MATERIALS

- BIOPAC Electrode Lead Set x 2 (SS2L)
- BIOPAC Disposable Electrodes (EL503,) 6 electrodes per subject
- BIOPAC Electrode Gel (GEL1) and Abrasive Pad (ELPAD) *or* Skin cleanser or alcohol prep
- Mat, cot or lab table and pillow for Supine position
- Protractor
- Two different colored pens/pencils
- Biopac Student Lab System: BSL 4 software, MP36, MP35 or MP45 hardware
- Computer System (Windows 7, Vista, XP, Mac OS X 10.5 – 10.7)

IV. EXPERIMENTAL METHODS

A. SETUP

FAST TRACK Setup

1. Turn the computer **ON**.
 - If using an MP36/35 unit, turn it **OFF**.
 - If using an MP45, make sure USB cable is connected and "Ready" light is **ON**.
2. **Plug the equipment in** as follows:
Electrode Lead Set (SS2L)—CH 1
Electrode Lead Set (SS2L)—CH 2
3. Turn **ON** the MP36/35 unit.

Setup continues...

Detailed Explanation of Setup Steps



Fig. 6.7 MP3X (top) and MP45 (bottom) hardware connections

4. Clean and abrade skin.
5. Attach six electrodes to **Subject**, as follows:
 - One above right wrist
 - Two above left wrist
 - Two above right ankle
 - One above left ankle

Attach six electrodes to flat spots inside wrists and ankles as shown in Fig. 6.8

If the skin is oily, clean electrode sites with soap and water or alcohol before abrading.

If electrode is dry, apply a drop of gel.

Remove any jewelry on or near the electrode sites.

For optimal electrode contact, place electrodes on skin at least five minutes before start of Calibration.



Fig. 6.8 Electrode Placement

Carefully follow the color code placement of each electrode lead

6. Clip the first Electrode Lead Set (SS2L) from CH 1 to the electrodes, following LEAD I in Fig. 6.9.
 - RED = LEFT wrist
 - WHITE = RIGHT wrist
 - BLACK = RIGHT ankle
7. Clip the second Electrode Lead Set (SS2L) from CH 2 to the electrodes, following LEAD III in Fig. 6.9.
 - WHITE = LEFT wrist
 - RED = LEFT ankle
 - BLACK = RIGHT ankle

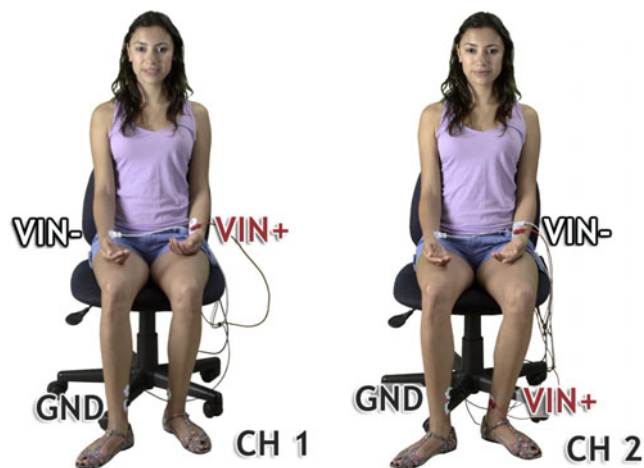


Fig. 6.9 Electrode lead connections: Lead I and Lead III

The pinch connectors work like a small clothespin, but will only latch onto the nipple of the electrode from one side of the connector.

Setup continues...

8. **Subject** gets in supine position (lying down, face up) and relaxes (Fig. 6.10).

Position the electrode cables so that they are not pulling on the electrodes.

Connect the electrode cable clip to a convenient location on **Subject's** clothes.



Fig. 6.10

9. Start the BIOPAC Student Lab program.
10. Choose lesson “**L06 – Electrocardiography (ECG) II**” and click **OK**.
11. Type in a unique **filename** and click **OK**.

If your lab is using multiple MP hardware types, choose the appropriate BSL program (shortcut icon contains MP number).



No two people can have the same filename, so use a unique identifier, such as **Subject's** nickname or student ID#.

A folder will be created using the filename. This same filename can be used in other lessons to place the **Subject's** data in a common folder.

12. Optional: Set Lesson Preferences.
- Choose File > **Lesson Preferences**.
 - Select an option.
 - Select the desired setting and click **OK**.

This lesson has optional Preferences for data and display while recording. Per your Lab Instructor's guidelines, you may set:

Grids: Show or hide gridlines

ECG filter: Set bandwidth

Heart Rate Data: Calculate and display Heart Rate data

Time Scale: Set the full screen time scale with options from 10 to 20 seconds.

Lesson Recordings: Specific recordings may be omitted based on instructor's preferences.

All setting changes will be saved.

END OF SETUP

B. CALIBRATION

The Calibration procedure establishes the hardware's internal parameters (such as gain, offset, and scaling) and is critical for optimal performance. **Pay close attention to Calibration.**

FAST TRACK Calibration

1. **Subject** is supine and relaxed, with eyes closed.
2. Click **Calibrate**.
 - **Subject** remains relaxed with eyes closed.
 - Wait for Calibration to stop.
3. Verify recording resembles the example data.
 - If similar, click **Continue** and proceed to Data Recording.
 - If necessary, click **Redo Calibration**.

Detailed Explanation of Calibration Steps

Subject must remain relaxed and as still throughout calibration to minimize baseline shift and EMG artifact.

Calibration lasts eight seconds.

Both channels should show recognizable ECG waveforms with a baseline at or near 0 mV, little EMG artifact and no large baseline drift.

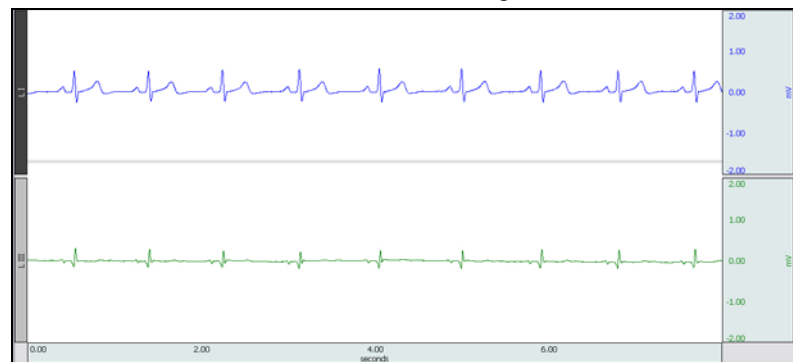


Fig. 6.11 Example Calibration data

If recording does not resemble the Example Data

- If the data is noisy or flatline, check all connections to the MP unit.
- If the signals look reversed, verify that transducers are plugged into the correct channels. (CH 1 for Lead I and CH 2 for Lead III.)
- If the ECG displays baseline drift or excessive EMG artifact:
 - Verify electrodes are making good contact with the skin and that the leads are not pulling on the electrodes.
 - Make sure Subject is in a relaxed position

END CALIBRATION

C. DATA RECORDING

FAST TRACK Recording

1. Prepare for the recording.
 - **Subject** remains supine and relaxed, with eyes closed.
 - **Review** recording steps.

Supine

2. Click **Record**.
3. Record for 30 seconds.
4. Click **Suspend**.
5. Verify recording resembles the example data.
 - If similar, click **Continue** and proceed to next recording.

- If necessary, click **Redo**.
- If all required recordings have been completed, click **Done**.

Recording continues...

Detailed Explanation of Recording Steps

Two conditions will be recorded*, one with **Subject** supine and another with **Subject** seated.

*IMPORTANT

This procedure assumes that all lesson recordings are enabled in lesson Preferences, which may not be the case for your lab. Always match the recording title to the recording reference in the journal and disregard any references to excluded recordings.

Hints for obtaining optimal data

To minimize muscle (EMG) artifact and baseline drift:

- **Subject's** arms and legs must be relaxed.
- **Subject** must remain still and should not talk during any recordings.
- Make sure electrodes do not peel up and that the leads do not pull on the electrodes.

Subject remains supine and relaxed, with eyes closed.

Both ECG waveform should have a baseline at or near 0 mV and should not display large baseline drifts or significant EMG artifact.

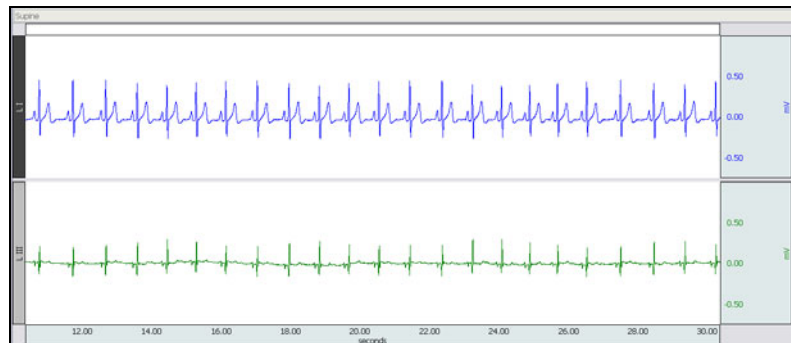


Fig. 6.12 Example Supine data

If recording does not resemble the Example Data

- If the data is noisy or flatline, check all connections to the MP unit.
- If the ECG displays baseline drift or excessive EMG artifact:
 - Verify electrodes are making good contact with the skin and that the leads are not pulling on the electrodes.
 - Make sure Subject is in a relaxed position

Click **Redo** and repeat Steps 2 – 5 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

Seated

- **Review** recording steps.
6. **Subject** gets up quickly and then settles into a seated position (Fig. 6.13).

Subject should sit with arms relaxed at side of body and hands apart in lap, with legs flexed at knee and feet supported.



Fig. 6.13 Proper position for “Seated” recording

7. Once **Subject** is seated and still, click **Record**.
8. **Subject** remains seated and relaxed.
- Record for 10 seconds and then ask **Subject** to increase depth of breathing.
 - **Subject** inhales audibly, **Recorder** presses F4 on the inhale.
 - **Subject** exhales audibly, **Recorder** presses F5 on the exhale.
9. Record for 5 more seconds.
10. Click **Suspend**.
11. Verify that recording resembles the example data.
- If similar, click **Continue** to proceed to optional recording section, or click **Done** if finished.

In order to capture the heart rate variation, click Record as quickly as possible after **Subject** sits and relaxes.

Note: **Subject** should not breathe in too deeply as to cause excessive EMG artifact or baseline drift.

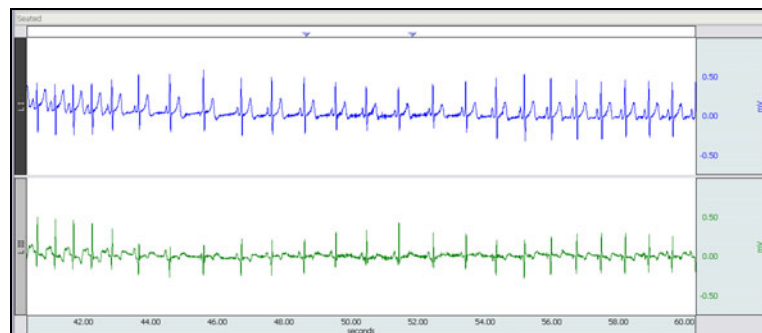


Fig. 6.14 Example Seated data

The data description is the same as outlined in Step 5 with the following exception:

- The ECG data may exhibit some baseline drift during deep breathing which is normal and unless excessive, does not necessitate **Redo**.

Click **Redo** if necessary. Note that the **Subject** must return to the Supine position for at least 5 minutes before repeating Steps 6 – 11. Once **Redo** is clicked, the most recent recording will be erased.

- If necessary, click **Redo**.

Recording continues...

OPTIONAL ACTIVE LEARNING PORTION

12. After clicking **Done**, choose an option and click **OK**.
13. Remove the electrodes.

With this lesson you may record additional data by clicking **Continue** following the last recording. Design an experiment to test or verify a scientific principle(s) related to topics covered in this lesson. Although you are limited to this lesson's channel assignments, the electrodes or transducers may be moved to different locations on the **Subject**.

Design Your Experiment

Use a separate sheet to detail your experiment design, and be sure to address these main points:

A. Hypothesis

Describe the scientific principle to be tested or verified.

B. Materials

List the materials you will use to complete your investigation.

C. Method

Describe the experimental procedure—be sure to number each step to make it easy to follow during recording.

Run Your Experiment**D. Set Up**

Set up the equipment and prepare the subject for your experiment.

E. Record

Use the **Continue**, **Record**, and **Suspend** buttons to record as much data as necessary for your experiment.

Analyze Your Experiment

- F.** Set measurements relevant to your experiment and record the results in a Data Report.

If choosing the **Record from another Subject** option:

- Repeat Setup Steps 6 – 9, and then proceed to Calibration.

Remove the electrode cable pinch connectors and peel off all electrodes. Discard the electrodes. (BIOPAC electrodes are not reusable.) Wash the electrode gel residue from the skin, using soap and water. The electrodes may leave a slight ring on the skin for a few hours which is quite normal.

END RECORDING

V. DATA ANALYSIS

FAST TRACK DATA ANALYSIS

- Enter the **Review Saved Data** mode.
 - Note Channel Number (CH) designations:

| Channel | Displays |
|---------|----------------------|
| CH 1 | Lead I |
| CH 2 | Lead III |
| CH 40 | Lead II (calculated) |
 - Note measurement box settings:

| Channel | Measurement |
|---------|-------------|
| CH 1 | Delta |
| CH 2 | Delta |
| CH40 | Delta |
- Set up the display window for optimal viewing of the first data recording.

Data Analysis continues...

DETAILED EXPLANATION OF DATA ANALYSIS STEPS

If entering **Review Saved Data** mode from the Startup dialog or lessons menu, make sure to choose the correct file.

Note: After **Done** was pressed in the final recording section, the program used Einthoven's Law to automatically calculate Lead II from Leads I and III and added a channel for Lead II to the initial two channel recording (Fig. 6.15).

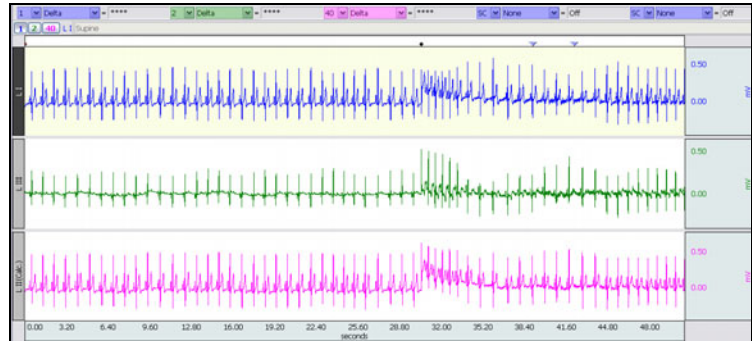



Fig. 6.15 Example data

The measurement boxes are above the marker region in the data window. Each measurement has three sections: channel number, measurement type, and result. The first two sections are pull-down menus that are activated when you click them.

Brief definition of measurements:

Delta: Computes the difference in amplitude between the first point and the last point of the selected area. It is particularly useful for taking ECG measurements, because the baseline does not have to be at zero to obtain accurate, quick measurements.

The “selected area” is the area selected by the **I-beam** tool (including endpoints).

Note: The append event markers  mark the beginning of each recording. Click on (activate) the event marker to display its label.

Useful tools for changing view:

Display menu: Autoscale Horizontal, Autoscale Waveforms, Zoom Back, Zoom Forward

Scroll Bars: Time (Horizontal); Amplitude (Vertical)

Cursor Tools: Zoom Tool

Buttons: Overlap, Split, Show Grid, Hide Grid, -, +

Hide/Show Channel: “Alt + click” (Windows) or “Option + click” (Mac) the channel number box to toggle channel display.

The data window should resemble Fig. 6.16.

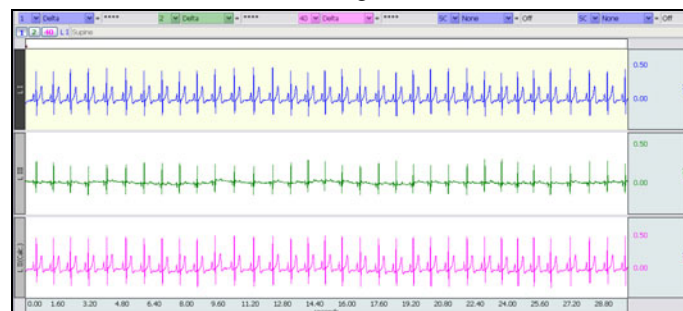


Fig. 6.16 Supine data

- Zoom in to select two consecutive “clean” cardiac cycles in the “**Supine**” recording.
- Place an **event marker** above the second R-wave to indicate which cardiac cycle will be used for measurements.

A clean cardiac cycle has ECG components that are easy to discern (Fig. 6.17).

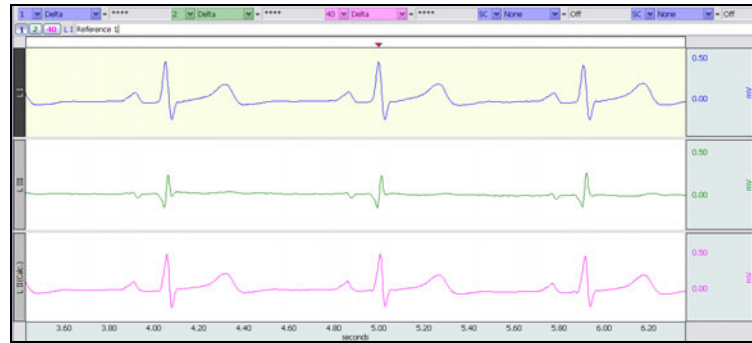


Fig. 6.17 Zoom in on Supine data

Insert the event marker directly above the R wave of the second cardiac cycle in the display.

To place an event marker (inverted triangle,) Right-click with the cursor in the event marker region and choose the contextual menu item “Insert New Event.” You can then move the marker by holding down the “Alt” key while clicking and dragging it.

Type “**Reference 1**” to label the marker.

- Use the **I-Beam** cursor to select the area from the midpoint between the cycles (baseline) and the R-wave of the second cycle

 A, B

Start at the midpoint between the T-wave of cardiac cycle 1 (left) and the P-wave of cardiac cycle 2. Press and hold the mouse and sweep the cursor to the right until the end of the selected area is at peak of the desired wave—monitor the Delta measurement to determine when the actual peak is reached; small movements to the right or left may be necessary.



Fig. 6.18 Selection from baseline to R wave peak

Note R-waves may be inverted on some of the leads; include the polarity of the Delta result in the Data Report tables.

- Scroll to the “**Seated**” recording, select two consecutive cardiac cycles and repeat the procedure described in Steps 4 and 5.



Do not use a section between the “**Start of inhale**” and “**Start of exhale**” event markers.

Note All remaining measurements are taken on Lead I and Lead III only so you may choose to hide Lead II (CH 40).

Data Analysis continues...

7. Scroll to the “**Start of inhale**” section and select two consecutive cardiac cycles and repeat the procedure described in Steps 4 and 5.



8. Scroll to the “**Start of exhale**” section and select two consecutive cardiac cycles and repeat the procedure described in Steps 4 and 5.



9. Go back to the “**Reference 1**” marker created in Step 4.

10. Measure the waves of the **QRS** complex and record the amplitudes for **Lead I** and **Lead III**.



11. Fill in the vectorgrams.
12. Answer the questions at the end of the Data Report.
13. **Save** or **Print** the data file.
14. **Quit** the program.

END OF DATA ANALYSIS

Type “**Reference 2**” to label the marker.

Type “**Reference 3**” to label the marker.

Use the event marker left and right arrows to move to different markers.

To measure a wave, select the area from the baseline (Isoelectric Line) to the peak of the wave.



Fig. 6.19 Sample measurement of the Q wave



Fig. 6.20 Sample measurement of the R wave



Fig. 6.21 Sample measurement of the S wave

- The L06 Vectorgrams are contained in the printed manual, or can be printed directly from the Help menu.
- An electronically editable **Data Report** is located in the journal (following the lesson summary,) or immediately following this Data Analysis section. Your instructor will recommend the preferred format for your lab.

END OF LESSON 6

Complete the Lesson 6 Data Report that follows.

ELECTROCARDIOGRAPHY II

- *Bipolar Leads (Leads I, II, III,) Einthoven’s Law, and*
- *Mean Electrical Axis on the Frontal Plane*

DATA REPORT

Student’s Name: _____

Lab Section: _____

Date: _____

Subject Profile

Name: _____

Height: _____

Age: _____

Gender: Male / Female

Weight: _____

I. Data and Plots

A. Einthoven’s Law—Simulated Confirmation: Lead I + Lead III = Lead II

Table 6.1 Supine

| Lead | Same Single Cardiac Cycle | mV* |
|----------|---------------------------|-----|
| Lead I | 1 Delta | |
| Lead III | 2 Delta | |
| Lead II | 40 Delta | |

*Include the polarity (+ or -) of the Delta result since R-waves may be inverted on some of the leads.

B. Mean Electrical Axis of the Ventricles (QRS Axis) and Mean Ventricular Potential—Graphical Estimate

Use Table 6.2 to record measurements from the Data Analysis section:

Table 6.2

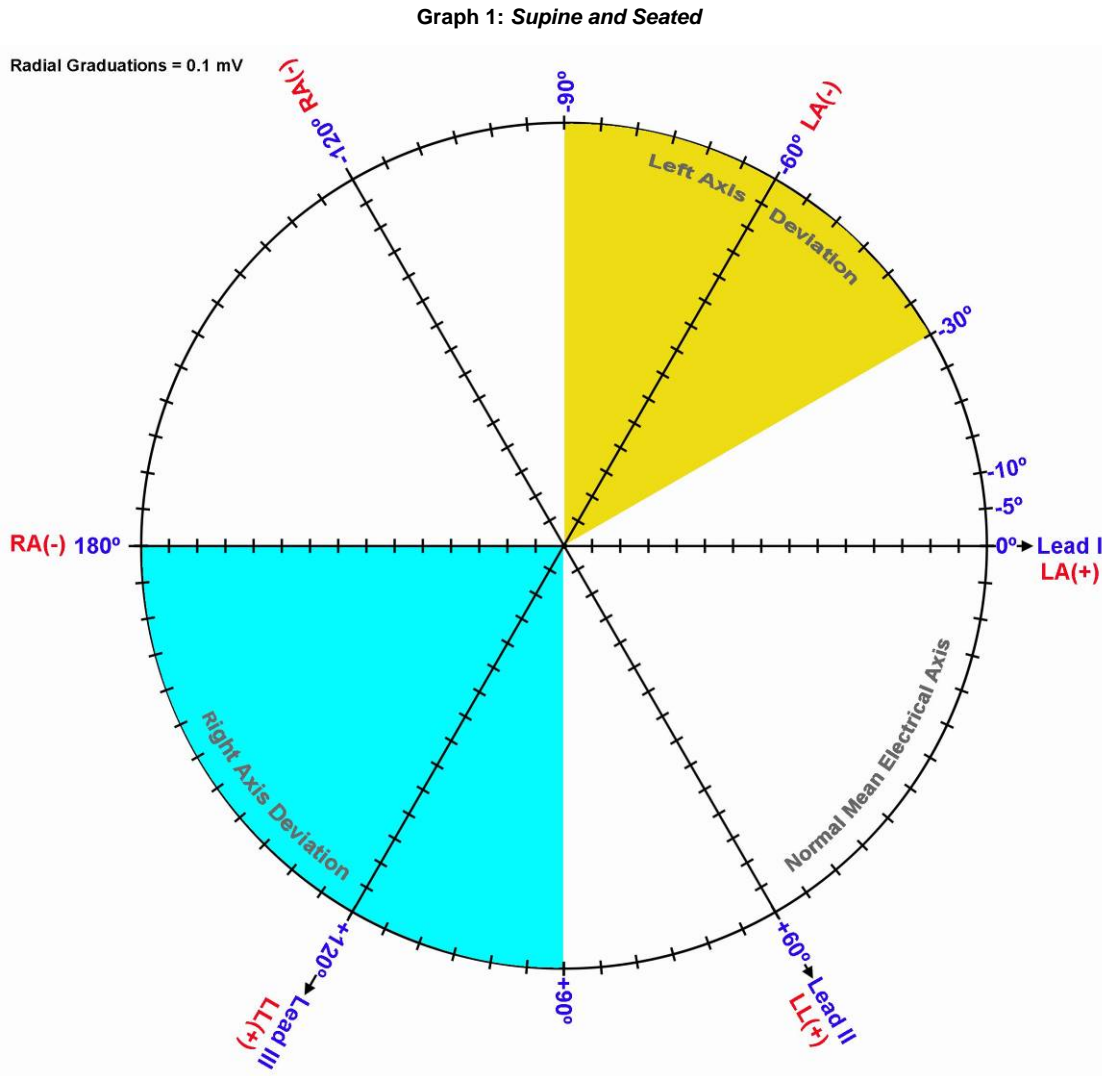
| CONDITION | QRS | |
|-----------------|-------------------|---------------------|
| | Lead I 1 Delta | Lead III 2 Delta |
| Supine | | |
| Seated | | |
| Start of inhale | | |
| Start of exhale | | |

One way to approximate the mean electrical axis in the frontal plane is to plot the magnitude of the R wave from Lead I and Lead III, as shown in the Introduction (Fig. 6.4).

1. Draw a perpendicular line from the ends of the vectors (right angles to the axis of the Lead) using a protractor or right angle guide.
2. Determine the point of intersection of these two perpendicular lines.
3. Draw a new vector from point 0.0 to the point of intersection.

The direction of this resulting vector approximates the mean electrical axis (QRS Axis) of the ventricles. The length of this vector approximates the mean ventricular potential.

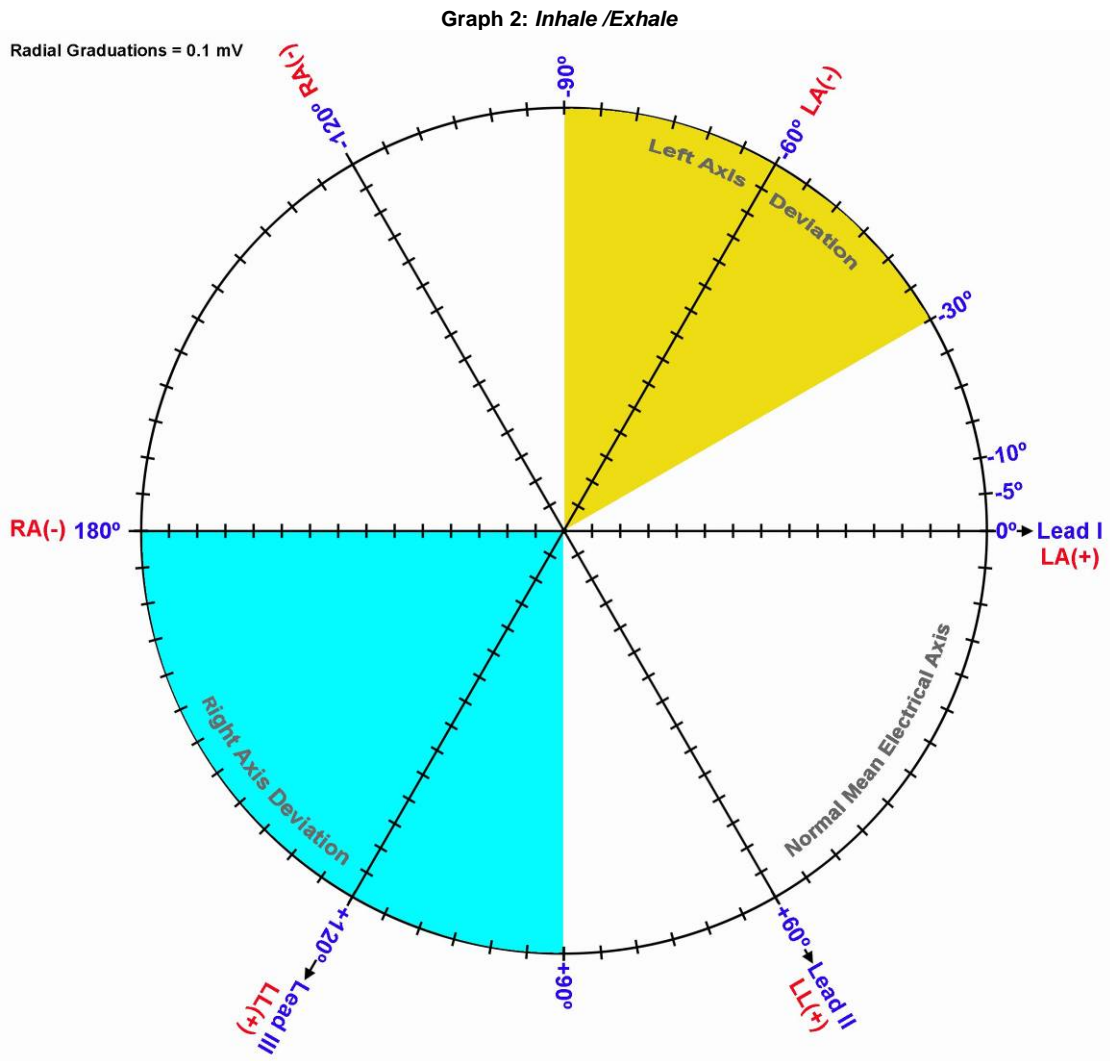
Create two plots on each of the following graphs, using data from Table 6.2. Use a different color pencil or pen for each plot.



From the above graph, find the following values:

| Condition | Mean Ventricular Potential | Mean Ventricular (QRS) Axis |
|-----------|----------------------------|-----------------------------|
| Supine | _____ | _____ |
| Seated | _____ | _____ |

Explain the difference (if any) in Mean Ventricular Potential and Axis under the two conditions:



From the above graph, find the following values:

| Condition | Mean Ventricular Potential | Mean Ventricular (QRS) Axis |
|-----------------|----------------------------|-----------------------------|
| Start of inhale | _____ | _____ |
| Start of exhale | _____ | _____ |

Explain the difference (if any) in Mean Ventricular Potential and Axis under the two conditions:

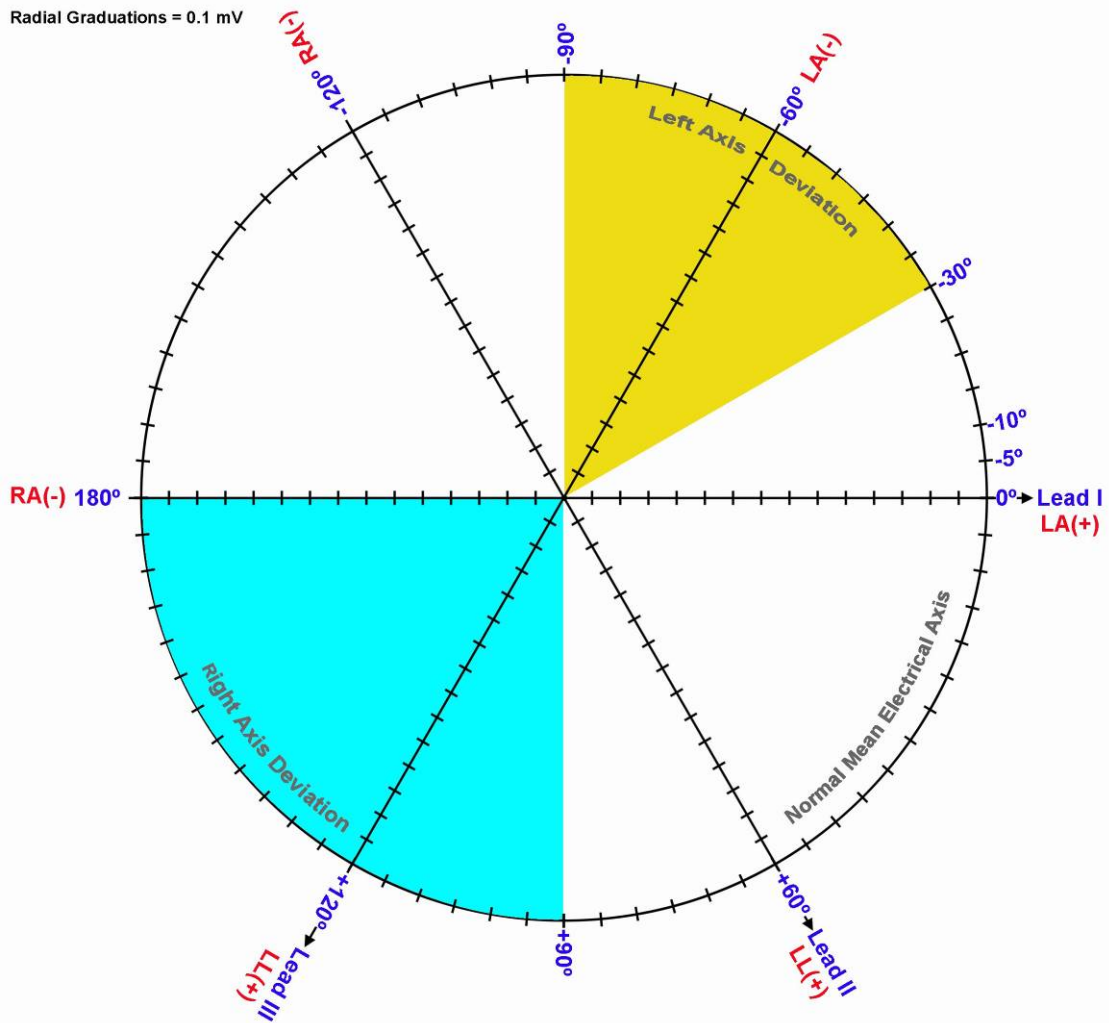
C. Mean Electrical Axis of the Ventricles (QRS Axis) and Mean Ventricular Potential—More Accurate Approximation

Use Table 6.3 to add the Q, R, and S potentials to obtain net potentials for Recording 1—Supine.

Table 6.3

| POTENTIAL | QRS | |
|-----------|--|--|
| | Lead I <input type="text" value="1"/> <input type="text" value="Delta"/> | Lead III <input type="text" value="2"/> <input type="text" value="Delta"/> |
| Q | | |
| R | | |
| S | | |
| QRS Net | | |

Graph 3: *Supine*



From the above graph, find the following values:

| Condition | Mean Ventricular Potential | Mean Ventricular (QRS) Axis |
|-----------|----------------------------|-----------------------------|
| Supine | _____ | _____ |

Explain the difference in Mean Ventricular Potential and Axis for the Supine data in this plot (Graph 3) and the first plot (Graph 1).

II. Questions

D. Define **ECG**.

E. Define **Einthoven’s Law**.

F. Define **Einthoven’s Triangle** and give an example of its application.

G. What normal factors effect a change the orientation of the **Mean Ventricular (QRS) Axis**?

H. Define **Left Axis Deviation (LAD)** and its causes.

I. Define **Right Axis Deviation (RAD)** and its causes.

J. What factors affect the amplitude of the R wave recorded on the different leads?

III. OPTIONAL Active Learning Portion

A. *Hypothesis*

B. *Materials*

C. *Method*

D. *Set Up*

E. *Experimental Results*
