Use of Concept Maps as an Assessment Tool in Mechanical Engineering Education

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ABSTRACT

The purpose of this study to investigate, how third year mechanical engineering students are able to use their knowledge of concept maps in their study of the topic of 'Introduction to the Internal Combustion Engines (IICE)'. 41students participated in this study. Firstly, the students were taught about concept maps and then asked to draw their concept map of the topic IICE. Afterwards, two achievement tests were administered. One test, namely, knowledge applications test (KAT) included questions on the application of knowledge of the topic of IICE and other test, knowledge recall test (KRT) contained the questions that require a recall of knowledge of the topic of IICE. The students' concept maps were scored by comparing with the expert map created by the teacher. The correlation between concept map scores (CMS) and the scores in tests which measure application of knowledge (KAT) was moderate while the correlations between score of concept map and the test that measures a recall of knowledge (KRT) was weak. While achievement tests measure knowledge in different context, CMS, on the other hand, measures knowledge about related concepts and relationships among concepts. As a result, concept maps can be used as a supplementary assessment method along with achievement tests. Most of the students were satisfied with use of concept mapping in the topic of internal combustion engine. They indicated that concept mapping helps them to understand the key concepts, to connect the various concepts with each other and to correct misconceptions.

INTRODUCTION

In recent times, student's assessment of concepts has become a useful factor in the teaching methodology. Many engineering educators use achievement tests as a major tool for assessing student leaning. However, these achievement tests are limited in what they measure and questions do not always correspond to what teachers have to convey (Novak & Govin, 1984). They are often tested on the topics for that particular class, or a particular course and there is rarely an effort to measure their knowledge they have gained over a period of time. To evaluate the personal potential of the students, a teacher can take the help of applied assessment methods. In this aspect, concept map strategy becomes an important tool. Concept maps can be used as a dependable research tool which gives a great advantage in academic studies (Novak & Gowin, 1984). A concept map represents the relation between concepts in a graphical representation. Concept maps help us to simplify and present the theoretical concepts on a graphical node. Concept maps can be used as a knowledge representation tool to reflect relationship between concepts that exist within an individual's long term memory (Jacobs-Lawson and Hershey, 2002). Concept maps can be used as a learning strategy, as an instructional strategy and as a means of student assessment (Novak, J.D., 1990)

The aim of education must be to develop effective and meaningful learning and to reduce rote learning. Ausubel's theory of meaningful learning played a crucial role in the development of idea of the concept mapping (Novak, 1990). According to him, 'the most important single factor affecting learning is what student already knows'. With the help

of this important factor, Novak et al. developed a tool which was at first called 'cognitive maps' and later 'concept maps'.

The major advantage of the concept maps is that it supports visual presentation, focuses on concepts and makes learning easy (Yester, et.al. 2007). It also helps the students in study and revision. In this way, learning becomes an active process. A number of studies have shown the benefits of concept maps to evaluate the cognitive degree of a set of relevant concepts for students (Hwang, Tseng & Hwang, 2010; Liu, Don & Tsai, 2005; Panjaburee et al, 2010; Ruiz-Primo & Shavelson, 1996).

We are interested in developing different teaching learning strategies for effective learning of the concepts in mechanical engineering. We had already used evaluation of the concepts maps in the study of engineering thermodynamics. Now, we are extending this approach to the study of internal combustion engine and in the course of time, would like to extend it to other subjects in mechanical engineering and related areas.

OBJECTIVES OF THE STUDY

The purpose of the present study is to determine students' knowledge and understanding of the topic of 'introduction to the internal combustion engines' (IICE) by comparing and contrasting two different methods namely, concept maps and two achievement tests, namely, KAT and KRT.

To our knowledge, there is little published work on concept mapping in the subject of internal combustion engines. Thus, this study was organized on the basis of the following objectives:

1. To develop and implement concept mapping as a teaching learning strategy for the topic of introduction to the internal combustion engine.
2. To investigate whether a correlation exists between two achievement test, namely, KAT and KRT and their performance in creating concept maps.
3. To study the attitude of the students towards concept mapping for the topic of IICE.

METHODOLOGY

The participants consisted of 41 students enrolled in the third year mechanical engineering undergraduate students for the course of internal combustion engine. The data collected at the end of instructions consisted of the results two tests, namely, knowledge recall test (KRT) and knowledge application test (KAT), concept map scores (CMS) and later anonymous survey about the perception of the concept maps.

Instruments

Two achievement tests, KAT and KRT were administered after the completion of the instructions. Few test questions are given in Appendix 1. KAT contains questions related to the application of knowledge in different situations and it has 27 questions. The K-R 20 reliability coefficient of this test was 0. 93. KRT contains questions related with the recall of knowledge of students. It has 15 questions and the K-R 20 reliability coefficient of the instruments was 0.77.

A satisfaction questionnaire was designed to find the attitude of students towards concept mapping strategy. The questionnaire has 10 items and was rated on a five point Likert scale from 1 (strongly disagree) to 5 (strongly agree). The Cronbach Alpha coefficient of this questionnaire was 0.87.

Procedure

This study was conducted over a six lecture module on the topic of the IICE. During the fall semester, 41 third year (sixth semester) university-level mechanical engineering students were instructed to draw a concept map showing their ideas and knowledge about the topic of 'introduction of internal combustion engine'. For effective drawing of concept mapping, they were made familiar with the nature of concept maps. At the start of first hour of instruction, they were taught about the aims and the nature of concept maps.

They were provided with a non –exhaustive list of concepts of the topic of IICE. The concept list is provided in table 1. No restriction was made on the size or structure of the concept map.

Table 1
A useful and non exhaustive list of concepts resulted during class discussion

Engine	Ignition system	Lower thermal efficiency
Internal combustion engine	Fuel pump and nozzle	Uniform turning moment diagram
External combustion engine	Alternative fuels	Non uniform turning moment diagram
Supercharging, turbo charging	Carburetor	Cars, buses
Spark ignition engine	Gasoline	Scooters, mopeds
Compression ignition engine	Diesel	Battery, magneto, electronic ignition system
Cooling and lubrication systems	Two stroke engine	Combustion inside the cylinder
Otto cycle	Four stroke ngine	Combustion outside the cylinder
Diesel cycle	High thermal efficiency	Open cycle gas turbine
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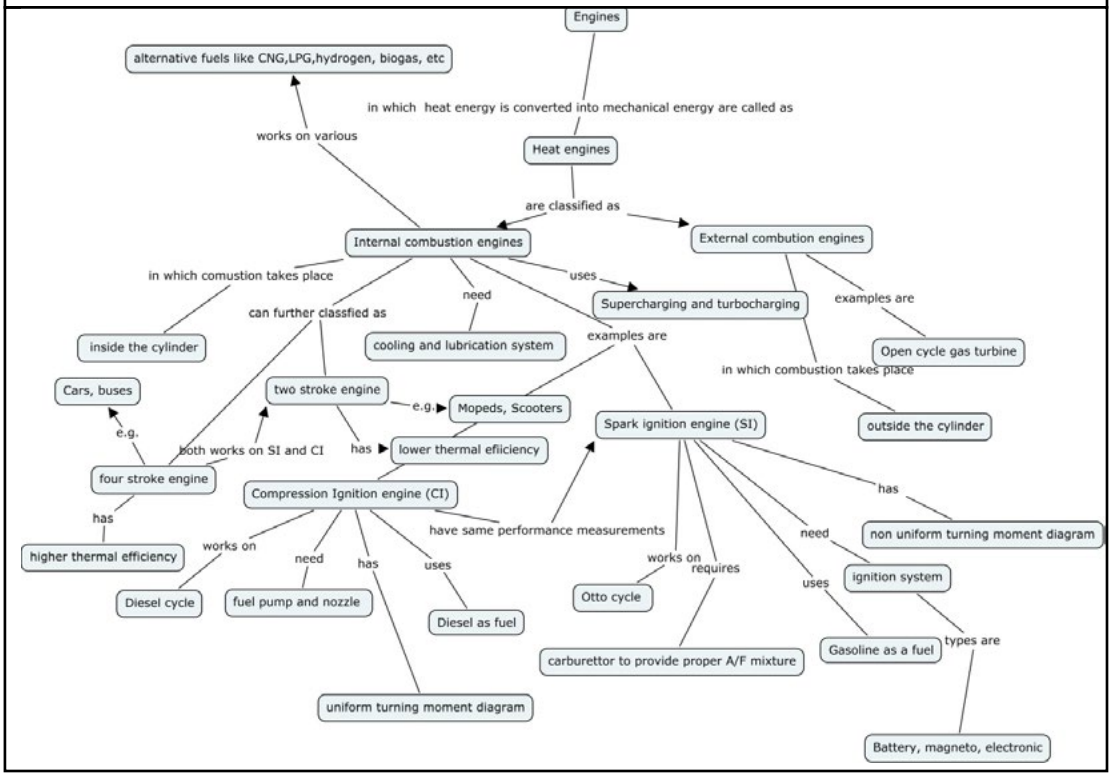
CONCEPT MAP SCORING RUBRIC

The evaluation of the concept maps are typically carried out by comparing them to an expert map (see figure 1, shown towards the end of paper) in either quantitative or qualitative forms.

Various techniques of concept mapping scoring systems can be found in the literature. Originally, Novak and Gowin have proposed basic scoring criteria to evaluate concept maps. While this method is limited to hierarchical maps, this procedure is generally accepted as the most comprehensive scoring method (Ruiz-Primo & Shavelson 1996) and has been reported to work quite well as long as the task of making concept map is well structured and is of a 'closed format' (i.e. the

Figure 1
A well developed concept map for the Introduction to the Internal combustion engine (IICE)



map structure training and the concepts are provided by the teacher).

There are other quantitative scoring techniques available in the literature i.e. making counts of characteristics; (for example, McClure et al. 1999, Ruiz-Primo & Shavelson 1996) or qualitative methods (i.e. describing the content and quality of the map to some extent; for example, Hoz et al. 199Ø, Lomask et al. 1992, White & Gunstone 1992).

Quantitative approach of scoring concept map is more objective than qualitative and depends upon the skill of the expert evaluator. This report follows quantitative method developed by Novak and Govin. The scoring system is as follows.

Prepositions	1 point per preposition
Hierarchy	5 point per hierarchy
Cross links	1Ø points per cross link
Examples	1 point per example

RESULTS AND DISCUSSION

Concept maps evaluate aspects of learning that the conventional achievement tests measure but they also assist in measuring other aspects of learning which conventional test do not measure (Ruiz-Primo et al. 1997, p.23). There are moderate correlations between scores of concept maps and conventional achievement tests. Students' performance in creation of the concept maps has been found to be significantly correlated with multiple choice tests (Liu & Hinchy 1993; Liu and Hinchey 1996; Rice et al. 1998). The strength of the correlations depends upon three factors: the type of conventional test, the type of concept map format, and the scoring rubric of the concept map (Stroddart, et .al. 1999, pg.1Ø).

The correlations between the scores of concept map and conventional achievement test were found to vary with type of the conventional achievement test (Stroddart, et .al. 1999, pg.1Ø). Higher correlations are found between score of concept map and conventional achievement test which measure applications of knowledge (Wilson 1993). Lower correlations are found between score of concept map and conventional achievement test which measure recall of knowledge (Wilson 1993; Nowak, Gowin and Johansen, 1983).

In our study, the students' scores of the concept map were rated out of 75 and then compared to the knowledge application test (KAT) and knowledge recall test (KRT) separately. The correlation between scores of the concept map and KAT was found to be Ø. 531 as shown in Figure 1[Pearson correlation factor, r= Ø.531, correlation is significant at

FIGURE 2
RELATIONSHIP BETWEEN SCORES OF CONCEPT MAP AND SCORES OF KAT.

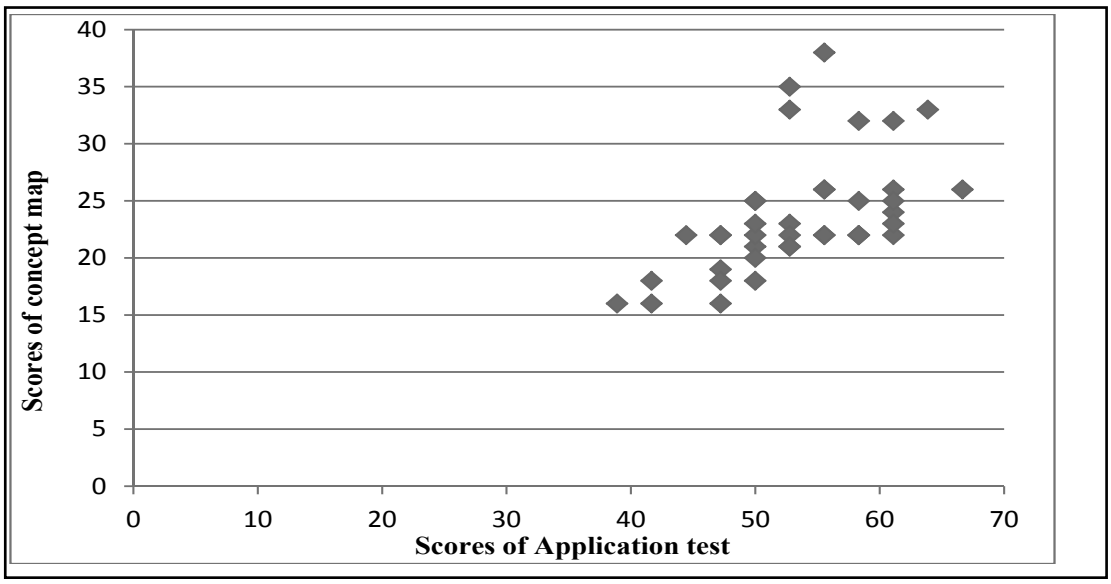
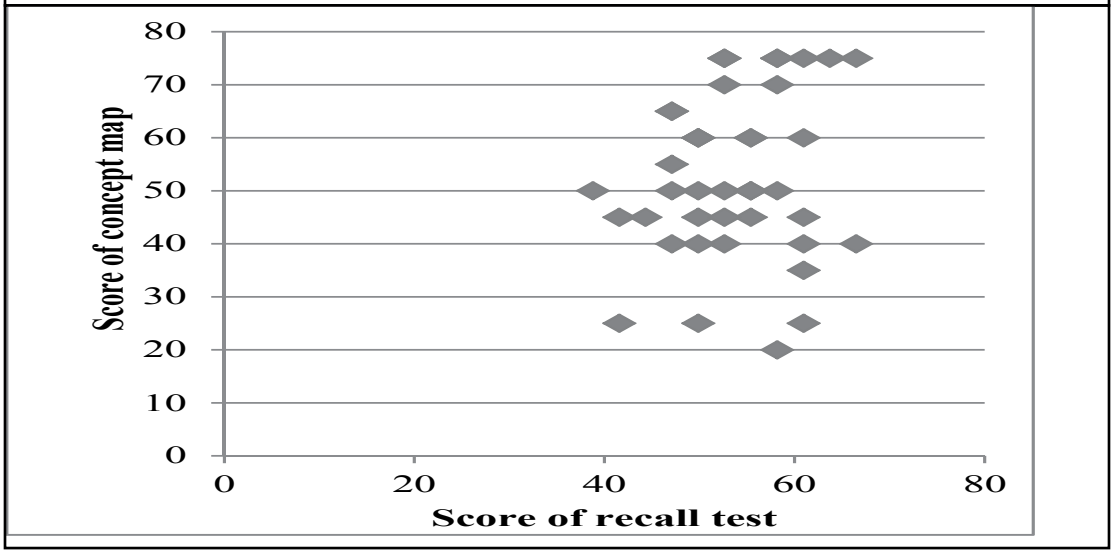


FIGURE 3
RELATIONSHIP BETWEEN SCORES OF CONCEPT MAP AND SCORES OF KRT.



Ø.Ø1 level (2 -tailed)]. This level of correlation is meaningful but moderate as shown in figure 2. The average score of the concept map score is 54.

The correlation between scores of the concept maps and KRT test was found to be Ø.166 (Pearson correlation factor, r = Ø.166).This level of correlation was meaningful but weak as shown in figure 3.

Figure 4 shows the scores of the students in KAT and KRT.

The figure 5 shows the distribution of the scores of prepositions, hierarchy, crosslink and examples in the concept map of the students. 8Ø % of the students are able to write at least 5Ø % of correct prepositions between concepts. Only 3Ø % students are able to connect crosslink between a) four stroke engines and two stroke engines, and b) Spark Ignition (SI) and Compression Ignition (CI) engine. 7Ø % students are able to write hierarchy of concepts like engine, internal combustion engine, external combustion engine, S.I. engine, C.I. engine, two stroke engine, and

FIGURE 4
DISTRIBUTION OF THE SCORES.

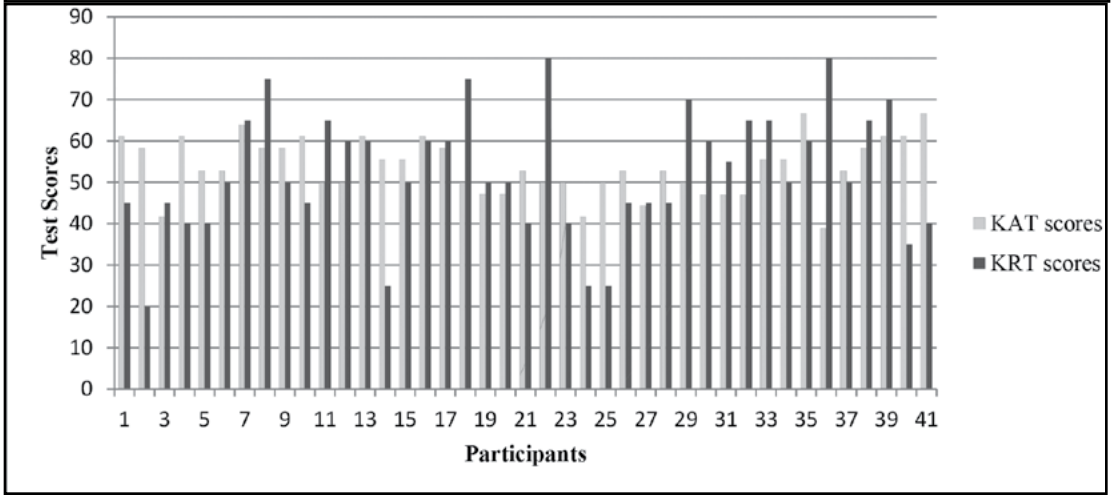
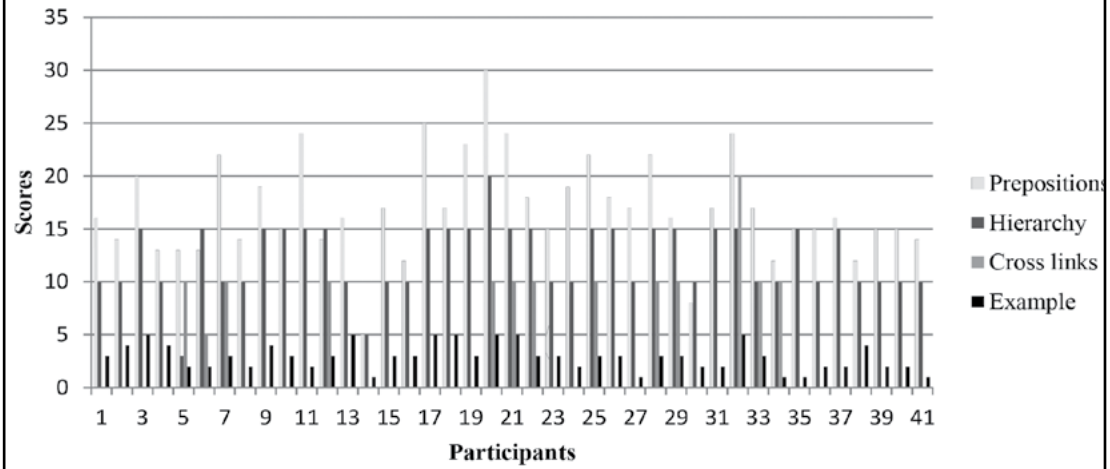


Figure 5
Distribution of the scores of prepositions, hierarchy, crosslink and example in the concept map



four stroke engine. 5Ø % students are able to give correct examples of various engines.

Our findings show that the students included sufficient number of the concepts, but they had difficulties in showing relationship between the concepts.

In order to evaluate the students' attitude towards concept mapping and the use of this tool in internal combustion engine classroom teaching, questionnaires were administered to the students. The students were questioned on several aspects of the concept mapping tool and its use in the classroom, the concept mapping tool itself and finally the impact it had on their learning. The reliability estimate based on the Cronbach Alpha method is Ø.87, which is consistent with reliability estimates of perceptions questionnaires from other such studies which obtained reliability estimates from Ø.5 to Ø.9 [Glenn, et. al. 2ØØ4]. The qualitative data below is representative of the students' responses to these questions (see Table 2). Most of the students were in favour for the use of the concept maps in the classroom.

CONCLUSIONS

In the present study, we found that there is a moderate correlation (r=Ø.531) between the students' performance in the conventional achievement test which measures application of knowledge (KAT) and their concept map scores (CMS). Also, there is week correlation (r=Ø.166) between the students' performance in the conventional achievement test which measures recalling of knowledge (KRT) and their CMS. Literature shows that there is either moderate or high correlation between KAT and CMS (Stroddart, et. al. 1999, pg.1Ø). Literature also shows that there is weak correlation between KRT and CMS. Our results are consistent with most of the literature results. It was also found that the students seem to enjoy the creation of the concept maps. The students feel that the tool of concept map has several benefits to their learning of the internal combustion engine.

Our findings indicate that even though the students performed better in achievement test than in the creation of concept maps; they had difficulties in establishing the relationship between the concepts of two stroke engine and four stroke engines, and between S.I and C.I. engine.

The present study suggests that concept mapping can be used to identify the major gaps in students' knowledge, to help a teacher to identify central key concepts to target in their teaching. CMS can also be used as an assessment tool to determine the extent and quality of new connections that the students are

Table 2
Student's feedback on different aspects of concept mapping (using the Likert scale)

Sr. no	Item	% Agree or Strongly Agree
1	Concept maps helped me to learn and identify key concepts of the topic	75.6
2	Concept mapping helped me to connect the various concepts with each other	80.48
3	This activity of concept mapping helped me in problem solving capacity	68.29
4	Concept maps helped me to rectify the misconceptions about the topic	58.53
5	Concept mapping activity is useful in understanding in memorizing/ recalling/visualizing the various key concepts	65.85
6	Concept mapping is useful activity for study and revision	87.8
7	Concept maps help in arranging more logical flow of concepts	78.04
8	Concept mapping helped me to see 'Big picture' of the topic	73.17
9	Concept mapping activity is useful to me and to apply to other subjects in near future	63.41
10	I have enjoyed concept mapping activity	82.92

able to make after the instructions. Concept maps measure aspects of learning which conventional tests do not measure.

The findings of this study have several implications for mechanical engineering curriculum. There are several other subjects in mechanical engineering curriculum which stress the importance of concepts, connections between concepts and hierarchy of concepts. Concept mapping as a teaching learning strategy in these subjects can help to assist in meaningful learning.

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Appendix 1
Sample questions of KRT and KAT.

Knowledge Recall Test (KRT)	Knowledge Application Test (KAT)
1) Which of the following engines has maximum thermal efficiency? a) Two stroke C.I. engine b) Four stroke C.I. engine c) Two stroke S.I. engine d) Four stroke S.I. engine	1) An Engine with 60% mechanical efficiency develops a brake power of 20 kW. Its frictional power in kW is a) 14 b) 20 c) 13.33 d) 25
2) What is the range of compression ratio for S.I. engine? a) 8-12 b) 12-14 c) 14-18 d) 18-22	2) A 4-stroke, 4 cylinder S.I. engine has a bore of 60 mm and stroke of 80 mm. The compression ratio is 6. Its clearance volume in cc is a) 55.24 b) 45.24 c) 65.24 d) 21
3) Which of the following can be used as an alternative fuel in S.I. engine? a) H_2 b) O_2 c) N_2 d) CH_4	3) A diesel engine has a brake thermal efficiency of 28%. If C.V. is 42,000 kJ/kg, its brake specific consumption in kg/kWh is a) 0.306 b) 0.506 c) 0.206 d) 0.606
4) Thermal efficiency is the ratio of a) B.P. /I.P. b) I.P/B.P c) F.P/B.P d) F.P. /I.P.	4) S.I. engines are a) Quantity governed b) Quality governed c) Both Quantity and quality governed d) None of the other three
5) Which of the following engine requires spark plug? a) S.I. b) C.I. c) both d) none	5) In diesel engine, the compression ratio in comparison to expansion ratio is a) One b) Less than one c) More than one d) Variable
6) Working of a four stroke engine requires a) Three strokes b) Six strokes c) Four strokes d) Two strokes	6) If the temperature of air supplied to I.C. engine increases, its efficiency a) Increases b) Decreases c) Does not change d) May increase or decrease depending on other factors
7) Ignition system is required in following engine a) S.I. b) C.I. c) both d) none	7) The air-standard Diesel cycle is less efficient than the Otto cycle for the a) Same compression ratio and heat addition b) Same pressure and heat addition c) Same rpm and cylinder dimensions d) Same pressure and compression ratio