- **The waves:**
  - o P: arterial depolarization
  - o QRS: ventricular depolarization
  - o T: ventricular repolarization
  - o R-R: cardiac cycle
- The ECG paper consists of squares, and it is divided into an X-axis and a Y-axis. The X-Axis is time, while the Y-axis is the voltage.
- The device's calibration is to move 25mm/sec; one small square is 1mm.
- Each square is .04 seconds (1/25).
  - o This is the standard ECG; however, in some cases, the ECG's calibration differs. In cases of tachycardia, a 25mm/sec pace would be too slow. This is why we speed up the device (50mm/sec)
- When we record an ECG, we have 3 biploar limb leads:
  - o lead I: right arm (-ve) and the other on the left arm (+ve).
  - o lead II: right arm (-ve) and left foot (+ve).
  - o lead III: left foot (+ve) and left arm (-ve).
    - ▪ The arrangement of the electrodes is in this manner to make sure that we get a positive recording in all leads.
- Einthoven's law: QRS-Lead I + QRS-Lead III = QRS-Lead II
  - o This is why we usually see that the QRS segment of Lead II is obvious.
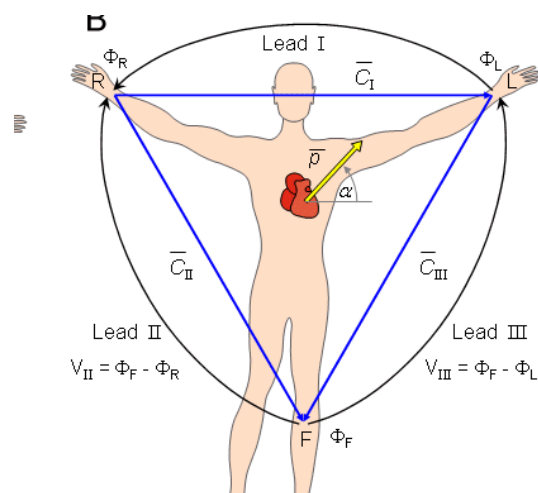
- Einthoven and Kirchhoff said that the electrical record from the leads form an equilateral triangle. Since this is an equilateral triangle, the center of the triangle (the heart) is the center of the circle that you can draw around this triangle. (refer to the figure in the previous page)
- In order to have a better view of the electrical activity of the heart, Wilson wanted to take into consideration other planes. Taking one view of the heart is insufficient.
- Wilson and Gilbert devised the unipolar leads. They connected the negative electrode of the limb leads with very high resistance (5000 Ω). The positive pole was put on the left arm, left foot, and right arm.
- When recording from a limb, you remove he high resistance from the limb.
- These leads go from the center (heart) to the desired limb:
  - aVF
  - aVR
  - aVL
- The ECG machine has 12 galvanometers that record from different places at different times.
- These 6 limb leads have to meet at the same point in order for us to be able to perform the calculations easily. To achieve this, you shift the leads' place without changing their direction or value. You move them in a parallel manner until they intersect at the center. With the three unipolar leads, this diagram is called the hexagonal axis of the heart.
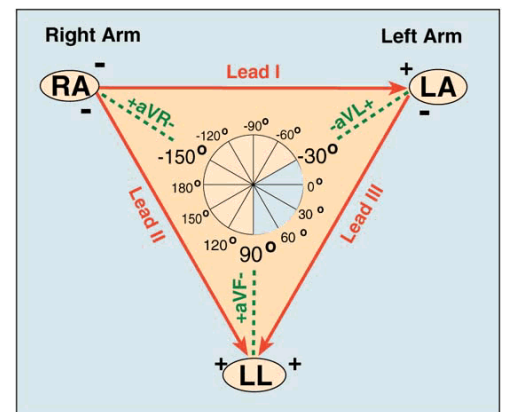

Calculations:

- Heart rate (beats per minute (bpm))
  - Your heartbeat can be:
    - Regular
    - Irregular:
      - Regular irregularity
      - Irregular irregularity.

- Intervals: (time calculations)
  - PR interval
  - QRS interval

o QT interval
- Segments (elevation or depression):
  o The reference point is the isoelectric line
  o PR segment
  o ST segment

For the following calculations, please refer to the figure below:

mm/mV   1 square = 0.04 sec/0.1mV
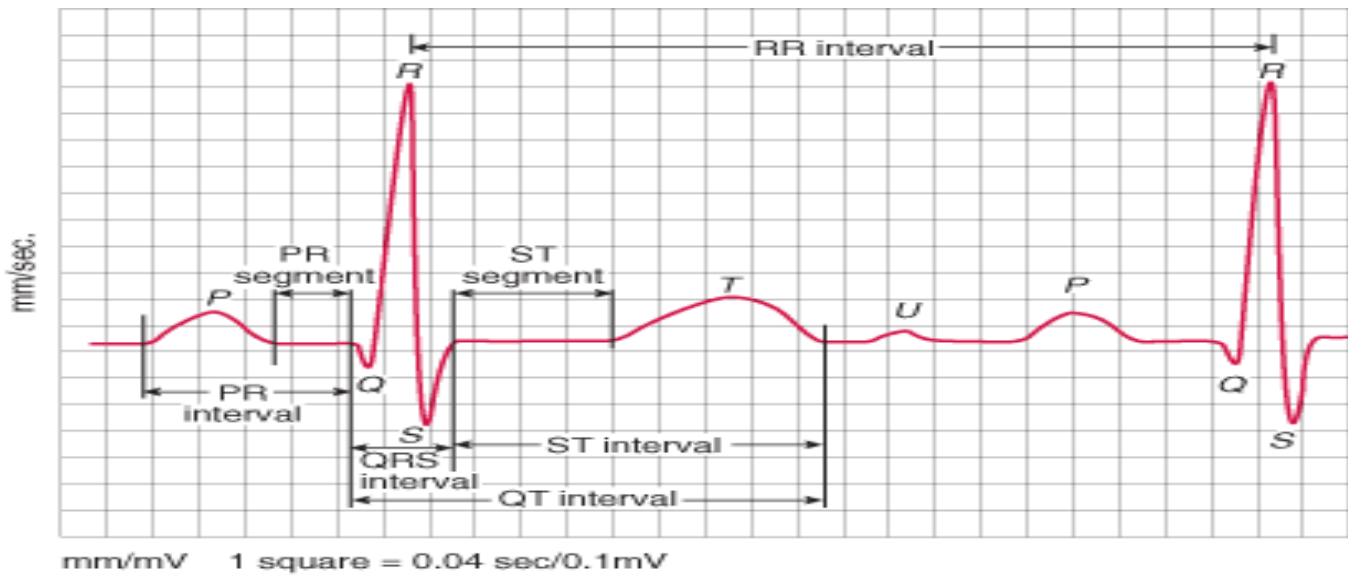
Heart Rate (R-R interval)

1) Count the small squares (each small square is .04 seconds)
   a. Let us suppose that we have 22 squares.

2) Multiply the number of squares by 0.04
   a. $22 \times 0.04 = 0.88$ sec/cardiac cycle
   b. This means that the number of beats per minute will be less than 75, as 0.8sec/cycle (our standard cycle) yields 75 bpm.

3) After multiplying by .04, you take 60 then divide it by the number you have.
   a. $\dfrac{60}{0.88} = 68$

- If the heart rate is irregular, there is another way for calculating the rate:
- Take a long strip of lead II and you count for 20 seconds
- Record the number of cycles in this interval.

- Then multiply by 3.
  - o If you take 15 seconds, multiply by 4
  - o If you took 30 seconds, multiply by 2

Other equations:

$$\frac{1500}{\#\ of\ small\ squares}$$

$$\frac{300}{\#\ of\ big\ squares}$$

- To test whether the cycles are regular or not, you take a piece of paper and mark the beginning and end of one cycle. Then, move the paper and see whether your markings meet the tops of other R-R intervals. If they do, the cycles are regular.
- Mean electrical axis: look at aVF and and lead I and calculate the resultant vector. If both waves were equal, the angle would be about 45. The normal angle (in clinical practice) is between 0 and 90.

The intervals:

PR interval: (From the beginning of P until the beginning of Q or R.)

1) Count how many small squares
2) Multiply by 0.04
3) The result should be less than .2 seconds
   a. no more than 5 small squares for the sake of simplicity

- If it is more than 0.2, but each P is followed by a QRS, this indicates an AV block. AV block will elongate the PR interval. If every P is followed by QRS, it means that it is a first degree AV block.
- In second degree AV block, not every P is followed by QRS.There is a regular pattern for the QRS 1:3, 3:2, 1:2.
- In 3rd degree AV block, the AV node does not conduct the impulse at all. The atrium pumps with the SA node. The ventricle pumps through Purkinje fibers. In that case, the heart rate is between 15 and 40 (The rate of Purkinje fibers). To treat this problem, we use an artificial pacemaker

- With third degree AV block, we see atrial repolarization. It is usually a downward reflection

QRS interval (beginning of Q until the end of S)

1) Count small squares
2) Multiply by 0.04
3) The result should not be more than 0.12
    a. No more than 3 squares
- If it is longer, this means that the ventricle took longer time to depolarize.
- This prolonged depolarization time might be due to:
    o Ventricular hypertrophy
    o Bundle branch block (left or right)
        ▪ If the left bundle is blocked, the left ventricle will not get depolarized through conduction. It will be depolarized through the muscles. Depolarization through muscles is much slower than Purkinje fibers depolarization
- Because the left ventricle takes longer time to depolarize, a current from the right ventricle passes towards the left ventricle. As we know, the current goes from the depolarized areas to the still polarized areas. This causes left axis deviation of the QRS

Prolonged QRS with left axis deviation →left bundle branch block

Prolonged QRS with right axis deviation→right bundle branch block

QT interval (from the beginning of Q until the end of T):

Use the aforementioned method. The time should be between 0.35 and 0.45 seconds.

Segments:

ST segment:

An elevation or depression in the ST segment indicates an ischemic problem in the ventricles. This is an emergency; if it is not treated immediately, the patient might go into a case of ventricular fibrillation (lethal). In the case of fibrillation we have saw-shaped QRS.
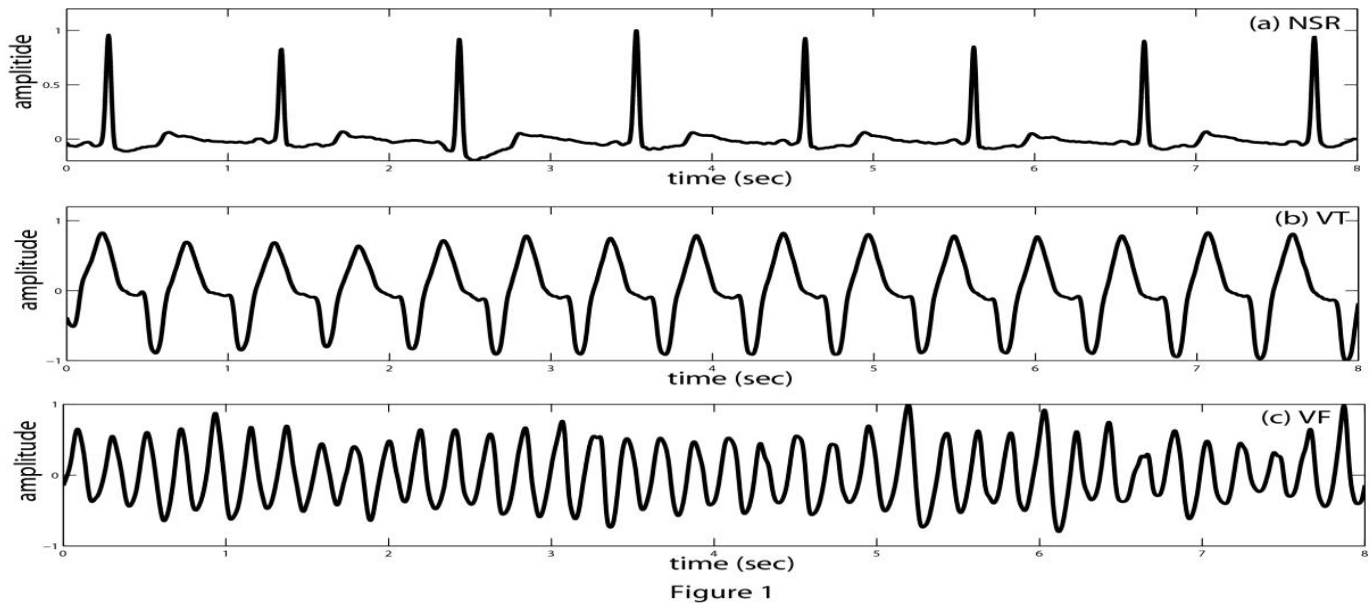
Figure 1

In the figure above, we can see ST depression, elevation, and ventricular fibrillation, respectively.

PR segment: (end of P until the beginning of Q)

A depression or elevation in the PR segment denoted a problem in the atria. It is not an emergency.