Investigation of Pulse Rate and ABPI (Ankle-Brachial Pressure Index) in Relax Condition and after Exercise

P Monalisa¹, S N Khotimah², F Haryanto², S Viridi²

¹Master Program in Physics Teaching, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Bandung, Indonesia
²Department of Physics, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Bandung, Indonesia

E-mail: nurul@fi.itb.ac.id

Abstract. Earth gravitational field influences physiological systems such as the cardiovascular and circulatory systems. Therefore changing the body position (standing, sitting, or supine) affects blood pressure. In addition to pressure, pumping blood throughout the body is also affected by the contraction of the hearts ventricles. The number of heartbeat per minute (pulse rate) for each person varies and is affected by physical activity. In this work, blood pressure and pulse rate for subjects in relax condition when supine, sitting, and standing positions are read using a set of digital sphygmomanometer OMRON type JPN-1. Blood pressure and pulse rate for subject after exercise are read in sitting position. From 14 subjects of this work, it was obtained that the blood pressure in brachial is lower than ankle in supine, sitting, and standing positions. The fluctuation range of ankle is about 7.4% - 67.33% which much higher than that in brachial about 0.7% - 14.89%. Furthermore, the difference magnitude value between brachial and ankle in sitting and standing positions is higher than in supine position. The ratio of the systolic blood pressure at the ankle to the systolic pressure at brachial is calculated for the ankle-brachial pressure index (ABPI). It was obtained that in relax condition the ABPI value of all subjects was relatively normal, meanwhile the results on post-exercise indicated that 2 smoker subjects were in risky condition of PAD. The human circulatory system in the arteries is analysed using the Bernoulli equation to estimate the mass density of the blood from the slope of a blood pressure to altitude curve. The blood density of 2 subjects is higher than the reference normal density (1060 kg/m³) and the other 12 subjects have lower value.

1. Introduction
Cardiovascular system of human is caused by the work of heart pumping blood through blood vessels. There are two physical quantities that can be used to monitor the performance of our heart called heart pulse rate and blood pressure. Heart pulse rate is the frequency of heart beating every minute and it is influenced by temperature, activity, emotional state, weight, age, and consumption of medicine[1]. Blood pressure, on the other hand, related with something called systole and diastole. Systolic blood pressure (SBP) is measured when our heart (ventricle) contracts while diastolic blood pressure (DBP) is a pressure in between heartbeats[2].

According to the basic health research of the ministry of health Republic of Indonesia in 2013, cardiovascular disease become the most uncontagious killing disease[3]. PAD (Peripheral Artery Disease) as one of the cardiovascular disease can be detected by non invasive technique called ABPI. ABPI is the ratio between SBP measured at ankle to that measured in brachial which is commonly...
taken when patient is in supine position where ankle and brachial will be at one level. However, some previous researches show that ABPI value can also take in sitting position but need extra calculation[4]. Hence, this work is aiming to apply the concept of fluid on the measurement of systolic blood pressure in three different positions (supine, sitting, and standing), determine the effect of exercise on heart pulse rate, to know the role of ABPI as the initial information of PAD on smoker and non-smoker subjects, and to determine the blood density through blood pressure measurement data in supine, sitting, and standing positions.

2. Method
Subjects in this work were 14 men that equally divided into two categories (smoker and non-smoker) with age over 45 years old. Before doing the measurement, every subject questioned about their profession and medical history in cardiovascular system. The equipment using to get blood pressure and heart pulse rate data was digital sphygmomanometer OMRON type JPN-1 which based on oscillometric method, while the height difference between cuff in brachial and ankle was obtained by a measuring tape. The data was taken in two conditions, that was relaxed and after doing an exercise. In relax condition, blood pressure and heart pulse rate were measured in 3 times repetition with 2 minutes time interval for each brachial and ankle (left and right) in supine, sitting, and standing positions. The exercise was done by going up and down in a stair for 2 minutes and followed by taking the data as in relax condition but only take once in sitting position. Figure 1 shows the positions of subject and the cuff installation during measurement in relax condition. The position of upper cuff (brachial) was always kept in the same level of heart so it could measure the SBP of ventricles.

In this work, blood flowing in main arterial vessels such as brachial and ankle is assumed as an ideal fluid because of several reasons. First, since subjects didn’t get any injured during measurement so the volume flow rate of blood should remain constant. Second, the diameter of blood’s corpuscles (2.5µm – 20µm) is the way much smaller than main arteries (4,000 µm) and aorta (30,000 µm), thus the friction between blood’s corpuscles and blood vessel wall can be neglected. Third, the blood flow rate in the main arteries is similar to the aorta which is around 33 cm/s so any turbulent flow can also be avoided[5,6].

The raw data getting from the measurement then is processed to achieve the aims of this work. Some data processing were used to calculate the value of ABPI and blood density from the SBP data. According to the recommendation of American Heart Association, the calculation of ABPI value is obtained by selecting the highest SBP between both ankle and brachial as written in equation (1)

![Figure 1. The position of subjects and the cuff installation during measurement in relax condition for (a) supine, (b) sitting, and (c) standing position.](image)
The ABPI is then interpreted to know whether a subject is in healthy condition or risky for PAD. The interpretation of ABPI value is pointed through Table 1 below. 

**Table 1. ABPI value range and its interpretation (33)**

| ABPI Value       | Interpretation                      |
|------------------|-------------------------------------|
| Greater than 1.4 | Calcification / vessel hardening    |
| 1 – 1.4          | Normal                              |
| 0.9 – 1.0        | Acceptable                          |
| 0.8 – 0.9        | Some arterial disease               |
| 0.4 – 0.8        | Moderate arterial disease           |
| Less than 0.4    | Severe arterial disease             |

The Bernoulli equation was used to analyze blood flow since its assumed as ideal fluid. The position of cuffs mounted in brachial and ankle are analogous as two points in a long tube with closed ends, so the Bernoulli equation can be re-written as equation (2) below,

\[
P_{\text{ankle}} + \frac{1}{2} \rho v^2 + \rho g h_{\text{ankle}} = P_{\text{brachial}} + \frac{1}{2} \rho v^2 + \rho g h_{\text{brachial}}
\]

since the velocity of blood in main arteries is similar, so the velocity section can be dismissed. Thus equation (2) become

\[
P_{\text{ankle}} + \rho g h_{\text{ankle}} = P_{\text{brachial}} + \rho g h_{\text{brachial}}
\]

\[
P_{\text{ankle}} - P_{\text{brachial}} = \rho g (h_{\text{brachial}} - h_{\text{ankle}})
\]

\[
P_{\text{ankle}} = \rho g (h_{\text{brachial}} - h_{\text{ankle}}) + P_{\text{brachial}}
\]

\[
\Delta P = \rho g \Delta h
\]

Equation (5) literally shows that blood pressure in ankle will be higher than brachial due to the height difference between them. Thus, before calculating the ABPI, the blood pressure in ankle need to be corrected by subtracting with \(\rho g \Delta h\) to get the right result. The acceleration of gravity (g) value used in this data processing is 9.78 m/s\(^2\) and the blood density (\(\rho\)) is 1060 kg/m\(^3\) (density of blood at 37 °C)\(^3\). In addition, the blood density of subjects can also be obtained from the equation (6) in which the relation between \(\Delta P\) and \(\Delta h\) is similar to linear equation where the gradient of the line corresponds to the product of \(g\) and \(\rho\).

3. Results and Discussion

The data of blood pressure getting from the measurement process can be seen in Tables 2 and 3. The blood pressure in both brachial and ankle shows a distinction when measured in different position. However, the fluctuation of blood pressure in ankle is noticeably higher than brachial between 7.4% - 53.21% meanwhile in brachial only 0.95% - 14.89%.
Table 2. Data of systolic blood pressure and pulse rate of smoker’s subjects

| Name   | Position/Condition | Δh (m) | Systolic Blood Pressure (mmHg) | Pulse |
|--------|--------------------|--------|--------------------------------|-------|
|        |                    |        | Ankle                         |       |
|        |                    |        | Left  | Right | Left  | Right |
| Subject 1 | Supine             | 0      | 162.33 ±1.53 | 167.67 ±2.08 | 143.67 ±6.66 | 149.33 ±3.21 | 62.83 ±1.73 |
|         | Sitting            | 0.67   | 223.67 ±4.04 | 210.67 ±1.53 | 153 ±3.60 | 151.33 ±4.16 | 67.58 ±1.17 |
|         | Standing           | 0.98   | 246 ±4.00    | 220.5 ±4.95  | 147.67 ±3.06 | 152.67 ±5.86 | 69.25 ±1.86 |
|         | Exercise           | 0.67   | 213 ±4.00    | 203 ±4.00    | 154 ±4.00   | 158 ±4.00   | 70.83 ±4.00 |
| Subject 2 | Supine             | 0      | 132.33 ±2.52 | 134.33 ±2.08 | 121.33 ±3.20 | 116 ±1.00 | 70.33 ±1.85 |
|         | Sitting            | 0.64   | 180.33 ±7.64 | 176 ±6.00    | 129.67 ±1.53 | 127 ±4.62 | 75 ±1.98 |
|         | Standing           | 1.03   | 218.5 ±0.71  | 211.33 ±9.07 | 121.33 ±3.06 | 127 ±7.79 | 77.79 ±2.73 |
|         | Exercise           | 0.64   | 211 ±9.07    | 197 ±9.85    | 131 ±2.64   | 124 ±2.73 | 75.75 ±2.73 |
| Subject 3 | Supine             | 0      | 128 ±6.08    | 134.33 ±2.31 | 121.33 ±3.20 | 116 ±3.20 | 70.83 ±1.85 |
|         | Sitting            | 0.66   | 152.67 ±5.51 | 146 ±3.20    | 109.67 ±1.00 | 116 ±4.00 | 61 ±1.96 |
|         | Standing           | 0.98   | 207 ±5.45    | 189.5 ±8.62  | 101.67 ±4.00 | 107.67 ±4.00 | 65.17 ±2.39 |
|         | Exercise           | 0.66   | 153 ±6.36    | 151 ±6.03    | 114 ±0.58   | 114 ±0.58 | 63.25 ±0.58 |
| Subject 4 | Supine             | 0      | 143 ±2.64    | 129.33 ±2.31 | 117 ±2.64   | 127.67 ±1.15 | 71.5 ±0.79 |
|         | Sitting            | 0.72   | 157.67 ±2.08 | 173.67 ±2.08 | 119 ±2.64   | 123.33 ±2.52 | 76.75 ±2.99 |
|         | Standing           | 1.11   | 226 ±4.58    | 222.67 ±4.95 | 128.67 ±2.52 | 139.67 ±2.52 | 85.67 ±2.99 |
|         | Exercise           | 0.72   | 172 ±4.40    | 184 ±2.52    | 141 ±2.52   | 151 ±2.52 | 78 ±2.39 |
| Subject 5 | Supine             | 0      | 159 ±3.60    | 169 ±1.00    | 135.33 ±1.53 | 133.67 ±1.53 | 64.33 ±0.88 |
|         | Sitting            | 0.75   | 196.67 ±1.53 | 206.33 ±3.21 | 124.67 ±2.52 | 120.33 ±2.52 | 68.58 ±1.18 |
|         | Standing           | 1.02   | 229.33 ±4.04 | 229.33 ±4.04 | 119.67 ±1.53 | 118.67 ±1.53 | 71.33 ±0.64 |
|         | Exercise           | 0.75   | 204 ±2.08    | 206 ±2.08    | 139 ±2.08   | 146 ±1.53 | 69.5 ±0.64 |
| Subject 6 | Supine             | 0      | 142.67 ±2.52 | 124.67 ±2.52 | 117.33 ±2.52 | 111 ±2.52 | 65.08 ±0.88 |
|         | Sitting            | 0.64   | 176.67 ±1.53 | 163.67 ±2.52 | 124.67 ±2.52 | 129.67 ±2.52 | 66.17 ±1.08 |
|         | Standing           | 1.03   | 236.67 ±4.04 | 210.67 ±4.04 | 119 ±2.52   | 121 ±2.52 | 68.42 ±1.08 |
|         | Exercise           | 0.64   | 189 ±4.04    | 181 ±4.04    | 101 ±2.52   | 142 ±2.52 | 70.5 ±1.39 |
| Subject 7 | Supine             | 0      | 158.33 ±3.51 | 148 ±2.00    | 132.33 ±2.52 | 126 ±1.00 | 64.83 ±0.76 |
|         | Sitting            | 0.62   | 176 ±1.00    | 179 ±4.00    | 120.67 ±1.55 | 123.67 ±3.21 | 60.33 ±1.60 |
|         | Standing           | 1.01   | 220.33 ±1.53 | 206 ±1.53    | 118 ±2.52   | 114.33 ±2.52 | 70.83 ±2.08 |
|         | Exercise           | 0.62   | 182 ±1.53    | 171 ±6.24    | 115 ±1.53   | 119 ±2.08 | 60.5 ±0.93 |
Table 3. Data of systolic blood pressure and pulse rate of smoker’s subjects

| Name      | Position/Condition | $\Delta h$ (m) | Systolic Blood Pressure (mmHg) | Pulse |
|-----------|--------------------|----------------|-------------------------------|-------|
|           |                    |                | Ankle | Brachial |                  |       |
|           |                    |                | Left  | Right    | Left  | Right    |       |
| Subject A | Supine             | 0              | 147   | 144      | 115.33 | 121.33    | 60.75 |
|           | Sitting             | 0.82           | 201   | 189.33   | 111.33 | 123.67    | 68.5  |
|           | Standing            | 1.17           | 217   | 221.33   | 121    | 119.3     | 75.75 |
|           | Exercise            | 0.82           | 211   | 197      | 125    | 140       | 74.25 |
| Subject B | Supine             | 0              | 133.67| 130.67   | 107.33 | 111.67    | 63.5  |
|           | Sitting             | 0.63           | 173   | 168.67   | 113    | 117       | 66.75 |
|           | Standing            | 1.04           | 214.5 | 190      | 110.67 | 124.67    | 69.54 |
|           | Exercise            | 0.63           | 204   | 185      | 124    | 131       | 71    |
| Subject C | Supine             | 0              | 137.67| 141.67   | 112.33 | 117.33    | 60.92 |
|           | Sitting             | 0.64           | 191.67| 179.67   | 131.33 | 131       | 67.75 |
|           | Standing            | 1.04           | 207.5 | 210.5    | 116.67 | 114.67    | 64.04 |
|           | Exercise            | 0.64           | 193   | 195      | 118    | 129       | 68.75 |
| Subject D | Supine             | 0              | 155   | 155.33   | 134    | 143.33    | 59.33 |
|           | Sitting             | 0.61           | 200   | 190.33   | 126.67 | 137       | 68 ±1.21 |
|           | Standing            | 0.87           | 224   | 218      | 134.33 | 130.67    | 71.54 |
|           | Exercise            | 0.61           | 219   | 190      | 133    | 139       | 68.5  |
| Subject E | Supine             | 0              | 128.5 | 119      | 118.5  | 120       | 65.75 |
|           | Sitting             | 0.62           | 162.5 | 162      | 102 ±0 | 116.5    | 70.75 |
|           | Standing            | 1.17           | 202.5 | 190.5    | 114    | 115       | 75.25 |
|           | Exercise            | 0.62           | 172   | 177      | 103    | 121       | 80    |
| Subject F | Supine             | 0              | 143.67| 151      | 137.33 | 133       | 78.5  |
|           | Sitting             | 0.66           | 211.67| 187.33   | 143    | 153.67    | 82.67 |
|           | Standing            | 1.01           | 242   | 199.33   | 132.33 | 145       | 87.33 |
|           | Exercise            | 0.66           | 202   | 210      | 133    | 153       | 82.75 |
| Subject G | Supine             | 0              | 128   | 132.67   | 125    | 121.33    | 100.33± |
|           | Sitting             | 0.71           | 175.67| 176.67   | 139    | 144       | 102.5 |
|           | Standing            | 1              | 199   | 195.33   | 117    | 126       | 113.08|
|           | Exercise            | 0.71           | 199   | 180      | 143.50 | 141       | 106.25|

Table 3. Data of systolic blood pressure and pulse rate of smoker’s subjects
3.1. Impact of Gravity and Height to Blood Pressure Measurement

According to table 2 and 3, the blood pressure in ankle is apparently higher than brachial in every position. Figure 2 and 3 below show the plot of the blood pressure difference ($\Delta P$) in every position to the height difference between ankle and brachial ($\Delta h$). It shows that $\Delta P$ gradually raised as $\Delta h$ increased. This result corresponds to theoretical analysis using Bernoulli equation as stated in equation (5) that the blood pressure in ankle will be higher than brachial.

![Figure 2. $\Delta P$ vs $\Delta h$ in relax condition of smoker’s subjects](image)

![Figure 3. $\Delta P$ vs $\Delta h$ in relax condition of non-smoker’s subjects](image)

3.2. Heart Pulse Rate

Based on table 2 and table 3 the pulse rate of every subject was then presented in the shape of histogram as in figure 4 and figure 5 below to show the change of pulse rate between relax and after exercise condition. In general, the pulse rate of all subject increased with the increment range between 0.1% to 13.7%.

![Figure 4. Heart pulse rate in relaxed and post-exercise condition of non-smoker’s subject](image)

![Figure 5. Heart pulse rate in relaxed and post-exercise condition of smoker’s subject](image)

Furthermore, in accordance with the profession of subjects, it was known that among other profession, subjects who worked as hodge were having the higher increment of heart pulse rate than others. The information on the increase in pulse rates of subjects with similar professions can be seen in table 4 below.

3.3. ABPI Value

ABPI value was obtained by using the equation (1) after correcting the SBP of ankle in sitting and standing position. The following table shows the final result of ABPI value of smoker subjects (table 5) and non-smoker subject (table 6) in both relaxed and after exercise condition. In relax condition, ABPI value of all subjects still categorized in normal range. However, in post-exercise results, two out of seven smoker subjects were indicated as subject with some arterial disease.
Table 4. Information of pulse rate increment in percent from subjects on similar profession

| Subject | Profession | Pulse rate increment in percent |
|---------|------------|----------------------------------|
| 1       | car driver | 0.7% - 3.7%                     |
| 2       | car driver |                                  |
| 7       | car driver | 6.5% - 13.07%                   |
| 4       | farmer     |                                  |
| 5       | farmer     |                                  |
| D       | farmer     |                                  |
| 6       | hodge      |                                  |
| E       | hodge      |                                  |

Table 5. ABPI results of smoker subjects

| Name   | Position  | Average of ABPI in relaxed | Post-Exercise |
|--------|-----------|-----------------------------|---------------|
|        | Supine    | Sitting                     | Standing      |
|        |           |                             |               |
| Subject 1 | 1.12 ± 0.04 | 1.12 ± 0.05 | 1.12 ± 0.06 | 1.12 ± 0.05 | 1.02 |
| Subject 2 | 1.11 ± 0.05 | 1.00 ± 0.07 | 1.09 ± 0.09 | 1.07 ± 0.07 | 1.23 |
| Subject 3 | 1.11 ± 0.17 | 0.87 ± 0.08 | 1.21 ± 0.06 | 1.06 ± 0.10 | 0.89 |
| Subject 4 | 1.12 ± 0.04 | 0.95 ± 0.03 | 0.99 ± 0.05 | 1.02 ± 0.04 | 0.85 |
| Subject 5 | 1.25 ± 0.02 | 1.18 ± 0.05 | 1.25 ± 0.03 | 1.18 ± 0.03 | 1.01 |
| Subject 6 | 1.22 ± 0.04 | 0.98 ± 0.02 | 1.29 ± 0.06 | 1.13 ± 0.04 | 0.98 |
| Subject 7 | 1.20 ± 0.05 | 1.05 ± 0.06 | 1.19 ± 0.04 | 1.15 ± 0.05 | 1.12 |

Table 6. ABPI results of non-smoker subjects

| Name   | Position  | Average of ABPI in relaxed | Post-Exercise |
|--------|-----------|-----------------------------|---------------|
|        | Supine    | Sitting                     | Standing      |
|        |           |                             |               |
| Subject A | 1.18 ± 0.06 | 1.11 ± 0.06 | 1.07 ± 0.09 | 1.12 ± 0.07 | 1.05 |
| Subject B | 1.19 ± 0.06 | 1.06 ± 0.09 | 1.07 ± 0.04 | 1.11 ± 0.07 | 1.18 |
| Subject C | 1.20 ± 0.12 | 1.08 ± 0.15 | 1.11 ± 0.06 | 1.13 ± 0.11 | 1.12 |
| Subject D | 1.08 ± 0.06 | 1.11 ± 0.05 | 1.16 ± 0.07 | 1.12 ± 0.06 | 1.23 |
| Subject E | 1.07 ± 0.08 | 0.98 ± 0.07 | 0.97 ± 0.18 | 1.01 ± 0.11 | 1.06 |
| Subject F | 1.10 ± 0.03 | 1.04 ± 0.01 | 1.12 ± 0.04 | 1.09 ± 0.03 | 1.04 |
| Subject G | 1.06 ± 0.02 | 0.84 ± 0.06 | 0.96 ± 0.01 | 0.95 ± 0.03 | 1.00 |
3.4. Blood Density

As stated in section 2, once $\Delta P$ and $\Delta h$ in between brachial and ankle are available, the blood density can be determined through the slope gradient of its plot or graph. The graph in figure 6 shows the plot of $\Delta P$ vs $\Delta h$ on subject 1.

![Figure 6. Plot of $\Delta P$ vs $\Delta h$ on subject 1 which is equipped with the equation of line and the r-squared](image)

The slope gradient getting from figure 6 is then divided with 9.78 to obtain the blood density of one subject. Using the same method for 13 other subjects, the blood density of all the subjects is shown in table 7 below.

| Subject | Slope gradient | $R^2$  | $g$ (m/s²) | $\rho_{\text{blood}}$ (kg/m³) |
|---------|----------------|-------|------------|-------------------------------|
| 1       | 8105.1         | 0.9973| 9.78       | 828.74                        |
| 2       | 9755.5         | 0.9313| 9.78       | 997.49                        |
| 3       | 9944.3         | 0.8699| 9.78       | 1016.80                       |
| 4       | 9725.9         | 0.9066| 9.78       | 994.47                        |
| 5       | 10880          | 0.9989| 9.78       | 1112.47                       |
| 6       | 10273          | 0.8578| 9.78       | 1050.41                       |
| 7       | 9340.6         | 0.9556| 9.78       | 955.07                        |
| A       | 8149.7         | 1     | 9.78       | 833.30                        |
| B       | 7572.1         | 0.9896| 9.78       | 774.24                        |
| C       | 8573.1         | 0.9699| 9.78       | 876.60                        |
| D       | 10856          | 0.9968| 9.78       | 1110.02                       |
| E       | 8836.5         | 0.9880| 9.78       | 903.53                        |
| F       | 8362.8         | 0.7631| 9.78       | 855.09                        |
| G       | 8360.5         | 0.8817| 9.78       | 854.86                        |
4. Conclusions
These results of measurement and data processing of blood pressure affected by earth gravitational field and height difference from 14 subjects lead to several conclusions. First, the blood pressure in brachial is lower than ankle when subject in supine, sitting, and standing positions. Second, the fluctuation range of ankle is about 7.4% - 67.33% which much higher than that in brachial about 0.7% - 14.89%. Third, the difference magnitude value between brachial and ankle in sitting and standing positions is higher than in supine position. Fourth, the heart pulse rate of all subjects increases in range of 0.1% – 13.07% after doing 2 minutes exercise and the pulse rate of subject working as a hodge tend to change rapidly than others. Fifth, the ABPI results in relax condition of all subjects is relatively normal, meanwhile the results on post-exercise indicates that 2 smoker subjects are in risky condition of PAD. Sixth, the application of Bernoulli equation to determine blood density shows that 2 subjects have higher result than normal density (1060 kg/m³) while others has lower value.

References
[1] http://www.heart.org/HEARTORG/Conditions/More/MyHeartandStrokeNews/All-About-Heart-Rate-Pulse_UCM_438850_Article.jsp#.WR0B3-uGPIU. [18 May 2017].
[2] https://www.education.com/science-fair/article/relation-between-pulse-blood-pressure. [12 May 2017].
[3] Agency for Health Research and Development 2013, Basic Health Research, The Ministry of Health Republic of Indonesia.
[4] Gornik H L, Garcia B, Wolski K, Jones D C, Macdonald KA and Fronek A 2008 J Vasc Surg 48 1204.
[5] Nave C R and Nave B C 1980 Physics for the Health Sciences (Philadelphia: W.B. Saunders Company)
[6] Halliday D, Resnick R and Walker J 2011. Principles of Physics (California: John Wiley & Sons, Inc)
[7] Aboyans V, Criqui M H, Abraham P, Allison M A, Creager M A, Diehm C, Fowkes G R, Hiatt WR, Jo¨nsson B, Lacroix P, Marin B, McDermott M M, Norgren L, Pande R L, Preux P M, Stoffers H E and Treat-Jacobson D 2012 Circulation, 126 2890
[8] Rac-Albu M, Iliuta L, Guberna S M and Sinescu C 2014, Maedica: a Journal of Clinical Medicine, 9 295.
[9] Cutnell J D and Johnson K W 2013 Introduction to Physics (Singapore: John Wiley & Sons, Inc.)
[10] Khairurrijal, Widiatmoko E, Srigutomo W and Kurniasih N 2012, Physics Education, 47 709