Physiology Lessons
for use with the
Biopac Student Lab

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Lesson 6
ELECTROCARDIOGRAPHY II
Bipolar Leads (Leads I, II, III)
Einthoven's Law
Mean Electrical Axis on the Frontal Plane
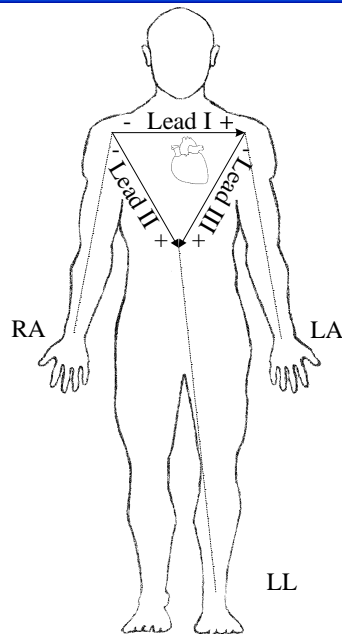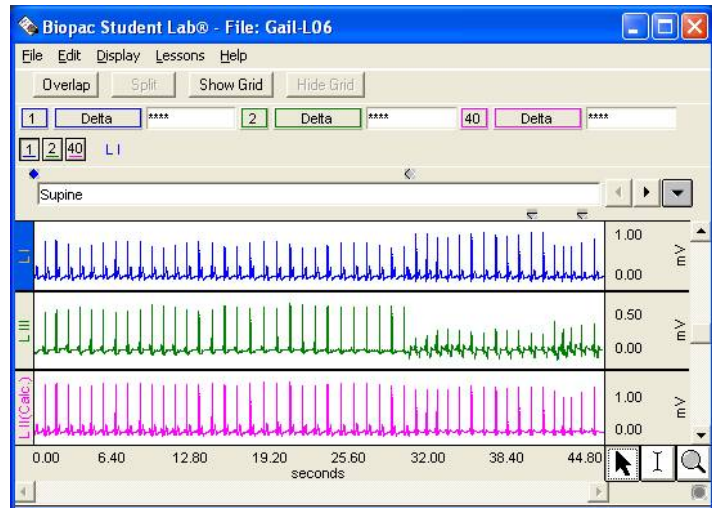
I. INTRODUCTION

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.

Fig. 6.1

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.
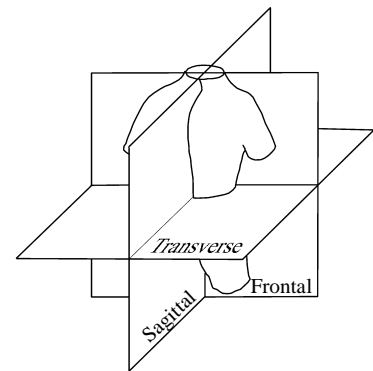
An *ECG lead* is a record of the electrical activity generated by the heart that is detected by electrodes placed on the skin. A lead composed of two discrete electrodes of opposite polarity (one positive and the other negative) is called a *bipolar lead*. A hypothetical line joining the poles of a lead 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 (+)	± 180° - 0°
Lead II	right arm (-) to left leg (+)	-120° - +60°
Lead III	left arm (-) to left leg (+)	-60° - + 120°

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.
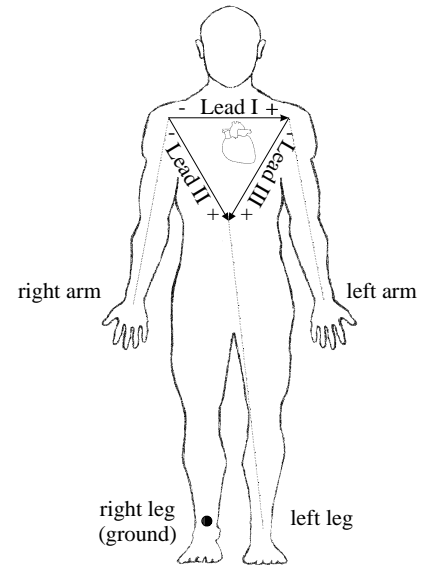
Fig. 6.2

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 (figure 6.3). 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 (figure 6.3). 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.
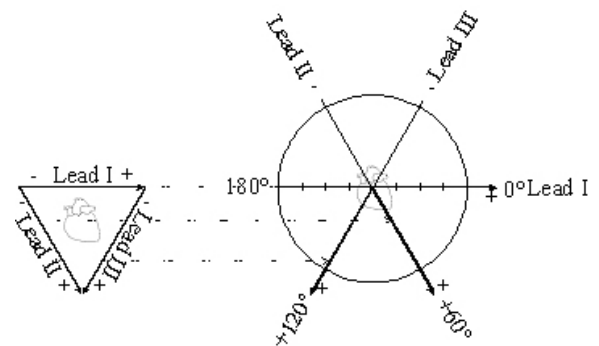
Fig. 6.3

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. 6.4). To plot R wave magnitiude:

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.
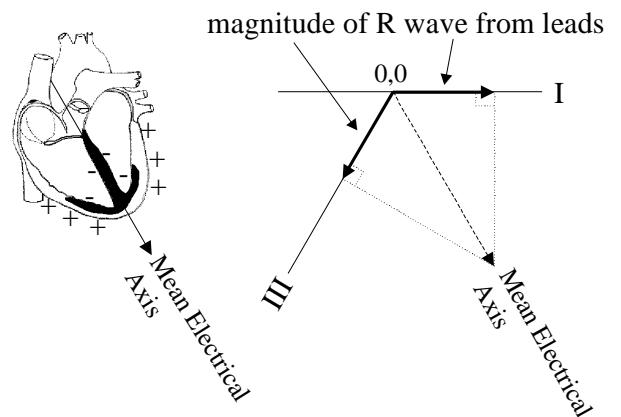3. Draw a new vector from point 0,0 to the point of intersection.

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.

magnitude of R wave from leads

Fig. 6.4

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.

A shift in the direction of the QRS axis from normal to one between +90° and +180° 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.

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 vinyl electrodes (EL503), 6 electrodes per subject
- BIOPAC electrode gel (GEL1) and abrasive pad (ELPAD) *or* Skin cleanser or alcohol prep
- Cot or lab table and pillow
- Protractor
- Two different colored pens/pencils
- Biopac Student Lab System: software BSL 3.7.7 or above
  data acquisition unit MP36, MP35, MP30 (Windows only), or MP45
- Computer System

IV.   EXPERIMENTAL METHODS

    📖   For further explanation, use the online support options under the Help Menu.

A.   SETUP

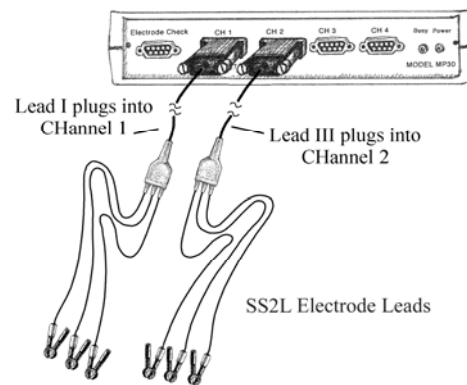| FAST TRACK	DETAILED EXPLANATION
1. Turn the computer **ON**. 2. Make sure the BIOPAC MP3X unit is turned **OFF**. 3. Plug the equipment in as follows: Electrode lead (SS2L)—CH 1 Electrode lead (SS2L)—CH 2 4. Turn the MP3X Data Acquisition Unit **ON**. **Setup continues…**	📖 The desktop should appear on the monitor. If it does not appear, ask the laboratory instructor for assistance. **Fig. 6.5 MP3X (top) and MP45 (bottom) hardware connections**

5. Place six electrodes on **Subject**, as shown in Fig. 6.6.

Place six electrodes as shown in Fig. 6.6:

- two electrodes on right leg, just above ankle bone
- one electrode on left leg, just above ankle bone
- two electrodes on left wrist (same side of arm as palm of hand)
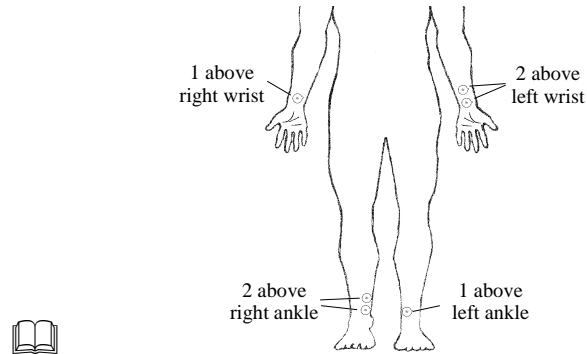- one electrode on right wrist (same side of arm as palm of hand)

Fig. 6.6 Electrode Placement

Note For optimal electrode adhesion, electrodes should be placed on skin at least 5 minutes before Calibration is started.

6. Attach the first electrode lead set (SS2L) from Channel 1 to the electrodes, following LEAD I in Fig. 6.7.

7. Attach the second electrode lead set (SS2L) from Channel 2 to the electrodes, following LEAD III in Fig. 6.7.

Each of the pinch connectors on the end of the electrode cable needs to be attached to a specific electrode. The electrode cables are each a different color, and you should follow Fig. 6.7 to ensure that you connect each cable to the proper electrode.

When the electrode cable is connected properly, the LEAD I and LEAD III electrode configurations will be established.
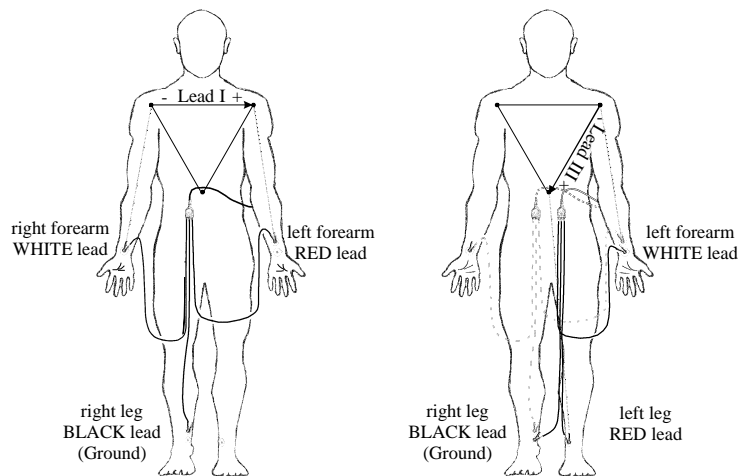

Fig. 6.7 Electrode lead connections: Lead I and Lead III

Note On the right ankle and on the left wrist, Lead I should go to the upper of the two electrodes and Lead III should go to the lower of the two electrodes.

The pinch connectors work like a small clothespin, but will only latch onto the nipple of the electrode from one side of the connector. Position the electrode cables such that they are not pulling on the electrodes. Connect the electrode cable clip (where the cable meets the three individual colored wires) to a convenient location (can be on **Subject's** clothes). This will relieve cable strain.

8. Have **Subject** lie down and relax.

Subject should not be in contact with nearby metal objects (faucets, pipes, etc.) and should remove any wrist or ankle bracelets.

Setup continues…

9. Start the BIOPAC Student Lab program.

10. Choose lesson **L06** and click **OK**.

📖
Lesson L06 is Electrocardiography (ECG) II.

11. Type in your filename and click **OK**.

📖 Use a unique identifier. Click OK to end the default setup.

12. *Optional*: Set Preferences.

- Choose File > 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:
   Journal Text: show minimum guiding text vs. detailed text
   Grids: show or hide gridlines
   ECG filter: set bandwidth
   Heart Rate Data: Calculate and display Heart Rate data
   Time scale: set horizontal time scale from 10-120 seconds
   Lesson Segments: Specific recording segments may be omitted based on instructor's preferences.

END OF SETUP

B. CALIBRATION

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

FAST TRACK	DETAILED EXPLANATION
1. Double check the electrodes, and make sure **Subject** is supine, relaxed, and still.	Make sure the electrodes adhere securely to the skin. If they are being pulled up, you will not get a good ECG signal. **Subject** must be relaxed during calibration. **Subject's** arms and legs need to be relaxed so that the muscle (EMG) signal does not corrupt the ECG signal.
2. Click **Calibrate**.	The **Calibrate** button is in the upper left corner of the **Setup** window. This will start the calibration recording, which will stop automatically after eight seconds. **Subject** needs to remain relaxed throughout calibration.
3. **Check** the calibration data.	At the end of the 8-sec calibration recording, there should be a recognizable ECG waveform with no large baseline drifts.

Fig. 6.8

- If <u>similar</u>, proceed to Data Recording.
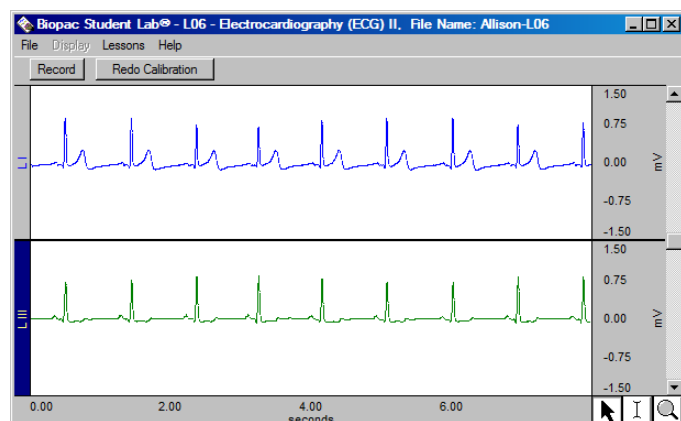
- If <u>different</u>, **Redo Calibration**.

If data resembles Fig. 6.8 (with allowance for any difference in vertical scaling), proceed to the Data Recording section.

If data shows any large baseline drifts, check that electrodes are making good contact and click **Redo Calibration**, then repeat the entire calibration sequence.

END CALIBRATION

C.   RECORDING LESSON DATA

FAST TRACK

DETAILED EXPLANATION

1. Prepare for the recording.

You will record two segments*, one with **Subject** supine and another with **Subject** seated. In order to work efficiently, read this entire section so you will know what to do before recording.

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

Hints for obtaining optimal data

To minimize muscle (EMG) corruption of the ECG signal and baseline drift:

a) **Subject** should not talk or laugh during any of the recording segments.

b) When supine or seated, **Subject** should be completely relaxed.

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

d) The recording should be suspended before **Subject** prepares for the next recording segment.

e) **Subject** should breathe normally during the recording to minimize EMG from the chest area.

f) Make sure electrodes do not "peel up."

Supine

2. Click **Record**.

When you click **Record**, the recording will begin and an append marker labeled "Supine" will automatically be inserted.

3. Record for 30 seconds.

Subject should be supine, relaxed, and still.

4. Click **Suspend**.

When you click **Suspend**, the recording should halt, giving you time to review the data.

5. Review the data on the screen.

    - If <u>correct</u>, go to **Step 6**.

If data looks similar to Fig. 6.9, proceed to Step 6.
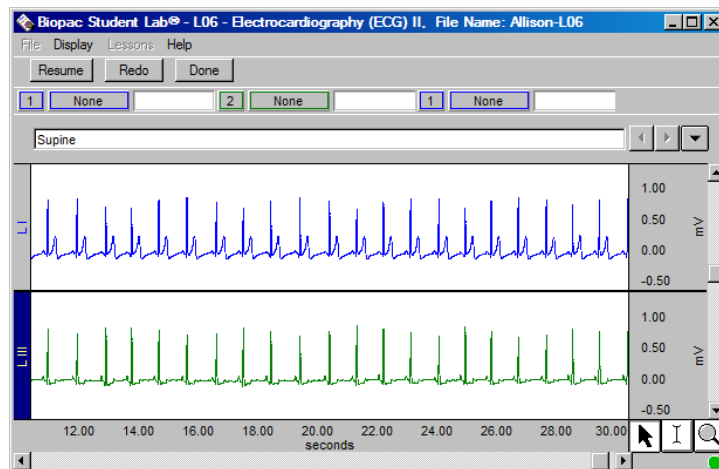

Fig. 6.9 (Supine)

    - If <u>incorrect</u>, click **Redo**.

The data would be <u>incorrect</u> if:

a) The **Suspend** button was pressed prematurely

b) An electrode peeled up, giving a large baseline drift

c) **Subject** has too much muscle (EMG) artifact

  Note: A little baseline drift when **Subject** breathes in and out is normal and does not indicate incorrect data.

Click **Redo** and repeat Steps 2-5. Note that when **Redo** is clicked, the data that was just recorded will be erased.

Recording continues…

Seated

6. Have **Subject** quickly get up and sit in a chair, with arms relaxed and feet supported. (Fig 6.10)

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

Fig. 6.10 Proper position for "Seated" segment

In order to capture the heart rate variation, it is important that you resume recording as quickly as possible after **Subject** sits. However, it is also important that you do not click **Resume** while **Subject** is in the process of sitting or you will capture motion artifact.

7. Click **Resume** as soon as possible after **Subject** is seated.

When you click **Resume**, the recording will continue and an append marker labeled "Seated" will be automatically inserted.

8. After 10 seconds of recording, **Subject** should **breathe in and out once** such that the breath is audible and the **Recorder** should **insert event markers**:

    a) **F4** at beginning of inhale.
    ∇ "start of inhale"

    b) **F5** at beginning of exhale.
    ∇ "start of exhale"

    c) Record for 5 more seconds.

After about 10 seconds of recording, the **Director** should instruct **Subject** to breathe in and out once such that the inhale and exhale are audible.

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

To insert pre-labeled **Event Markers**, press F4 (inhale) and then F5 (exhale).

   📖   Labels can also be entered manually (F9 on Windows, Esc on Mac) or edited after data is recorded.

The recording should run for about 30 seconds total.

9. Click **Suspend**.

The recording should halt, allowing you to review the data.

10. Review the data on the screen.

    •   If similar, go to **Step 11**.

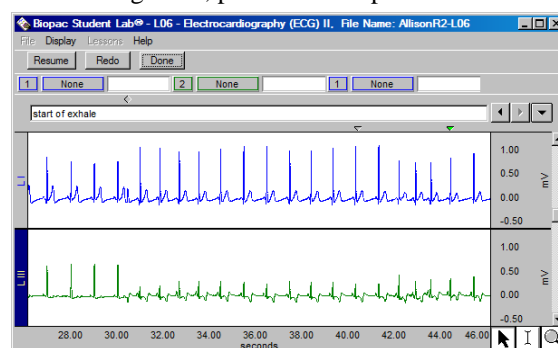If data looks similar to Fig. 6.11, proceed to Step 11.

Fig. 6.11 (Seated)

Recording continues…

- If <u>different</u>, **Redo**.

The data would be <u>different</u> if:

    a) The **Suspend** button was pressed prematurely.

    b) An electrode peeled up, giving a large baseline drift.

    c) **Subject** has too much muscle (EMG) artifact.

Note A little baseline drift when **Subject** breathes in and out is normal and does not indicate incorrect data.

If different, click **Redo** and repeat Steps 7-11. Note that once you press **Redo**, the data that was just recorded will be erased.

OPTIONAL ACTIVE LEARNING PORTION

With this lesson you may record additional data segments. Design an experiment to test or verify a scientific principle(s) related to topics covered in this lesson. You are limited to this lesson's channel assignments; however 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 will you 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 **Resume**, and **Suspend** buttons to record as many segments as necessary for your experiment.

Analyze Your Experiment

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

11. Click **Done**.

12. Click **Yes**.

After you press **Done,** a dialog with options will be generated. Make your choice and continue as directed.

If choosing the "Record from another Subject" option:

    a) Attach electrodes per Setup Step 6 and continue the entire lesson from Setup Step 11.

    b) Each person will need to use a unique file name.

13. Remove the electrodes.

END RECORDING

Disconnect the lead cables. Peel off and discard the electrodes (BIOPAC electrodes are not reusable). Wash the electrode gel residue from your skin using soap and water. The electrodes may leave a slight ring on the skin for a few hours, which is quite normal.

V.   DATA ANALYSIS

FAST TRACK	DETAILED EXPLANATION

FAST TRACK

1. Enter the **Review Saved Data** mode.

   - Note Channel Number (CH) designations: 1 2 40

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**

DETAILED EXPLANATION

📖 Enter the **Review Saved Data** mode.

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, which is why three channels are displayed in Review Saved Data mode (Fig. 6.12).
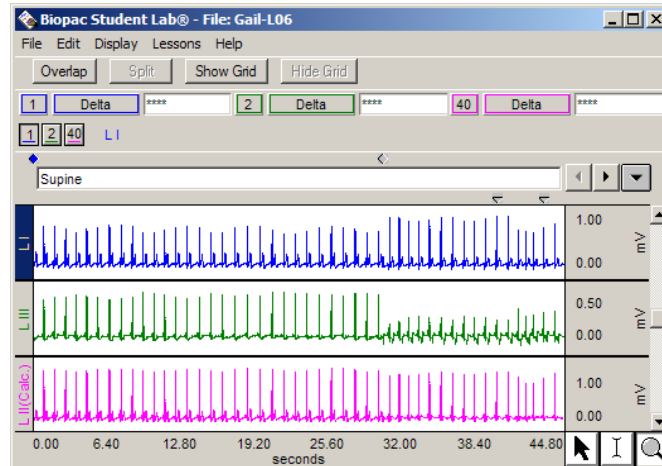
Fig. 6.12

📖 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.

> **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.

2. Set up the display window for optimal viewing of the first data segment.

The following tools help you adjust the data window: 📖

Display menu: Autoscale horizontal Autoscale waveforms, Zoom Previous
Scroll Bars: Time (Horizontal); Amplitude (Vertical)
Cursor Tools: Zoom Tool
Buttons: Overlap, Split, Show Grid, Hide Grid

The first data segment is the area from the append marker "Supine" at Time 0 to the next append marker. The data window should resemble Fig. 6.13.
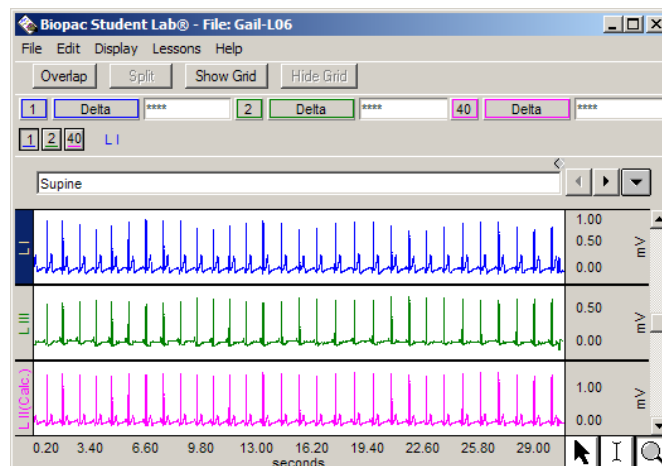

Fig. 6.13

Data Analysis continues…

3. Zoom in to select two consecutive "clean" cardiac cycles in the "**Supine**" segment.

4. Place an **event marker** above the second R-wave to indicate which cardiac cycle will be used for measurements.

The "Supine" segment begins at the first append marker, and represents the time when **Subject** was supine, breathing normally, in a relaxed state. Zoom in to so that there are two "clean" cardiac cycles displayed. A clean cardiac cycle has low noise and the ECG components are easy to discern (Fig. 6.14).
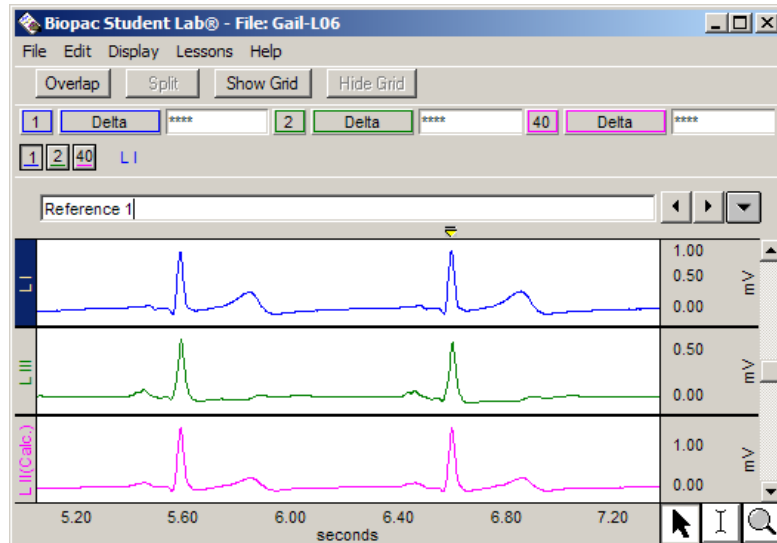
Fig. 6.14

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

To place an event marker, click the cursor in the event marker region under the marker label bar (above the top data channel). An inverted triangle should appear which, when selected, will be the color yellow.

Type "**Reference 1**" to label the marker.

5. Use the **I-Beam** cursor to select the area from the midpoint between the cycles (baseline) and the R-wave of the second cycle and complete "**Supine**" segments in the data report.

    📄 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.
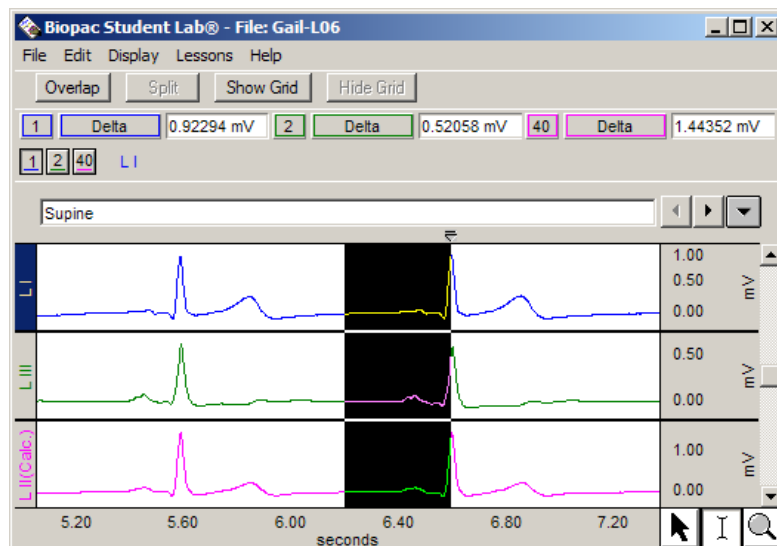

Fig. 6.15

Note R-waves may be inverted on some of the leads (Fig. 6.16); include the polarity of the Delta result in the Data Report tables.

Data Analysis continues…

Fig. 6.16 Inverted R-wave on Lead II and Lead III

6. Scroll to the "**Seated**" segment and select two consecutive cardiac cycles as described in Step 5.

    B

Use the append markers to find the proper data segment and then use the display tools to adjust the data window if necessary. 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). "Ctrl+click" (Windows) or "Option+click" (Mac) the channel number box to toggle between hiding and showing channel data.

7. Scroll to the "**start of inhale**" section and select two consecutive cardiac cycles as described in Step 5.

    B

Use the event markers to find the proper data section and use the display tools to adjust the data window if necessary.

8. Scroll to the "**start of exhale**" section and select two consecutive cardiac cycles as described in Step 5.

    B

Use the event markers to find the proper data section and use the display tools to adjust the data window if necessary.

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

This is the same cardiac cycle event marked inserted in Step 4.

    Use the marker tools to move to different markers.

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

    C

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

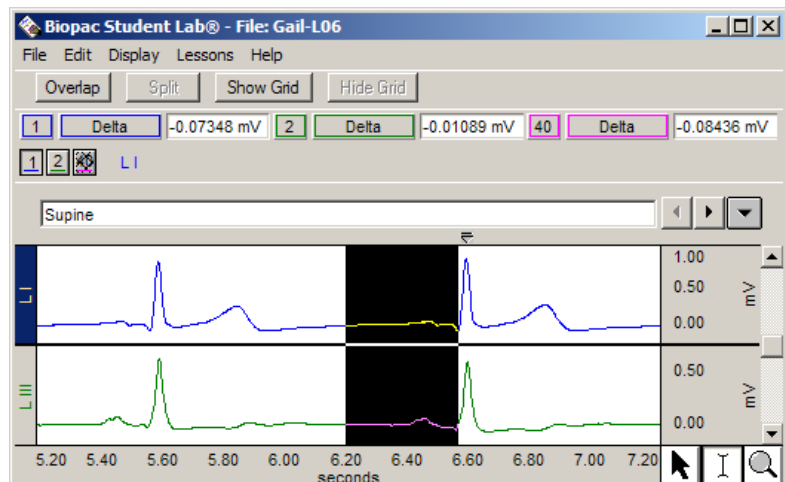Fig. 6.17 Sample measurement of the Q wave

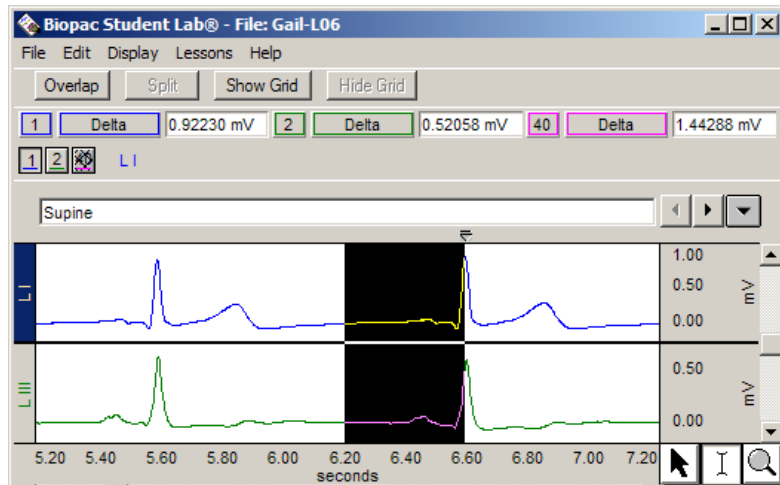**Data Analysis continues…**

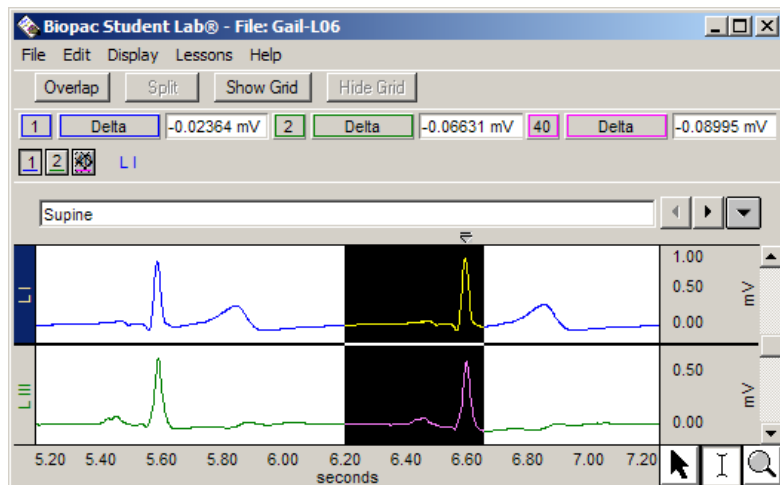Fig. 6.18 Sample measurement of the R wave

Fig. 6.19 Sample measurement of the S wave

11. Save or print the data file.

12. Exit the program.

      END OF DATA ANALYSIS

    📖 You may save the data to a drive, save notes that are in the journal, or print the data file.

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]	+ or -
Lead III	[2] [Delta]	+ or -
	SUM	+ or -
Lead II	[40] [Delta]	+ or -

Note   The software automatically computes and then displays Lead II values. Actual confirmation of Einthoven's law requires all three bipolar limb leads to be simultaneously recorded.

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

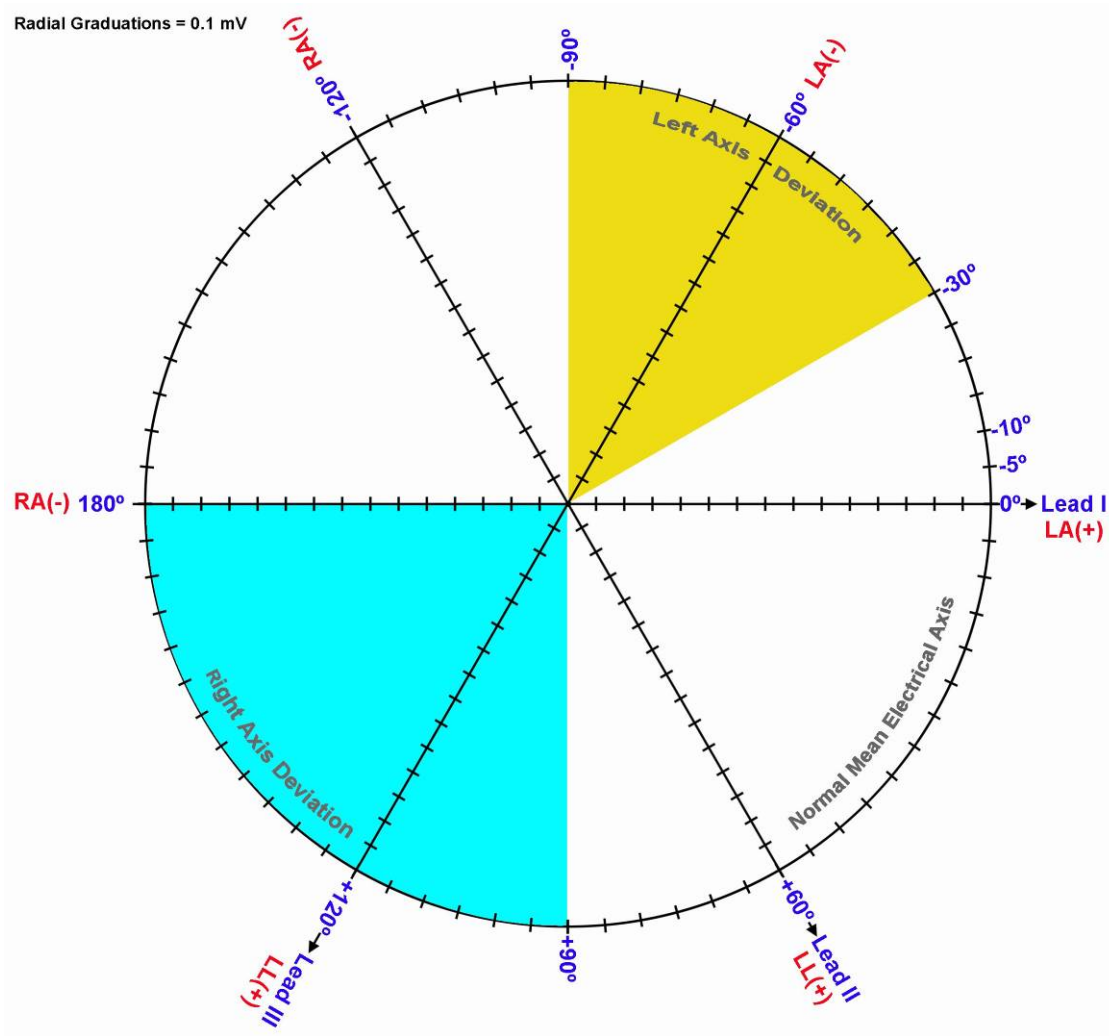| CONDITION	QRS	
	Lead I [1] [Delta]	Lead III [2] [Delta]
Supine		
Seated		
Start of inhale		
Start of exhale		

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.

Graph 1: *Supine and Seated*

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:
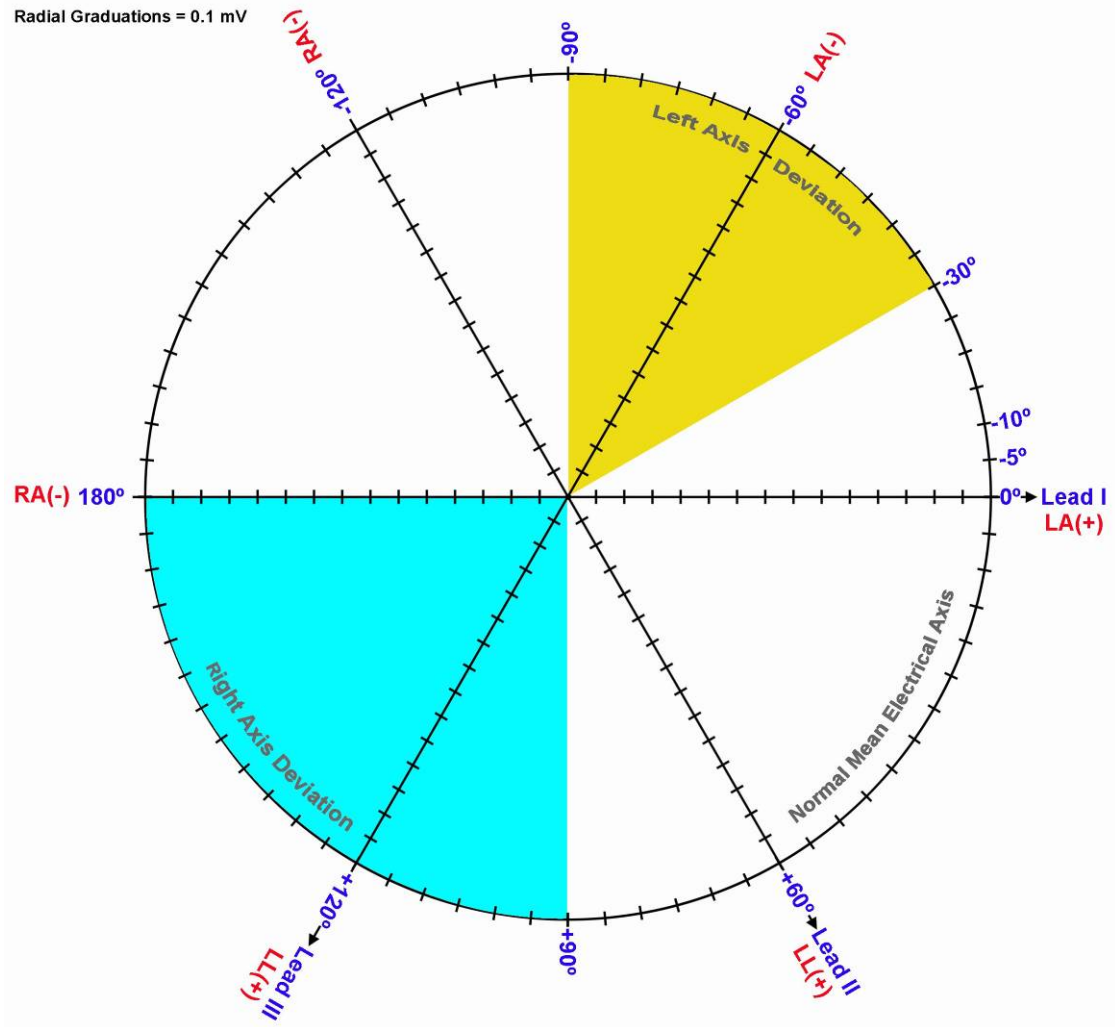
_____

_____

_____

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Graph 2: *Inhale /Exhale*

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:
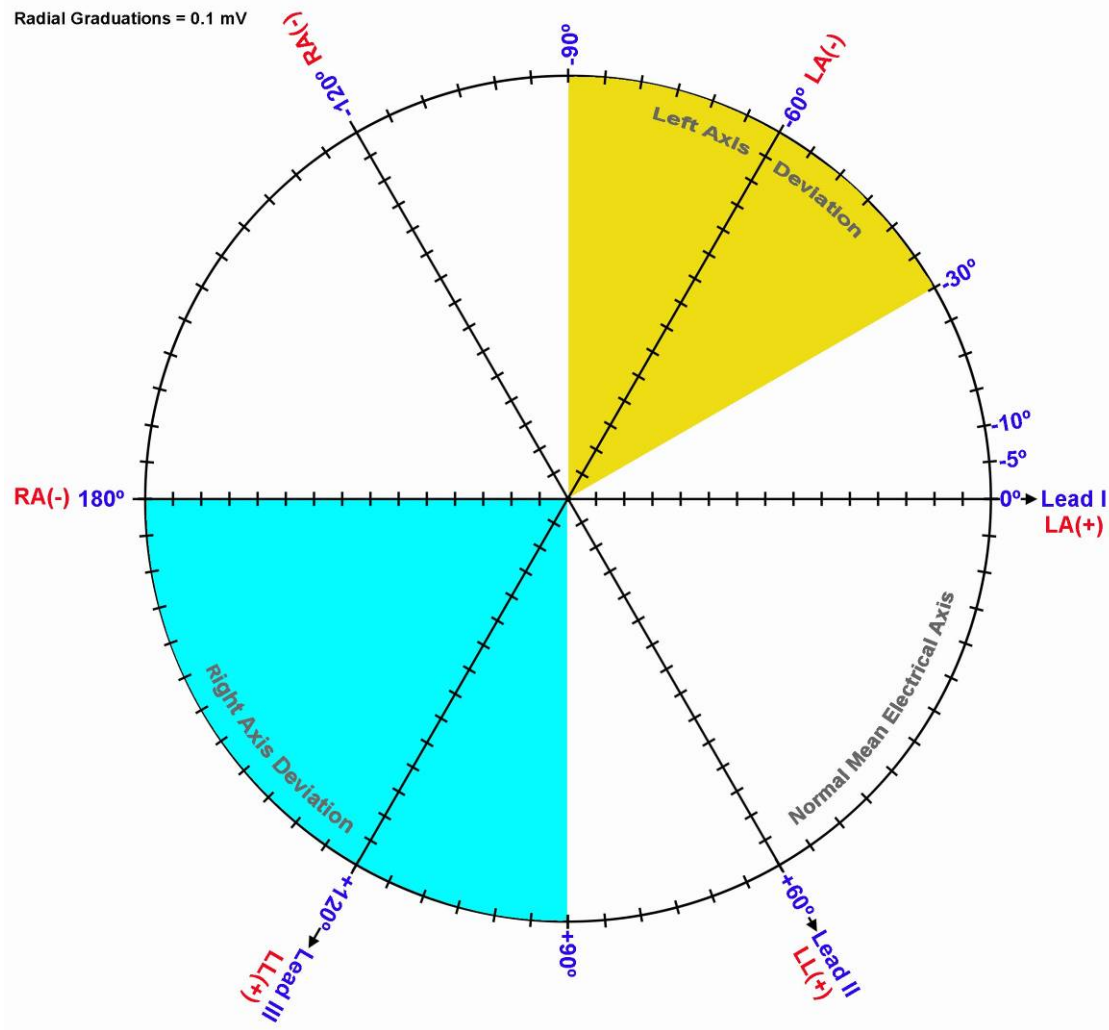
_____

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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 Segment 1—Supine.

Table 6.3

POTENTIAL	QRS Lead I [1] [Delta]	Lead III [2] [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**.

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*

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C. *Method*

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D. *Set Up*

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E. **Experimental Results**

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End of Lesson 6 Data Report