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The Effect of Problem Based Learning (PBL) Instruction on Students' Motivation and Problem Solving Skills of Physics

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ABSTRACT
Through the learning of physics, students will acquire problem solving skills which are relevant to their daily life. Determining the best way in which students learn physics takes a priority in physics education. The goal of the present study was to determine the effect of problem based learning strategy on students' problem solving skills and its role in building their motivation. A quasi-experimental research method was adapted. Problem solving inventory test and motivation scale were used to collect data. Subjects included were 81 grade 12 students taken from Wachemo Preparatory school. There was a mean difference between comparison and experimental groups. The covariate analysis shows that the difference was statistically significant with effect size above average. However, there was insignificant difference in motivation to learn physics. The study suggested that to improve students' achievement, schools must adapt the PBL method carefully. However, students' motivation to learn physics remains vague.
Keywords: motivation to learn physics, problem based learning, problem solving skill, quality of physics graduates

BACKGROUND OF THE STUDY

Science plays important and dominant roles in spearheading technological advancement, promoting national wealth, improving health and accelerating industrialization which aid development in many countries (Validya, 2003). Physics is one of the branches of science that attempts to describe how nature works using the language of mathematics. It involves the

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State of the literature

- Although there are a number of studies in physics education for testing the effectiveness of problem based learning strategy, there are few studies such as (Becerra-Labra, Gras-Martí & Torregrosa, 2012) that investigate its role in improving students' quantitative problem solving skills and motivation to learn.
- On the other hand, most of the studies found in the literature did not mention whether motivation or achievement has to be improved first, to sustain the change obtained.
- Most of the studies found in the literature give less emphasis to gender comparison.

Contribution of this paper to the literature

- It explores the change in students' quantitative problem solving skills of electro-statics and steady electric current in problem based learning environment.
- It finds out that students' quantitative problem solving skills was improved in problem based learning environment.
- It discloses that students' motivation remains static.

study of universal laws and the behaviors and relationships among a wide range of physical phenomena.

Teaching of Physics provides the learners with understanding skills and scientific knowledge needed for scientific research (Minishi et.al, 2004). The adoption of diverse learning contexts, learning and teaching strategies as well as assessment practices stimulates students' interest and motivation for learning. A major research domain in physics education is focused on the study of the effects of various types of teaching interventions aimed to help students' alternative conceptions (Jimoyiannis & Komis, 2001).

Since students' interest to study and learn physics and achievement in physics is still declining, the current debate is to determine the best way in which students learn physics. Unfortunately, there is no best theory of learning that fits for all students and the road ahead in determining precisely what should be done by educators still remains vague (Weegar & Pacis, 2012). Hence, the focus of this study was whether the Problem Based Learning (PBL) method improves students' problem solving skills and motivation towards physics.

Studies show that students learn better by constructing solutions to open-ended, complex, and problematic activities with class-mates, rather than listening passively to lectures. Such activities take time but can be extremely rewarding when students achieve their learning goals (Allen, Duch & Groh, 1996; Gallagher & Stepien, 1996).

PBL is an instructional method where relevant problems are introduced at the beginning of the instruction cycle and used to provide the context and motivation for the learning that follows (Michael, 2004). This definition requires active and usually (but not necessarily) collaborative or cooperative conditions. It involves a significant amount of self-directed learning on the part of the students (Michael, 2004).

Though the Ethiopian government gives high priority for science and technology (TGE, 1994), students achievement and interest in those fields is low (Semela, 2010). Physics education is still undergoing a crisis. Enrolment in physics courses and achievement in Ethiopia is low. According to Semela (2010) one reason for this is weak mathematics background.

Correspondingly, other studies in different contexts show that interest and motivation in secondary school physics learning is decreasing and examination results are getting worse (Garwin & Ramsier, 2003; Manogue & Krane, 2003). Thus there is a need to help students to learn physics confidently in such a way that they become innovative as required by the country's policy direction. One dimension to help students is to find comparatively better way of teaching; that is the way physics is presented to students, which was the aim of this study. Hence the purpose of this study was to determine the effect of PBL instruction on students' problem solving skills of physics as well as motivation to learn physics.

STATEMENT OF THE PROBLEM

Finding strategies to maintain students' interest in learning physics and improving their problem solving skills is important for national development. So far, the instructional strategies employed in teaching physics have not improved students' achievement and motivation in the subject to a considerable extent. As a result, developing better strategies of teaching physics has been and becoming one of the core issues that scholars deal with in physics education.

Objectives of the Study

In this study the following objectives were addressed:

- To investigate the effect of Problem-Based Learning (PBL) instruction on students problem-solving skills.
- To investigate the effect of Problem-Based Learning (PBL) instruction on students' motivation to learn physics.
- To examine gender difference in problem solving skills and motivation to learn physics.

Hypothesis of the Study

H_{01}: There is no significant difference between experimental and comparison groups in problem solving skills of students.

H_{02}: There is no significant difference between experimental and comparison groups in students' motivation to learn physics.

H_{03}: There is no gender difference in problem solving skills across groups.

H_{04}: There is no gender difference in motivation to learn physics across groups.

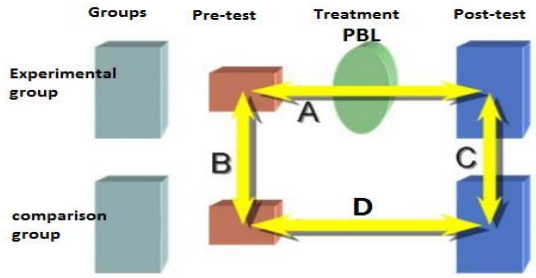

Figure 1. Design of the study

RESEARCH METHODOLOGY

To achieve the goal of this study, a quasi-experimental research approach was used; because, according to Bogdan & Biklen (2003) the theoretical perspective most often associated with cause and effect relationship is an experimental study. It is called quasi-experimental since it is not possible to conduct true experiment on human beings. Thus, the study was non-randomized pre-test, post-test control group design. Hence, intact classes were used instead of randomly composed samples. This is because, school classes exist as an intact groups and school authorities do not allow the classes to be taken apart and rearranged for research purposes.

The most spread quasi-experimental design in educational research is the non-equivalent control group design (Campbell & Stanley, 1963). Still contemporary studies such as (Selcuk, Çaliskan, & Şahin, 2013; Sungur, 2006; Idris, 2006; Selcuk, 2010) employed this design in their quasi-experimental research. However, this design is subject to the internal validity threat of selection; since any prior differences between the groups may affect the outcome of the study. According to Dannis and Boruch (1989), this type of design is a weak design; because, it can lead the researcher to conclude that the program didn't make a difference when in fact it did, or that it did make a difference when in fact it didn't. So, to resolve this limitation, in this study a matched group design was used instead. This design involves a step to make the experimental and comparison groups more comparable. The following paragraph deals with the specific steps taken to make the two groups as similar as possible.

Prior to the start of the experiment, a test similar to that of the post-test was administered to all sections of grade 12 in the school. Based on the result, four sections (groups) were found to have nearly the same mean value. Then after, the researchers selected two groups randomly. Using similar method, one group was assigned to the experimental group and the other was assigned to the comparison group. Diagrammatically, the design of the study is represented in **Figure 1**: note that similar colors refer the similarity of the two groups accordingly.

Table 1. Participants of the study

Groups	No of students		Total	
	Male	Female	Subtotal	Overall total
Experimental	29	11	40	81
Comparison	28	13	41	

According to Flick (2006), this type of design allows to compare the final post-test results between the two groups, giving them an idea of the overall effectiveness of the intervention or treatment in this case PBL (arrow C in **Figure 1**). It also allows the researcher to see how both groups changed from pre-test to post-test, whether one, both or neither improved over time (arrow A and D in **Figure 1**). Again the researchers can also compare the scores in the pre-test, to see whether the two groups are initially the same or not on the variables being measured (arrow B **Figure 1**).

Participants of the Study

A suitable school for this quasi-experimental study was found to be Wachemo preparatory school, as it was user friendliness and it is also near to the researchers for giving the treatment as required by the study. Demographic information of the participants of the study is given in **Table 1**.

Data Collection Instruments

Data for this study were collected using quantitative problem solving tests and motivation scale.

Measure of Motivation to Learn Physics

Motivation is a student's willingness, need, desire and compulsion to participate in and be successful in the learning process (Bomia et al., 1997). On the other hand, Middleton & Spanias (1999) define motivation as reasons individuals have for behaving in a given situation. To measure students' motivation, a 27- item and 5-point Likert scale was used. The Scale was adapted from Pintrich & DeGroot, (1990). The pilot analysis using the Cronbach alpha coefficient shows that the internal consistency reliability of the scale was 0.76, which is an acceptable level.

Quantitative Problem Solving Inventory Tests

Quantitative problem solving involves recalling formulas and solving problems quantitatively. The test comprises of 10 multiple choice items. The test was validated by scholars in the area before its use in the pilot as well as in the actual study. Using Cronbach alpha coefficient, the internal consistency reliability was found to be 0.74, which is an acceptable level of reliability. Furthermore, the item analysis shows that the average difficulty

Table 2. Descriptive statistics for the variables treated in the study

Variables	Experimental group (n= 40)				Comparison group (n=41)			
	Pre-test		Post-test		Pre-test		Post-test	
	M	SD	M	SD	M	SD	M	SD
Problem solving inventory test	22.25	11.655	50.25	16.091	22.20	11.514	38.54	15.742
Motivation to learn physics	93.00	11.620	94.88	7.849	89.90	10.139	92.93	8.214

index for the test was 0.53 which shows the test was neither too difficult nor too simple. Hence, the test was reliable and valid (Dudek, 1979).

Method of Data Analysis

The analysis of data was carried out using parametric statistical tests; t-test and ANCOVA. The post-test score for problem solving skill was subjected to Analysis of Covariance (ANCOVA) using pre-test scores as covariates. The benefit of ANCOVA is to "statistically control" for a third variable known as a confounding variable. A p-value of less than 0.05 was considered to be statistically significant.

FINDINGS AND DISCUSSION

Descriptive Statistics of the Variables Treated in the Study

Table 2 shows mean and standard deviation for the response of problem solving inventory test and motivation to learn physics.

The result of the study shows the mean score of the experimental group on the problem solving skill when tested before the treatment (22.55) and that of the comparison group (22.20) was nearly the same. This was a good starting point to infer the effect of the treatment (PBL) after the intervention. Hence, if the experimental groups score higher than the comparison groups on the post-test it will hopefully be due to the treatment, provided that other confounding variables are controlled.

The researchers controlled all the possible confounding variables such as time difference, the effect of the teacher and topics to be covered. Thus, it is evident to deduce the effect of the treatment. The post test result shows that the two groups increased dramatically and the increase made by the experimental group is much better; 50.25 mean score for experimental group and 38.54 mean score for comparison groups. For the second variable (motivation to learn physics) both groups report nearly the same result during both the pre-test and the post-test.

Analysis of Group Difference on the Pre-test

Scores obtained from the inventory test and motivation scale were analyzed by applying independent samples t-test as shown in **Tables 3** and **4**.

Table 3. Comparison of experimental and comparison groups on the pre-test scores of the inventory test and motivation scale

Variables	Groups	N	M	SD	t	df	p
Problem solving inventory	Experimental group	40	22.25	11.655			
	Comparison group	41	22.20	11.514	-.021	79	.983
Motivation to learn physics	Experimental group	40	93	11.620			
	Comparison group	41	89.90	10.139	-1.279	79	.205

Table 4. Comparison of male and female students across groups on the variables treated in the study

Variables	Male (n=57)		Female(n=24)		t	df	p
	M	SD	M	SD			
Problem solving inventory	43.16	15.255	47.08	20.319	.851	34.416	.401
Motivation to learn physics	93.47	7.184	94.88	9.901	.714	79	.478

Table 3 above, shows that there was no statistically significant difference between experimental and comparison group on the pre-test inventory test ($df = 79$, $t = -0.021$, $p > 0.05$). This shows that experimental and comparison groups scored nearly the same on the pre-test inventory test. Hence, we can infer the effect of the intervention after the post-test. The negative t-value was obtained as a result of subtracting the smallest sample mean from the biggest sample mean. When using the magnitude of the t-value for significance, the negative value is treated as their positive counterpart (take the absolute value of the result). If the absolute t-value is bigger than the critical t-value of reference, the null hypothesis is rejected (Elliott & Woodward, 2007). However, by disregarding this notion, in this study P-values were used to decide whether to accept or reject the null hypothesis. Note that both methods bring about the same conclusion.

The result of the study shows that there was no significant difference between the two groups in motivation to learn physics when measured before the treatment ($df = 79$, $t= -1.279$, $p > 0.05$). This shows that initially the two groups possess nearly the same motivational level, since the highest and lowest means do not differ by more than the shortest significant range within the group (Best & Kahn, 2006).

Analysis of Gender Difference on the Post-test

Post-test mean score of students on problem solving inventory and motivation to learn physics were used, and also independent sample t-test were carried out to determine the difference according to gender.

Table 4 above shows insignificant difference between male and female students in problem solving ($df=34.416$, $t=.851$, $p >.05$) and motivation to learn physics ($df=79$, $t=.714$, $p >.05$); showing that both male and female students scored nearly the same on the post-test. Hence, it was evident that there was no domination of gender in the results obtained for both the experimental and comparison groups. In the case of problem solving, the Levene's test shows that the assumption of equality of variances of the two groups (male and female) was

Table 5. Pre-test and post-test comparison within groups for problem solving inventory and motivation to learn physics

Observations	Group	Paired differences					
		N	Mean difference	Std. Deviation	t	df	p
Post test – pre test	Experimental	40	28	23.555	7.518	39	.000
	Comparison	41	16.341	23.319	4.487	40	.000
Post motivation – pre motivation	Experimental	40	1.875	12.235	.969	39	.338
	Comparison	41	3.024	10.903	1.776	40	.083

violated (F=4.513, P<.05). Hence, the Levene's test adjusts the variation. In this case the degree of freedom becomes 34.416 instead of n-2. But, the result shows insignificant difference as it is discussed above. This finding is in parallel with (Adeoye, 2010) who found insignificant gender difference in his quasi-experimental research. But it is against with the finding of (Lawrenz, et al., 2009), which reported the domination of male students in both achievement and motivation.

Pre-test and Post-test Analysis of both the Experimental and Comparison Groups

The mean score of students in the experimental group on the post-test (50.25) was greater than their score on the pre-test (22.25). For comparison groups, the mean score on the post-test was (38.54) while the mean score on the pre-test was (22.20). A paired sample t-test shows that the difference for both the experimental group ($t_{(39)} = 7.518$, $p < 0.05$, $d = 1.99$) and comparison group ($t_{(40)} = 4.487$, $p < 0.05$, $d = 1.185$) was statistically significant on the inventory tests. This difference, according to Cohen (1988) is much larger than typical. This shows that both groups increased in a statistically significant extent. However, it is evident that the increase on the part of the experimental group is better than that of the comparison groups. As shown in **Table 5**, experimental groups scored above the minimum base line for passing a subject. The cutoff point is 50% (TGE, 1994). The experimental groups performed more on the post-test and the effect size was also more than typical.

The result of the study shows statistically insignificant difference in motivation to learn physics for both experimental ($t_{(39)} = 0.969$, $p > 0.05$) and control groups ($t_{(40)} = 1.776$, $p > 0.05$); depicting that there was no improvement on students' level of motivation whether they were taught by PBL (the experimental groups) or by the conventional method (the comparison group). Though PBL improves students' problem solving skills, it fails to improve their motivation to learn physics. This shows the existence of some other factors that delineate motivation of students to learn physics. The finding disagreed with the findings of Hmelo-Silver (2004) that is PBL lead students to become intrinsically motivated to learn.

Analysis of Covariance

Results indicated that after statistically controlling the effect of the pre-test, the mean score of experimental group (50.27) was higher than the mean score of comparison group (38.52) on the problem solving skills. **Table 6** presents the means and standard deviations for

Table 6. Adjusted and unadjusted means and variability for problem solving skills using pre-test as a covariate

Group	No	Unadjusted		Adjusted	
		M	SD	M	SE
Experimental	40	50.25	16.091	50.27	2.262
Comparison	41	38.54	15.742	38.52	2.290

Table 7. ANCOVA result for problem solving skills

Source	df	Mean square	F	p	η^2
Pre-test	1	3853.063	18.602	.000	.193
Group	1	2793.659	13.487	.000	.147
Error	78	207.136			
Total	81				

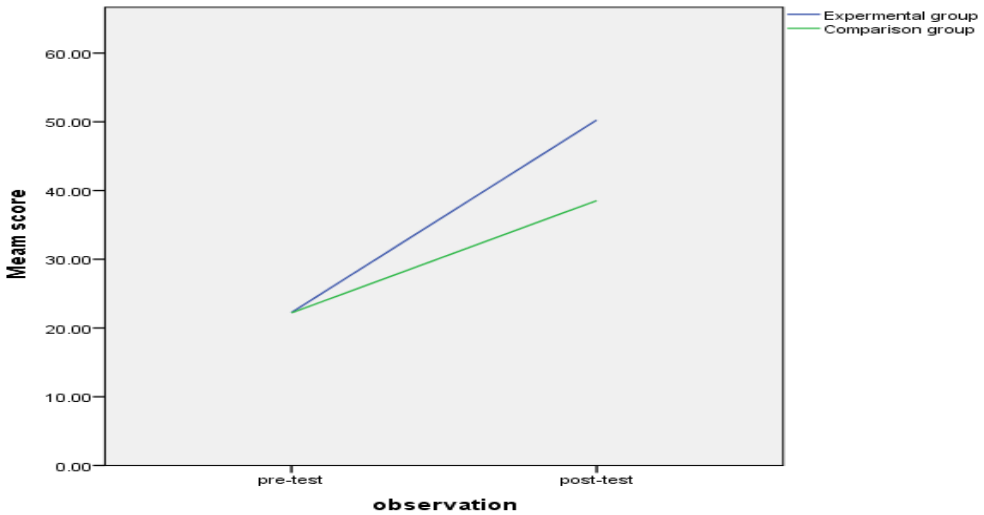

Figure 2. The effect of the treatment on students' problem solving skills

experimental and comparison groups on problem solving inventory test, before and after controlling for the pre-test. As it was seen from this table, there was a reasonable difference between experimental and comparison groups.

The analysis of covariance presented in **Table 7** shows the existence of significance difference between experimental and comparison groups in problem solving skills ($F_{(1, 78)}$ = 13.487, $p < 0.05$, η^2=0.147). The effect size eta-squared, is interpreted as small, medium and large effects if it possesses the values 0.01, 0.06 and 0.14, respectively (Stevens, 1992). Since η^2=0.147 for this study, the effect size is large.

Generally, the result of this study shows that PBL could be more effective on problem solving skills than the conventional teaching method. But, the result of the study shows that students' motivation to learn physics failed to improve in both cases. Hence there was an indication of another de-motivating factor for students. This result was in parallel with the results of research which was based on the PBL (Aslihan & Mustafa, 2014; Selcuk, 2010; Sahin, 2010; Becerra-Labra, et al, 2012).

Figure 2 shows the pre-test and post-test scores of students in both experimental and comparison groups. As it can be seen, the increase made by the experimental group was higher than that of the comparison group and this increase was significant at $\alpha = 0.05$ level.

CONCLUSIONS AND RECOMMENDATIONS

From students' perspective, physics is considered as one of the hardest subjects in schools and they believe that only special gifted students understand the concept. However, this study shows that students' achievement in physics can be improved by using the PBL. Diggs (1997) also explained that PBL method allows students to grasp science better. Previous studies which were conducted on PBL method in different settings by different researchers as well as this study prove PBL as more effective method of instruction for the selected physics topics as compared to the conventional method of teaching. Therefore, PBL is a good alternative teaching method to improve the academic achievement of students. In doing so, students need to develop social skills in order to be active in group discussion and exercise independent learning. There should also be a sense of trust among students. Based on the aforementioned discussion and the findings of the study, the following conclusions were drawn:

- The problem solving skills of both the experimental and comparison groups increased in a significant extent. But motivation of both groups remains stagnant.
- The statistical results rejected the null hypothesis posed in this study, which stated that there is no significant difference between problem solving skills of students taught with problem based learning instruction and those taught with traditional method after the effect of mean scores of pre-test was controlled.
- The statistical result accepted the three null hypotheses rose in this study, which stated (1) there is no significant difference in students' motivation to learn physics between the experimental and comparison groups (2) there is no gender difference in problem solving skills across groups (3) there is no gender difference in motivation to learn physics across groups.
- PBL method is a more effective teaching method for teaching physics as compared to the conventional teaching method. This was because students in the experimental group achieve better than those students found in the comparison group.
- There is no evidence as to why students fail to improve their motivation.

- There is no gender difference in problem solving as well as in motivation to learn physics. Hence no domination of gender existed in the results obtained in both the experimental and comparison groups.
- For future researchers it is highly recommended to investigate factors affecting students' motivation and to investigate whether achievement of students are dependent on motivation or vice versa. This is because it was found that although there was a significant increase in achievement, the study shows no improvement on motivation of students to learn physics.

Since the results of a few studies are insufficient to decide about the maximum use of PBL method, additional studies should be conducted in different topics of physics to see the effectiveness of the method.

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APPENDICES

Appendix 1

Problem Solving Inventory Test

1. How much force should act on an electron that passes between two plates with a potential difference of $500\ V$ and a separation of $10\ cm$? [Use $e = 1.6 \times 10^{-19}\ C$].

   A. $1.28 \times 10^{-34}\ N$ B. $1.6 \times 10^{-34}\ N$

   C. $5 \times 10^{-34}\ N$ D. $3.13 \times 10^{-34}\ N$

2. How much is the magnitude of the force between a proton and an electron separated by a distance of $1\ m$? [Use $k = 9 \times 10^{-12}\ Nm^2/C^2, e = 1.6 \times 10^{-19}\ C$].

   A. $1.44 \times 10^{-45}\ N$ B. $5.63 \times 10^{-46}\ N$

   C. $2.30 \times 10^{-49}\ N$ D. $9 \times 10^{-46}\ N$

3. An electron experiences a force of $6\mu N$ when passing through an electric field. Calculate the electric field strength. [Use $e = 1.6 \times 10^{-19}\ C$].

   A. $6 \times 10^{13}\ N/C$ B. $2.67 \times 10^{12}\ N/C$

   C. $3.2 \times 10^{13}\ N/C$ D. $3.75 \times 10^{13}\ N/C$

4. What is the electric potential $3mm$ from a point charge of $5nC$? [Use $k = 9 \times 10^{-12}\ Nm^2/C^2$].

   A. $1.67 \times 10^{-18}\ V$ B. $1.5 \times 10^{-17}\ V$

   C. $3 \times 10^{-18}\ V$ D. $6 \times 10^{-19}\ V$

5. Two capacitors with capacitances of $2\mu F$ and $8\mu F$ are connected in parallel. What will be the total capacitance of the capacitors?

   A. $4\mu F$ B. $10\mu F$

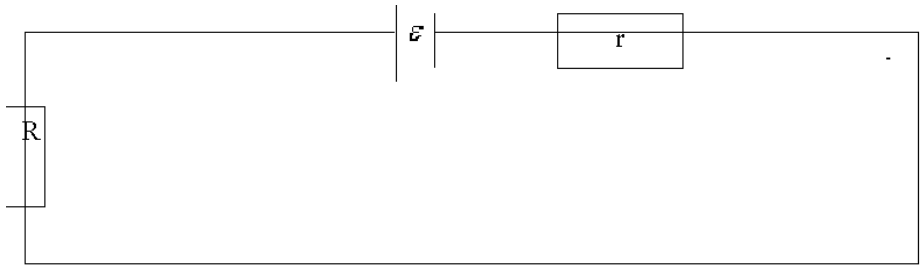
   C. $6\mu F$ D. $1.60\mu F$

6. What will be the resistance of a copper cable if it has a cross-sectional area of $1\ cm^2$ and a length of $2m$? [Use the resistivity of copper, $\rho_{copper} = 2 \times 10^{-8}\,\Omega\, m$].

   A. $4 \times 10^{4}\,\Omega$ B. $1 \times 10^{-4}\,\Omega$

   C. $4 \times 10^{-8}\,\Omega$ D. $1 \times 10^{-8}\,\Omega$

Based on the following diagram, answer Q_7 and Q_8:



The battery has an e.m.f. of $12V$ and an internal resistance of $3\,\Omega$.

7. What will be the current supplied to the resistor R, with value $12\,\Omega$?

   A. $4A$ B. $36A$

   C. $0.8A$ D. $8A$

8. What will be the power used in the external resistor?

   A. $7.68W$ B. $12W$

   C. $32W$ D. $9.6W$

9. Three resistors with resistances $1\,\Omega$, $2\,\Omega$ and $3\,\Omega$ are connected in series. What will be the total resistance of the resistors?

   A. $5\,\Omega$ B. $6\,\Omega$

   C. $2\,\Omega$ D. $0.54\,\Omega$

10. Calculate the energy stored in a capacitor of capacitance $10\mu F$ connected to a source of e.m.f of $2 \times 10^{4}V$.

    A. $2 \times 10^{2}J$ B. $2 \times 10^{3}J$

    C. $2 \times 10^{5}J$ D. $4 \times 10^{4}J$

Appendix 2

Some Items from Motivation Scale (Pintrich & DeGroot, 1990)

No	Items	SA	A	N	D	SD
1	I prefer class work that is challenging so I can learn new things					
2	When the portion is hard to me, I either give up or study only the easy parts					
3	I like what I am learning in physics class					
4	I am uncomfortable and feel upset when I take a physics test					
5	I think I will score highest in physics in this class					
6	Even when I do poorly on a test, I try to learn from my mistakes					
7	Before I begin studying, I think about the things I will need to do to know					
8	Even when study materials are dull and uninteresting, I keep working until I finish					
9	Understanding physics is important to me					
10	When I do homework, I try to remember what the teacher said in class so I can answer the questions correctly					