A REPORT ON

PROJECT BASED LEARNING (PBL)

for

Second Year and **Third** Year **Undergraduate Students** of **Mechanical and Automobile Engineering** Departments of **MES's Pillai College of Engineering, New Panvel** for the **Academic Year 2017-2018 (Odd Semesters)**

Semesters – III(CBCGS) & V(CBSGS)

Objective—To enable the students to apply concepts of the present semester subjects (including those of previous semesters) in the form of a design project based on certain application. It is hoped that it shall eventually lead to a better learning experience as opposed to text-book learning.

A common topic is assigned to all students of the same year, to provide a common yardstick for comparison and enable healthy competition among the different teams. The students work in groups (maximum 5-6 students per group) and assign and distribute various aspects of work so as to realize the project based on a timeline of about 2 months. Queries and doubts are clarified by interactions with the PBL coordinators and subject experts. Student groups submit the PBL report during their demonstrations on a specified date in front of the faculty members.

PBL Coordinators—M.Durga Rao and Shaligram Avinash

Judges for the PBL Demonstrations—All Mechanical and Automobile Engineering Faculty Members, including Teaching Assistants.

PBL Topic for Second Year Mechanical/Automobile Engineering: MOUNT-BOARD STOOL

Develop a Mount-board Stool with the idea of creating structural module, which can hold a person's weight for seating usage, with only mount-board material. With fine-tuned detail and precisely manufactured pieces, the stool should be assembled without any glue or fasteners.

The Challenge— Design a Stool! This activity asks student to design and build a full-sized stool from **mount-board** (a type of paper board which is ideal for presenting artwork, picture framing and model making). The stool must support a pre-determined weight that is selected by the team for at least a few minutes. Students will get an opportunity to learn about paper and mount-board as a building material and the statics and dynamics of structures. This design challenge is designed to encourage and reward excellence in design that integrates **function** (does the stool work); **aesthetics** (is it pleasing to the eye); **ergonomics** (is it comfortable for the average person); **details** (are my drawings and actual construction accurate); and **fun**.

Objective— Create a fully functional mount-board stool that holds the weight of an adult **without** the use of adhesives of any kind (glue/tape/hot-gun etc.) or mechanical fasteners.

Rules for Construction—

1. The stool must have a seat, without any arm-rests and back (as in a chair).
2. No mechanical fasteners will be permitted.
3. Glue of any type is not accepted.
4. The maximum weight of a person for the stool to support is limited to 80 kg.
5. The seat of the stool must be at least 16" from the floor.
6. The stool should be aesthetically pleasing to the eye, and comfortable to sit on.
7. The stool is not expected to swing.
8. Student may find stool designs in some sources, but advised to build a stool based on student's unique ideas.

Procedure/Steps—

1. **Study the properties of papers of varying thickness:** Perform simple tests on paper, journal-file card paper, and mount-board materials to assess their properties viz., tensile strength, tearing strength, and critical-load estimation for buckling of columns. Students may make use of the Strength of Materials laboratory equipments for the same, or build a basic kit themselves. Observe the location of failures, and the shape taken by the failed specimen. Discuss on the above. **Document the same in student reports.** Check out the paper tensile test in the Ed Goldman's "Design in the Classroom" Timeline Videos, at http://designintheclassroom.com/designTasks/cChair/index.html.
2. Watch the videos/links/documents, and look up examples of stools.
3. Start the brainstorming process of creating a unique stool with mount-board. **Have various possible ideas drawn in pencil (freehand) in the form of orthographic projections (minimum two views)**. Each member of a group is expected to come out with some unique idea.
4. Understand the proper use of the materials.
5. Study various methods for joining mount-board pieces without glue or fastener.
6. Create small models of the stool— **¼ scale** using **A4 sized card paper**, and **½ scale** using **journal-file card paper**. **Each student in a group shall prepare a model stool** of his/her idea**,** to both the scales mentioned.
7. **Select the best possible idea** in the group based on various considerations. Students may make certain modifications in the final design. Sign-off is required prior to initiating the CAD model or the build phase of final design.
8. Prepare a **Computer Aided Design (CAD) model** of the selected design, using SolidWorks or similar CAD software.
9. Create the **full size stool** that supports the weight of a person, based on the final design idea.
10. **Document** the process of creating the stool in a video or slideshow, and also as a detailed report.

NOTE: The structural strength of the stool is created by the material property and surface friction. Due to its structural system and using neither fasteners nor glue, the most challenging aspect of designing mount-board stool is the precise dimensioning and accurate manufacturing. A few prototypes or models may need to be created to test the joint/s and the tolerance of mount-board material. The structure may become weak when the joint gap exceeds even a fraction of a millimeter. The changes in dimensions and design may happen a few times to achieve perfect fitting. Student may also opt to use **Laser Cutting Machine (in the Research Lab./Components Library)** to cut development profiles on the mount-board for precise assembly of the mount-board joints. Student may need to perform scoring/creasing to bend the mount-board properly. Students are also advised to consider a combination of 3-D solid primitives (basic 3-D shapes viz. cone, cylinder, cube, pyramid, prism etc.) along with planar elements, for attaining a variety of stool design ideas.

Materials Required—

1. A4 Paper and Journal-File Card Paper (for scaled models)
2. Mount-board (Any number of sheets and thickness)
3. Ruler
4. Thermacol or Cardboard Cutter, or a Utility Knife
5. A pair of Scissors

Expected Questions asked by faculty/jury members while project is in progress (student-groups are required to answer these questions in their document reports, briefly):

a. What makes some mount-board structures stronger than others?
b. Why do other designs support more weight?
c. What's the best way to orient, combine, and join the mount-board for maximum strength?
d. What's the best way to hold the different parts of the stool together?
e. How do student keep the stool from wobbling and twisting when student sit on it (stability issues)?
f. How do student keep the seat from tearing and breaking, or bending/deforming?

g. How the five forces that affect engineered structures were considered when designing and building their stools. The five forces are: compression, tension, bending, shear, and torsion. What location/part in the stool caused each of the forces mentioned?
h. Is there any chance of buckling in the original design? If yes, indicate the possible failure location of buckling in the stool. What preventive action has been taken to avoid buckling?
i. What factors seem to affect strength, stiffness, and stability? What would student change about student's original design?
(**Note**—During the design and prototype phase, consider stiffness, strength, and stability. Try building small-scale prototypes before building full-scale stools. If student's design is not stiff, there will be too much deflection when student sit in it and the stool might collapse. The strength of any material can be increased or decreased by changing its form. Weak materials can be strengthened through folding, creasing or other modifications. Load distribution is key in identifying areas of potential weakness. Stability will also be an issue. Make sure the stool won't be too easy to tip over, even when student lean slightly on the back side.)

<u>**Rubrics**</u> **for assessing the overall PBL work include** (but not limited to)—

1. **Form & Function** of the stool (comfort & aesthetics).
2. **Presentation of the Solution** (academic display / presentation / report)
3. **Structural Integrity** of the Stool (stability, rigidity, strength*)

(***Actual weight supported divided by the weight of stool model** equals a strength design factor. High numbers are best.)

Additional References (referred to Chair as a structural module):

1. https://www.questia.com/library/journal/1G1-162183845/designing-and-building-a-cardboard-chair-children-s
2. http://www.mschangart.com/architecture/card-board-chair-design-challenge
3. http://blog.nomadpress.net/blog/maker-space-project-design-a-chair

NOTE—In order to avoid last minute hassles and for ensuring effective learning, the project work was evaluated and monitored continuously, in <u>two stages</u> as follows:

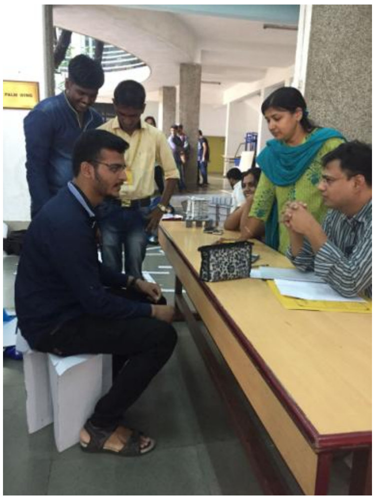
<u>Stage I</u>: Steps 1-8 of the Procedure/Steps section (till preparation of CAD model of the final selected design idea)—scheduled on the re-opening day/week after Ganesh Chaturthi holidays.
<u>Stage II</u>: Steps 9-10—scheduled at the end of the theory course.

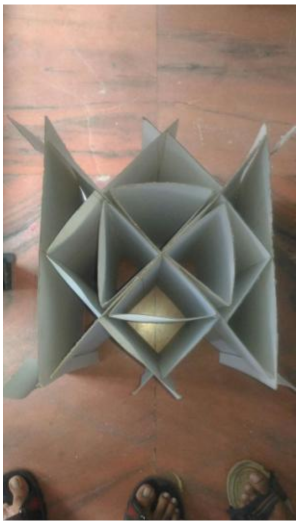
Related Subjects: Strength of Materials, Materials Technology, Production Processes, Engineering Drawing, Computer Aided Machine Drawing.

Term-Work Marks Allocation for PBL:
CAMD: 10 marks (out of 50)
MSP-I: 10 marks (out of 50)
SOM: 05 marks (out of 25)
MT: 03 marks (out of 25)

In this academic session, we introduced and conducted <u>online feedback</u> of the Project Based Learning, as experienced by the SE and TE students, and the results were very satisfying. A majority of the students enjoyed this way of learning and found to be better as compared to conventional class-room learning. Students strongly felt that this method of learning should be continued in future academic sessions too.

Some photos taken during the Mount-Board Stool Project Demonstration (on 09 October 2017):










Before the actual demonstration of the student projects, a short faculty-training session was conducted to make them aware of all the do's and don'ts and update on the technical aspects. The following document was shared with the faculty summarizing the same before the faculty training session began.

GENERAL INFORMATION TO FACULTY (JUDGES) FOR ASSESSING PBL PERFORMANCE OF SE STUDENTS

REQUIREMENTS: Develop a STOOL to hold a person's weight (capable of lifting a maximum load of 80 kg.), using only mountboard (type of cardboard) material. Pieces of the mountboard need to be assembled without any glue or fasteners. The seat of the stool must be at least 16" from the floor.

The Plan of Action (from students' perspective):

Students plan for the configuration of the stool—no. of columns to be used, their cross-sectional shapes etc. and put their ideas on paper in the form of rough sketches. They come together and discuss the relative merits and demerits of each, and including modifications, come out with the best configuration from various aspects viz., function, stability, manufacturing considerations, cost, aesthetics etc.

A ¼ or ½ scale model of the stool is first studied to develop confidence in the design process and identifying shortcomings if any. The calculations for critical load are made for the same, assuming the dimensions of the column cross-section, including the thickness. Rankine's (Rankine-Gordon) formula is used for the calculations. This is the theoretical estimate of the failure load of the stool. The failure may be either due to buckling (transverse deformation – or deflection of the column due to an applied axial load), or by crushing (max. stress in some location of the stool exceeds the yield or ultimate stress depending on the material). In crushing, we may expect localized deformation (compressive type) of a small area of one of the columns. The reduced model is then tested experimentally for supporting maximum load till it fails—either by buckling or by crushing. This load is validated with the theoretical result as discussed earlier. We expect that both the theoretical estimate of the failure load and the experimental value, agree within close limits. Also, we may expect that the experimental value can exceed safely the theoretical value in some cases. This completes the Stage-I of the PBL work.

In the concluding stage (Stage-II), the validated theoretical formula (Rankine's formula) is used to design the full-sized stool (i.e. the thickness of mountboard pieces is estimated). The critical load here is a known parameter in this stage. The steps of the calculations are summarized as follows:

Max. Load to be supported by the stool = 80 kg. i.e. 800 N (approx.)
Take a factor of safety (to account for overloading) i.e. N = 1.5 or 2. If N = 2 is selected, then design load to be supported = 1600 N.
No. of columns = n (as decided by students).
Total load to be supported per column = 1600/n. Let us assume, n = 4. Hence, Load per column = 400 N. This is the critical load to be supported by each column.

Rankine's expression for critical load is given by: Pcr = $\frac{\sigma.A}{1+\alpha.\left(\frac{l_e}{k}\right)^2}$ where $\alpha = \frac{\sigma}{\pi^2 E}$ is a constant for a material. From internet sources, σ = crushing stress = 0.2 MPa, and E = 4 MPa, are the average values of various types of cardboards available. l_e *is the equivalent length = l/2. Here, l* = actual length of columns (min. 16 inches). The (l_e/k) is called as slenderness ratio. This slenderness ratio has a critical value corresponding to the yield or ultimate stress of the material. When the actual slenderness ratio is more or less than the critical value of slenderness ratio, we call it a long or short column respectively which decides whether the column fails by buckling or by crushing respectively. *k* is called as the radius of gyration, calculated from $I = Ak^2$. Here, I is the minimum area-moment of inertia of the column cross-section. We consider 'minimum', since the bending (buckling) if happens, should be about the axis which is weaker in resisting bending. Minimum I relates to minimum resistance against bending. Hence, in the formula, the only unknown will be in terms of the thickness of the column *t* (here, A and *k* are expressed as functions of t). After calculating t, we get to know how many multiples (stacks) of single mountboard piece need to be assembled to form the column cross-section.

Hence, students prepare the full-scale model of the mountboard stool based on the above calculations. Note that, no calculations are expected for the seat (supposed to be lying on top of the columns) since its theory (as a plate) is beyond the scope of the SOM syllabus.

Rubrics & Assessment Sheet for the topic MOUNT-BOARD STOOL (Second Year):

If among TOP-3 projects of the class, indicate the RANK (1-3):

Mahatma Education Society's
PILLAI COLLEGE OF ENGINEERING, New Panvel
Department of Mechanical & Automobile Engineering
PROJECT BASED LEARNING (PBL) DEMONSTRATION – RUBRICS & ASSESSMENT SHEET

Topic—MOUNT-BOARD STOOL **Year & Class—S.E.-MECH-B** **Date of Demonstration—09/10/2017**

JUDGES: 1. Prof.Meeta V 2. Prof.G N Thokal 3. Prof.Lalit M 4. Prof.Sanjay S
Signatures: ________________ ________________ ________________ ________________

STUDENT GROUP NO.— 1

NAME	PILLAI S	PISHARODY A	SINGH K	SHINU B	VISAL S
ROLL NO.	326	327	347	343	356
SIGNATURE					

TERM-WORK MARKS ALLOCATION:

SUBJECT	CAMD (/10)	MSP-I (/10)	SOM (/05)	MT (/03)
MARKS ATTAINED				

1. No. of configurations of the Concept Stool created (Check Rough Sketches included in Report): ______
2. Any comparative study reported (Relative merits and demerits) of different configurations (Y/N): ____
3. Whether CAD drawing images created, for the selected configuration? _______
4. Reduced Scale Size of the model (1/4 or ½): _______
5. Theoretical Critical Load (as per Rankine formula) of the reduced scale model: __________ N
6. Method used for measuring Actual Load Sustained by reduced scale model (Dead Weights / UTM): ____
7. Actual Load sustained by the reduced model prior to failure (either buckling or crushing): __________N

   (**Check**: Load in Sr.7 ≥ Load in Sr.5 above, nearly same values are expected)
8. Self Weight of the reduced scale model: ______ N as measured using load cell (approximately, kg x 10)
9. **<u>Strength Design Factor</u> for the reduced scale model (Values of Sr.7 ÷ Sr.8, high numbers are best, for comparison of various models):** ___________
10. No. of columns used: _________
11. Shape/s used for forming cross-section of columns: ____
12. Thickness of the mount-board used for constructing the stool: ________ mm.
13. Thickness of the column (as calculated from Rankine's formula) for the **full-scale stool model**: __________ mm.
14. Is the stool able to withstand a person's weight comfortably, without failure? __________
15. Is the stool RIGID enough? (min. Deformation expected): ________
16. Is the stool STABLE enough? (should not topple or sway while a person is sitting on top of it):________
17. Has the report been properly documented? _______
18. Approx. Cost of the Project: Rs. _________
19. **Overall Build Quality** (Rate from 1-5, 5 being the best): ___________
20. **Overall Remarks of PBL Work** (Rate from 1-5): ________

1 Problem Description

A hero engine or the Aeolipile is an ancient device that uses steam to produce rotational motion. Water is heated inside a chamber and the steam produced is released from a pair of nozzles. This produces a torque causing the device to rotate.

In the 1st century AD, Heron of Alexandria described the device, and many sources give him the credit for its invention. The aeolipile Heron described is considered to be the first recorded steam engine or reaction steam turbine. The name – derived from the Greek word Aeolic and Latin word pila – translates to "the ball of Aeolus", Aeolus being the Greek god of the air and wind.
Students will be asked to design in solidworks, generate a mathematical model and finally build and test the device. The device should be able to rotate at a certain peak RPM, for a fixed amount of time and it needs to be attached to a generator to generate a voltage of atleast 1V. The device will be developed in multiple stages. Students will be tasked to do the following

Figure 1: Illustration of an Aeolipile .

1. **Model the device** and derive equations for the following (20 marks)
   - (a) Time required for the device to start spinning
   - (b) Time required for the device to stop spinning
   - (c) The angular velocity for the device assuming no friction and and that the fluid is incompressible
   - (d) The pressure that is developed inside the boiling chamber
   - (e) The torque generated when the chamber is prevented from rotating
   - (f) The relationship between the angular velocity and the voltage generated
2. **Detailed assembly drawing of the device** that includes the boiling chamber along with the nozzles, the attachment of the chamber to a generator or a motor with leads that can be used to measure the voltage. The device should be fixtured correctly such that chamber does not wobble. Students are encouraged to watch videos online (on youtube) of the different types of designs other people have developed. They should analyze pros and cons of the different orientations (horizontal and vertical) before picking their own design. Also note that the leads should not be rotating. (25 Marks)
3. **Fabrication of the device**. The chamber must be made using materials that have a melting temperature of atleast 200 °C or above. Students should also try and use low friction bearings for the attachment of the chamber to the fixtures. There should also be a way to refill the device with water when needed and the reseal for further testing. (25 Marks)
4. **Testing of the device** to measure the time to start and finish, the final angular velocity and the voltage generated. The device should be supplied with no more than 100 ml of water. It should start spinning within 1min of supplying heat and stop within 10 mins. Students should assume that we will be supplying heat with a candle or a burner that can generate heat of around 50 watts. Students should also ensure that the device is safe to operate (30 Marks)

Some photos taken during the Aeolipile Project Demonstration (on 09 October 2017):

There were two student group evaluations—Stage I and Stage 2. Students were asked to form groups consisting of minimum 2 and maximum 5 numbers. In all, approximately 45 groups of students participated. The students were quite excited to work on this topic as it was both interesting and challenging. The following sheets give the rubrics formats for State I (Design) and final demonstration stage (Stage2).

TE PBL Progress (Stage 1) Review on 7/9/2017

Branch: **Div:** **Group No (if any):**

Name(s) of Students:
1)
2)
3)
4)
5)

Sr No	Calculations/Design/Material Selection	Done Y/N	Remarks
1	Theoretical Equations/Calculations for i) Time required to start the spinning ii) Time for which the device will spin iii) Angular velocity/Max RPM of the device iv) Torque generated when the chamber is prevented from rotating		
2	Axis orientation of the spinning device : horizontal/vertical		
3	Whether the spinning device will be separate from the steam generating chamber		
4	Materials selected for components : Should withstand temp of 200 0C		
5	Nozzle design : Inside diameter/No of nozzles		
6	Safety of the device considered		
7	How the steam pipes will be connected to the spinning chamber?		
8	Generating voltage: what device will be connected?		
9	SolidWorks Assembly/Component drawings/BOM		
10	Whether bearings are included in the design? What type of bearings?		

Note: Finally students can be told to study/read about Reaction Turbines which will give them more insight.

Overall progress: Poor/Satisfactory/Good/Excellent

Remarks/Suggestions for further work:

Reviewed by:

Rubrics & Assessment Sheet for the topic AEOLIPILE (Third Year)—Final Demonstration (10 October 2017):

Mahatma Education Society's
PILLAI COLLEGE OF ENGINEERING, New Panvel
Department of Mechanical & Automobile Engineering
PROJECT BASED LEARNING (PBL) DEMONSTRATION – RUBRICS & ASSESSMENT SHEET

Topic—Aeolipile (Heron Engine) **Year & Class—T.E.-MECH/AUTO** **Date of Demonstration—10/10/2017**

JUDGES:
Signatures: ________________ ________________ ________________ ________________

STUDENT GROUP NO. —

NAME					
ROLL NO.					
SIGNATURE					

TERM-WORK MARKS ALLOCATION:

SUBJECT	**HT(/10)**	**MMC/MQE (/5)**	**PP (/05)**	**TOM-II (/05)**
MARKS ATTAINED				

1. Modelling of the device/calculations done : (Y/N)
   i) Time required for device to start spinning__________
   ii) Max RPM__________
   iii) Torque generated when the chamber is prevented from rotating_________
2. CAD Drawings prepared for components and assembly: ____
3. Axis orientation : Horizontal/Vertical
4. Is the steam generating chamber separate from the spinning device: _______
5. Material selection
   i) Steam generating chamber :________________
   ii) Spinning device: ______________________
   iii) Steam pipes (if applicable):________________
   iv) Bearing (if used) :____________________
   v) DC Motor or Cycle Dynamo (if used):___________
   vi) Supporting frame: ______________________
6. Nozzle design/Inside Diameter/Material :
7. Testing of the Device :
   i) Time(s) observed: _________________ sec
   ii) RPM (Max) observed: _______________
   iii) Voltage generated? : (Y/N)________ V
8. Is any wobbling of the spinning device observed? ______________
9. Manufacturing/fabrication/joining processes used ______________________________________
10. Safety of the device: __________
11. Report prepared : (Y/N)
12. Approx. Cost of the Project: Rs. __________
    i) Material cost
    ii) Assembly/Fabrication time
13. **Overall Device Quality** (Rate from 1-5, 5 being the best): ____________
14. **Overall Remarks of PBL Work** (Rate from 1-5): _________
15. What improvement can be done in the device?

____