

# Puzzle Cube Design Project

Based on a project assigned by: Duncan McGehee, PhD, *Cuyamaca College, El Cajon, CA*  
Adapted by: Dom Dal Bello, *Allan Hancock College, Santa Maria, CA*

## Materials Provided:

27 0.75" wooden blocks; 1 bottle of glue; 1 sheet isometric paper; 5 sheets of quad-grid paper;  
1 plastic bag (to hold blocks and glue); 1 manila folder (for paper). Extra sheets of paper  
are available, if necessary (just ask).

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**Situation:** Your design firm has been approached by a toy manufacturer with the request to design a  
3-dimensional puzzle cube for children from 8 through 10 years old.

**Problem Statement:** Design a 3-dimensional puzzle cube for children 8–10 years old.

## Design Constraints:

1. The assembled cube must be composed of  $3 \times 3 \times 3$  smaller cubic elements.
2. The assembled cube must have overall dimensions of  $2.25" \times 2.25" \times 2.25"$ .
3. The cube must be composed of 5 pieces, each a different color.
4. Each piece must incorporate between 3 and 6 smaller cubic elements.
5. Some of the pieces must interlock.
6. All parts are to be made of polyvinyl chloride (PVC).

**Deliverables** (provide to the “toy manufacturer”/instructor):

(1) **Design Report**, composed of eight (8) total pages, stapled, and in order:

- (a) a **cover sheet** (general description of project; 1 page of copy paper)
- (b) an **exploded assembly drawing** (isometric view of how system pieces fit together;  
1 page of isometric paper)
- (c) a **bill of materials** (table of parts; 1 page of copy paper)
- (d) a **detailed part drawing** for each of the 5 individual parts (3 orthogonal views and an  
 $2/3$ -scale oblique view of each part; 5 pages of quad graph paper).

The **bottom of each drawing** should be **placed at the right of each page** in the packet.

(2) **Prototype** of your puzzle, made of wood.

A **prototype** is a *mock-up* of the real (production-grade) object so that a 3D object can be  
handled and analyzed.

The prototype is not necessarily made of the same material as the real object. The materials  
used for prototypes are generally easy to work with and/or readily available so that the  
prototype (and revised prototypes) can be quickly and inexpensively made. The prototype for  
this project is made from  $3/4"$  wooden blocks. The parts that we “will manufacture for sale”  
will be PVC plastic (Item #6 of the Design Constraints). The notes on your drawings should  
indicate the material is PVC (not wood).

The following pages describe the **deliverables** in detail. **CREATE YOUR OWN PUZZLE CUBE DESIGN.**  
**Do not copy the design given in the following pages.**

**Figures 2, 4 and 5** show the exploded assembly and detailed part drawings with *instructional notes*.  
**Figures 10 and 11** show the drawings without instructional notes/markings. **Do not include the  
instructional notes in your drawings** (yours should look similar to **Figures 10 and 11**).

## 1. DESIGN REPORT

A *design report*, composed of, in order:

- (a) a *cover sheet*.
- (b) an *exploded assembly drawing*.
- (c) a *bill of materials*.
- (d) *detailed part drawings*, one for each of the 5 individual parts, in order.

The bottom of each drawing should be placed at the right-side of each page.

### a. COVER SHEET

The *cover sheet* must be typed and include the following information:

- your name.
- the words *ENGR 100*.
- the words *Puzzle Cube Design Project*.
- the due Date.
- the problem statement.
- the design constraints.

See *Figure 1* for what the *cover sheet* should look like. Use this format. Note that the material listed is for the production parts: PVC (not wood, which is the prototype's material).

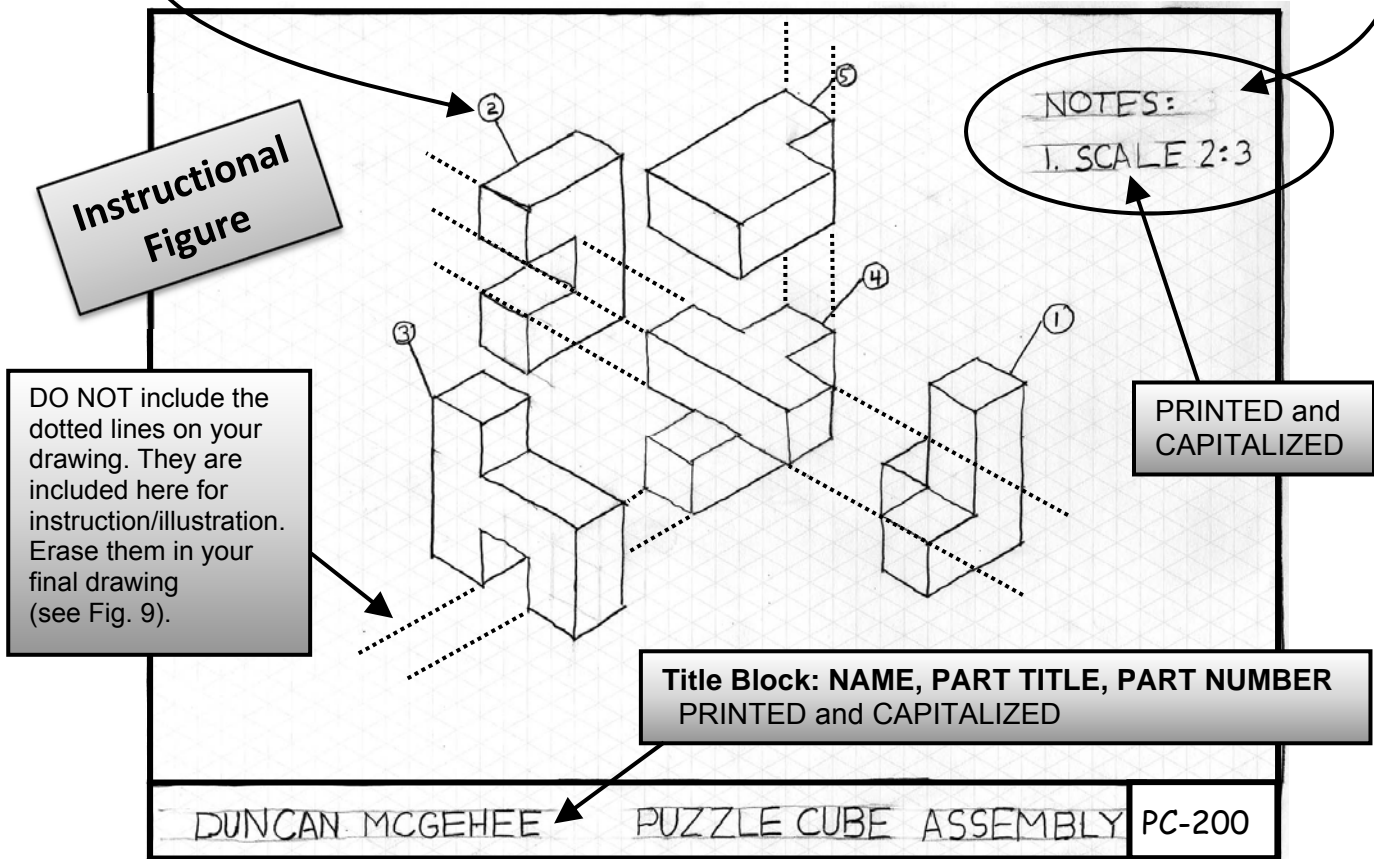
<p>Duncan McGehee</p> <p>ENGR 100</p> <p>Puzzle Cube Project</p> <p>Due May 5, 2015</p> <p><b>Problem Statement:</b> Design a 3-dimensional puzzle cube for children 8–10 years old.</p> <p><b>Design constraints:</b></p> <ol style="list-style-type: none"><li>1. The assembled cube must be composed of 3×3×3 smaller cubic elements.</li><li>2. The assembled cube must have overall dimensions of 2.25" × 2.25" × 2.25".</li><li>3. The cube must be composed of 5 pieces, each a different color.</li><li>4. Each piece must incorporate between 3 and 6 smaller cubic elements.</li><li>5. Some of the pieces must interlock.</li><li>6. All parts are to be made of polyvinyl chloride (PVC).</li></ol>
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**Figure 1** Cover sheet of design report.

**b. EXPLODED ASSEMBLY DRAWING**

The *exploded assembly drawing (Figure 2)* shows how the parts fit together by separating them along the three primary axes (directions) of the assembly. The *exploded assembly drawing* should:

- be drawn on isometric paper (provided) to represent the parts in 3D. **Hint: use a ruler.**
- be drawn at a scale of 2:3 (2/3 full size), with a note on the drawing indicating the scale. Each equilateral triangle on the paper has a side of 1/4" (0.25"). Two sides (1/2"=0.50") will represent the edge of one 3/4" (0.75") wooden cube (the ratio 0.50:0.75 is 2:3).
- **show one part in a fixed position, with all other parts shifted away from it to show how they fit together.** Each part should be shifted in **only one direction**, and the parts should not touch each other in the picture. It is recommended that you choose the "central" piece of the puzzle to be in a fixed position (draw that piece at the center of the isometric paper). In *Figure 2*, Item #4 is the central piece; all other pieces are slid away from it.
- **show the parts oriented as in the assembled puzzle.** Do not rotate them. The *assembly drawing* is the "solution" to the puzzle.
- not represent the individual 3/4-inch cubes. Draw each part as if it is one solid piece.
- **number the parts** (①, ②, ③, ④, ⑤) to agree with the *bill of materials*.
- not include any dimensions, and not include hidden lines.
- include the following information in the *title block (PRINTED, CAPITAL LETTERS)*:
  - your **NAME**.
  - the title **PUZZLE CUBE ASSEMBLY**.
  - The drawing number **PC-n00**, where *n* is a non-zero digit of your choice (here, PC-200).



**Figure 2** Exploded Assembly Drawing on isometric paper. Follow this format, but **do not copy this design**. Here, Part 4 is the central part, with each of the other parts moved away from it along one axis (direction) as illustrated by dotted lines (isometric paper makes representing one part in 3D relatively easy, but spatial relationships between parts can be difficult to see). **Do not include the dotted lines on your drawing (erase them); they are included here for instruction/illustration;** see *Figure 10* for the assembly drawing without instructional notes.

### c. BILL OF MATERIALS

The **Bill of Materials** (shown in **Figure 3**) lists the parts and quantity of each part needed (sometimes more than one copy of a particular part is needed). The Bill of Materials (BOM) ensures all parts are on-hand when assembling (or packing) the system.

The BOM should be typed, and be on a separate page after the exploded assembly drawing. The BOM should:

- list the individual parts with Item No. matched to the exploded assembly drawing.
- use the individual drawing number as the part number.
- indicate the quantity of each part required.
- include a brief description of the part (e.g., “Red part”). Parts are given numbers (for organizing), and names (e.g., an engineering part might be labelled “baseplate”, “gasket, 3.5-inch” or “Bolt, 3/8 in. diameter”)

Bill of Materials: Puzzle Cube

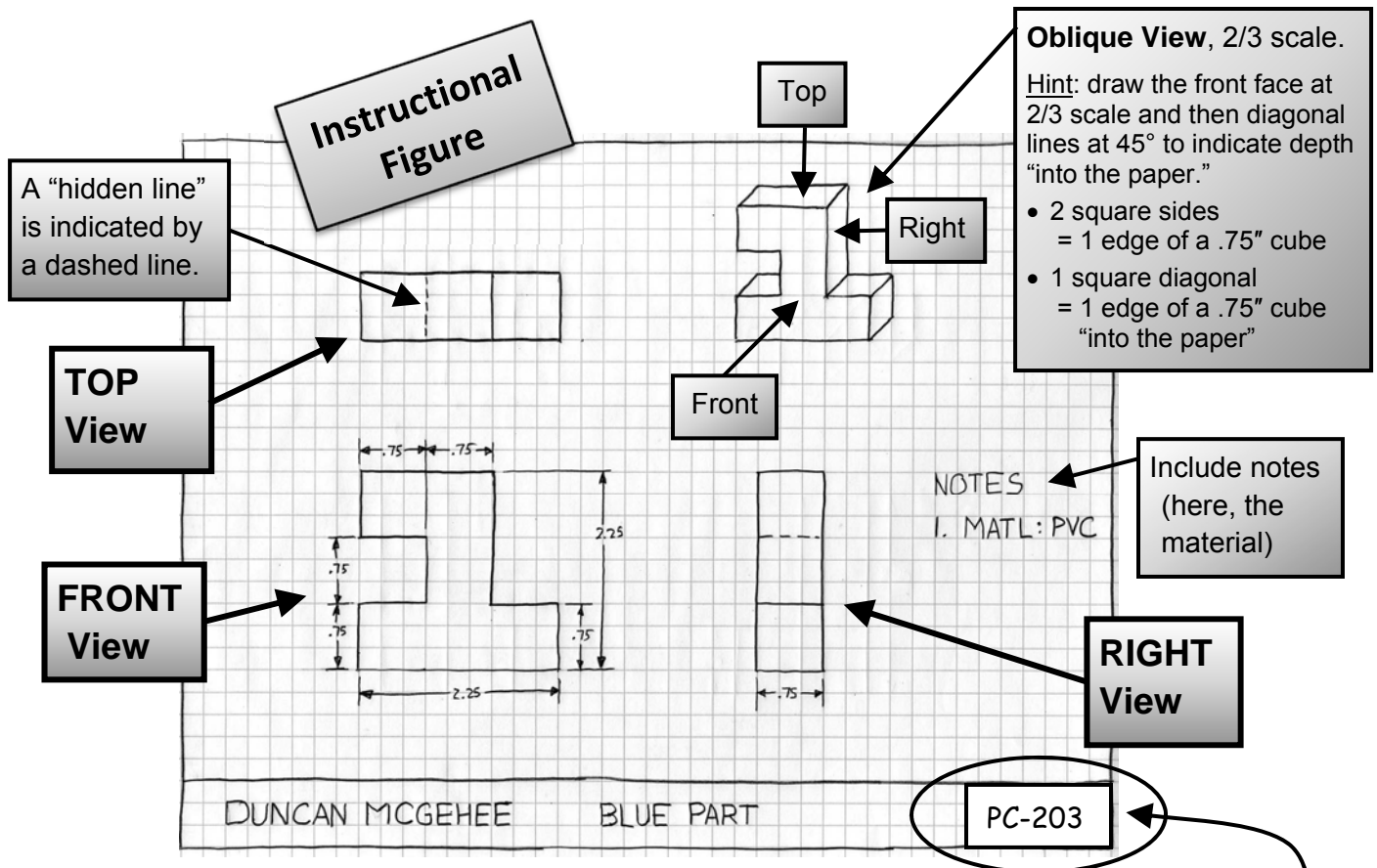
Item No. in Exploded View	Part Number	QTY	Description
1	PC-201	1	Red part
2	PC-202	1	Green part
3	PC-203	1	Blue part
4	PC-204	1	Yellow part
5	PC-205	1	White part

**Figure 3** *Bill of Materials*. Make the part-numbers correspond to the drawing numbers. Item 1 is Part Number PC-201, which is in drawing PC-201; Part 2 is Part No. PC-202, etc.

### d. FIVE (5) INDIVIDUAL DETAILED PART DRAWINGS

The **five (5) individual detailed part drawings** should each follow these general rules:

- Include the three **orthographic views: front, top, and right side** arranged as shown in **Figure 4**. Draw the views at 1:1 scale (full scale), and completely dimension them. Each square in the quad-grid paper is 1/4", so 3 squares is 3/4" (the edge of one wooden cube).
- Include a 2/3-scale **oblique drawing** in the upper right corner. This view should show the **front** orthographic view in its true form, with the **top** and **right** side views receding 45° “into the paper.” Do not include dimensions in the oblique view. Draw the oblique view at 2/3 scale, but do not include the scale information in the view.
- Do not label “Front”, “Top” “Right” “Oblique” for the views. This arrangement is standard for engineering drawings; the reader would know that the **front** is at the lower left of the page.
- Align the views as illustrated in **Figure 5**. The tops and bottoms of the **front** and **right views** should align, the lefts and rights of the **front** and **top views** should align.
- Do not draw the individual 3/4-inch cubes, only the overall shapes of the parts (remember the wooden cubes are being used only to make the prototype; the parts are one solid piece).
- The drawings should be completely dimensioned and not over-dimensioned.
- Dimensions are given in inches, and to 2 decimal places, e.g., .75, 1.50, 2.25 (not 1.5). In the United States, inches are the assumed dimension in engineering drawings, so no inch marks are typically not included, i.e.: 1.50 not 1.50". In engineering drawings, there is no zero in front of the decimal place.

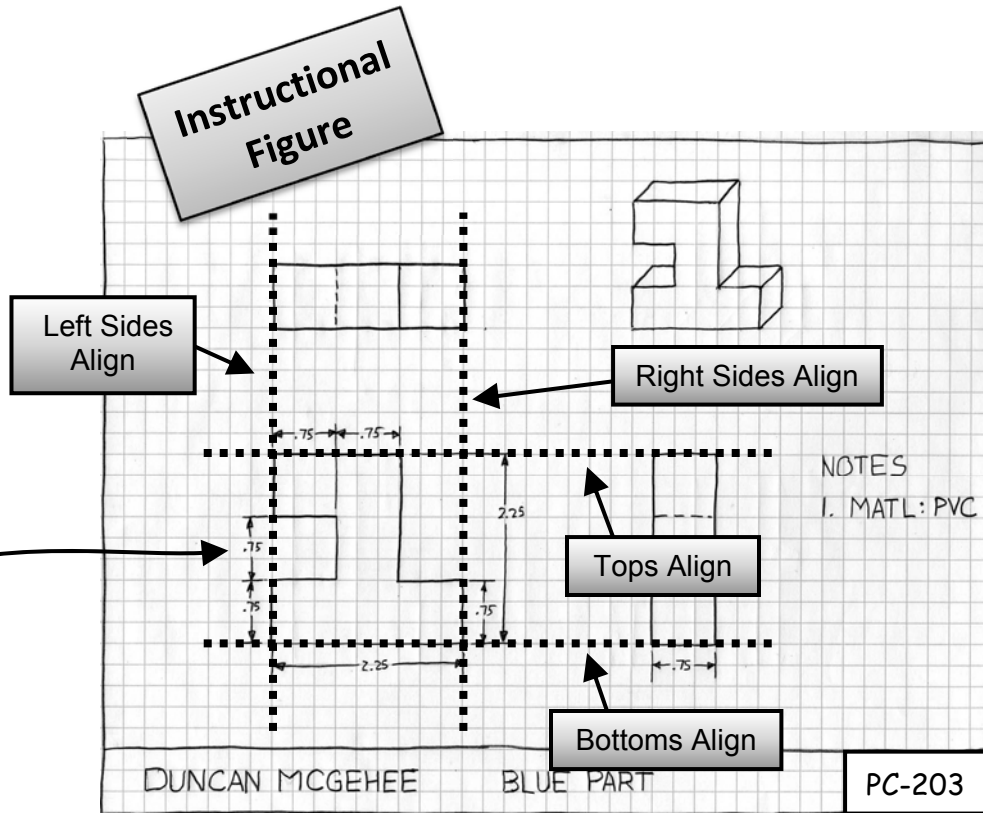


**Figure 4** Individual detailed part drawing for production. Follow this format, but do not copy this design. The positioning of the views, clockwise from lower right, is: **right view, front, top, oblique**. **Do not label “right”, “front”, etc.**, in your drawing; this format is standard for engineering drawings.

Note 1: Hidden lines are indicated with dashed lines.

Note 2: PC-203 represents is “Puzzle Cube Part 203.” Consider this the “200-series” of the Puzzle Cube line; Drawing “200” is the assembly drawing; “201” is part #1, “202 is part #2, etc. See **Figure 11** for the detailed part drawing without instructional notes.

- **Dimension lines have arrowheads at both ends.**
- **Do not over-dimension.** *Over-dimensioning* means the same feature is located more than once on the drawing, which causes confusion since there are different origins from which to measure. The location of each feature should only be indicated once in the three orthogonal views (avoiding ambiguity).
  - Example 1: in **Figure 4**, in the **front view**, notice that the dimensions on the left side are .75" and .75", but there is no third .75" dimension to reach the top of the part. The overall height of 2.25" is already indicated on the right side of the front view.
  - Example 2: in **Figure 4**, only the thickness of the part is indicated on the **right view**... the vertical distances of the step and notch above the bottom (indicated by solid and dashed lines) are not dimensioned because they are already located in the **front view**.
  - Example 3: in **Figure 4**, the **top view** has no dimensions since all necessary dimensions have already been given in the **front** and **right views** (this may not always be the case).



**Figure 5** Alignment of the three orthogonal views and dimensioning hints.

**Hint 1:** Plan out where the views will be located so as a group they are approximately centered on the page. The first view you will draw is the **front view**, as it is related to each of the other views by a simple 90°-turn of the part. The front is typically the widest and tallest view.

**Hint 2:** The **top and bottom sides** of the **front view** and **right view** are aligned, as illustrated by the heavy dotted lines. The **left and right sides** of the **front** and **top views** are aligned. Aligning the views makes interpreting the drawing easy. Do not include the heavy dotted lines on your final drawings; they are included here for illustration purposes. Your final drawing should look like the drawing in **Figure 11**.

**Hint 3:** Here, the dimensions in each view are consistently drawn from the same origin or baseline(s), so that measurements are made in the same directions. In the **front view**, the origin is at the bottom-left. Horizontal dimensions always build (add) from the left side (towards the right); vertical dimensions build from the bottom (upward). In the **front view**, the top of the notch is dimensioned upward .75" from the bottom of the notch, not downward .75" from the top edge.

- Be careful not to assume dimensions.
  - Example: in **Figure 4**, in the **front view**, the dimension  $.75''$  is given at both the lower left and lower right sides since they locate two different features (the bottom of the notch and the top of the right step). While it looks like those two features are the same distance above the bottom, never assume someone else can read your mind. Make the dimension of each feature clear so that the feature is made where you want it. If the  $.75''$  at the lower right of the front view is not indicated, the right step might end up  $.75''$  from the bottom, or it might not. When dimensioning drawings, it is important to be clear, complete and unambiguous.
- Draw dimensions from a single origin and set of baselines, as discussed in **Figure 5** (i.e., on the Front, dimension horizontal lengths from the left, vertical lengths from the bottom).
- **Dimension lines** have arrowheads at both ends to indicate the dimension is “from here to here”. Include arrowheads.
- Don't forget to include a single-view general **oblique** drawing in the upper right corner. This view should show the Front orthographic view in its true form (at  $2/3$  scale), with the Top and Right side views receding  $45^\circ$  “into the paper.” Do not include dimensions in this view. Draw this view at  $2/3$  scale, but do not include the scale information in the view.
- Include the material information in the drawing **NOTES** as follows: **1. MATL: PVC.**
- Include the following information (**PRINTED, CAPITAL LETTERS**) in the title block:
  - Your **NAME**
  - The part name (e.g., **RED PART, BLUE PART**)
  - The drawing number, e.g., **PC-201** through **PC-205** (or replace “2” with any non-zero digit of your choice).

### Quick Hints on Drawing Orthogonal Views, Visible Lines and Hidden Lines

An **orthogonal view** of a 3D object (part) is a view along one of the three main axes of the object. Think of putting the object in an invisible cube and looking perpendicularly (orthogonally) through the front of the cube, then through the right side, and finally through the top. This gives you the **front view**, **right view** and **top view** of the object. Two-dimensional (2D) drawings are made of each view; the three orthogonal views as a group illustrate the 3D object. For a simple cube, you would draw a square for each of the three views. For a cylinder standing on its end, the **front** and **right views** would be drawn as rectangles (the sides of the cylinder have no sudden changes in geometry), and the **top view** would be drawn as a circle.

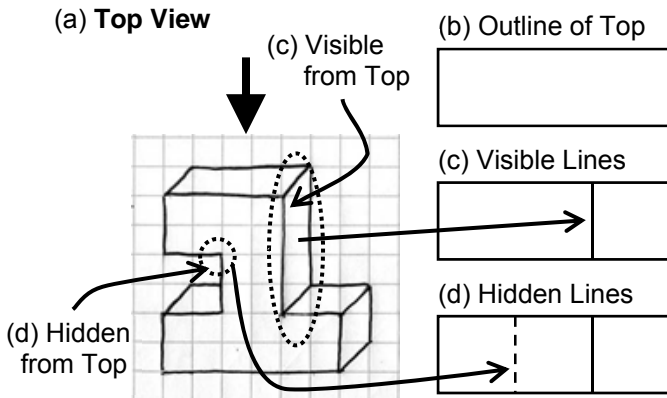
The first step in drawing an orthogonal view is to draw the outline of the part in the view you are considering, and then draw any **visible** and **hidden** features. These features are sudden changes in geometry that you would encounter as you move into or out-of the paper.

A sudden change in the geometry that you can see in the view is indicated by drawing a **solid line**, called a **visible line**. Examples include steps along the direction of the viewing axis (i.e., perpendicular to the paper).

A sudden change in the geometry that you cannot see in the view is indicated by drawing a **dashed line**, called a **hidden line**. A feature is **hidden** from view when it is behind physical material. However, it is still drawn (as a dashed line) to help visualize what is going on in 3D.

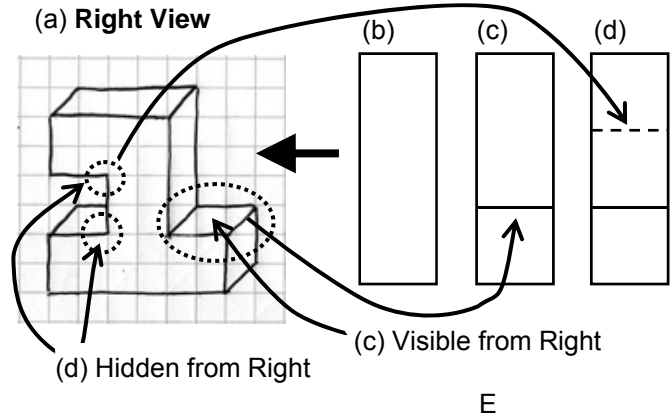
Figures 6 and 7 show how the **top** and **right views** are created for the Blue Part (Figure 4). Note that there are no solid or dashed lines within the outline of the **front view** of Figure 4 because there are no changes in depth of the part as viewed from the front – it is uniformly one-block thick.

Figure 8 shows how a 3-dimensional object is viewed from the **top**, **front**, **right**, and the three 2-dimensional drawings that result.



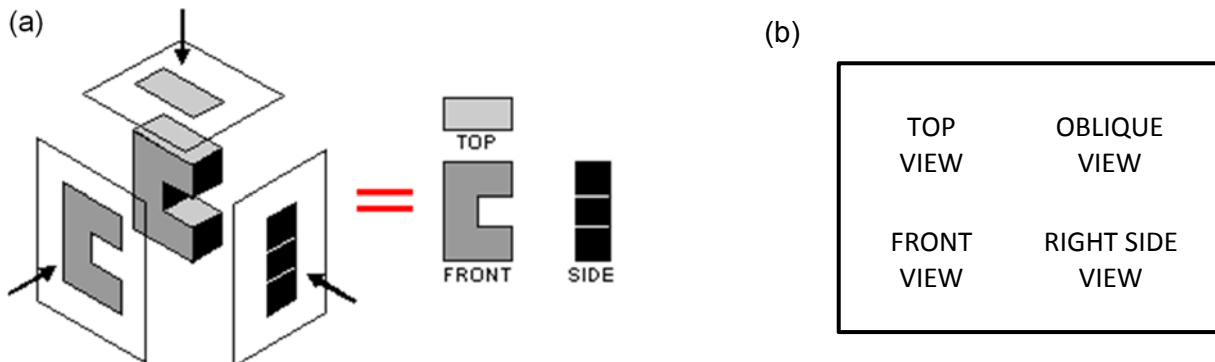
**Figure 6** Drawing the **Top View**.

- View the Top of the Blue Part (see Figure 4).
- Draw the outline of the **top view**.
- Draw sudden changes in geometry that are visible with solid lines (visible lines).** Here the depth of the part changes due to the step/edge at the right. The solid line locates the step/edge.
- Draw sudden changes that are hidden with dashed lines (hidden lines).** The notch at the left of the part cannot be physically seen from the top. The top right of the notch is located by the dashed line. The bottom right of the notch is a hidden line behind a hidden line, so the bottom of the notch is not drawn.



**Figure 7** Drawing the **Right View**.

- View the Right Side of the Blue Part.
- Draw the outline of the **right view**.
- Draw visible lines with solid lines;** Here the top of the step, 1/3 of the way up.
- Draw hidden lines with dashed lines.** The notch on the left cannot be seen from the right. The top of the notch is located by the dashed line. The bottom of the notch is behind the top of the right step – a hidden line behind another (visible) line; thus, the bottom of the notch is not represented.



**Figure 8** (a) Three-dimensional object viewed from the **top**, **front**, **right side**, and the three 2-dimensional drawings that result. <http://www.foothillsgraphics.com/images/ortho1.gif> Accessed October 4, 2017. (b) Location of views on detailed part drawings.



## 2. WOODEN PROTOTYPE

A *full-scale hardwood prototype (Figure 9)* must be included with the report.

To build the prototype, glue several 0.75" wooden cubes together to make each of the 5 individual parts. The 5 parts should fit together to form the larger puzzle cube.

**CAUTION:** align the individual cubes carefully or you will have difficulty putting the individual parts together.

Each part may be painted the appropriate color, OR labeled with its name (e.g., BLUE).

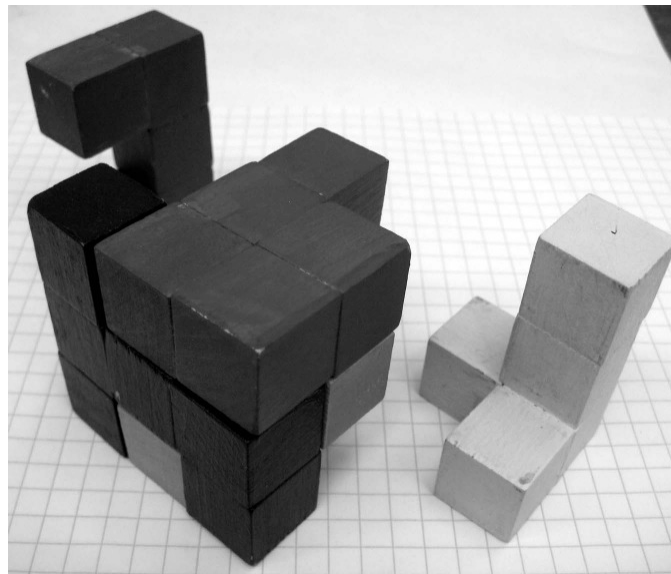
Paints are available in M-212. Please arrange with the instructor if you wish to use them.

**CAUTION:** If you choose to paint, let the parts dry before assembling the puzzle.

**CAUTION:** Thick coats of paint will make it difficult to fit the puzzle together. The paints in M-212 should provide a coat that is thin enough.

The prototype that is submitted must:

- a. be submitted fully assembled (the cube must be "solved").
- b. be able to be disassembled into the 5 individual parts.
- c. have individual parts that are:
  - colored the appropriate color, or
  - labeled with its appropriate color (e.g., BLUE).



**Figure 9** *Wooden prototype.*

Appendix A: Format for drawings without instructional notes on them.

Your final drawings should look like these examples.

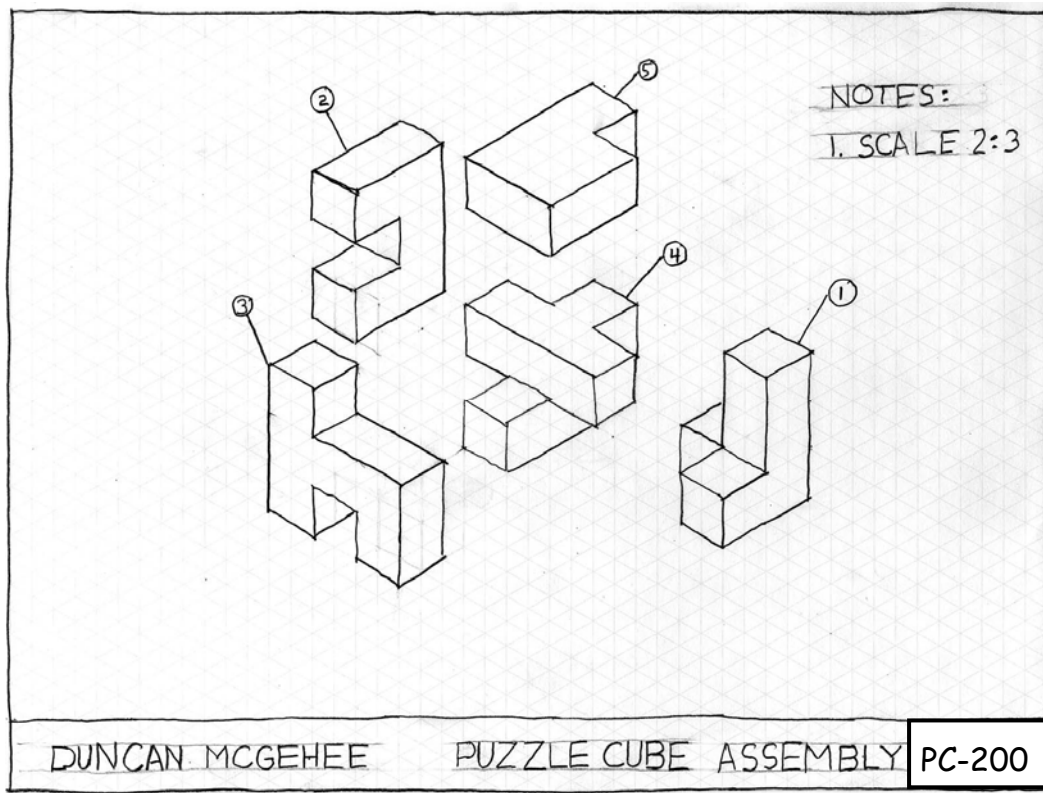


Figure 10 Exploded Assembly Drawing on isometric paper (guide lines erased).

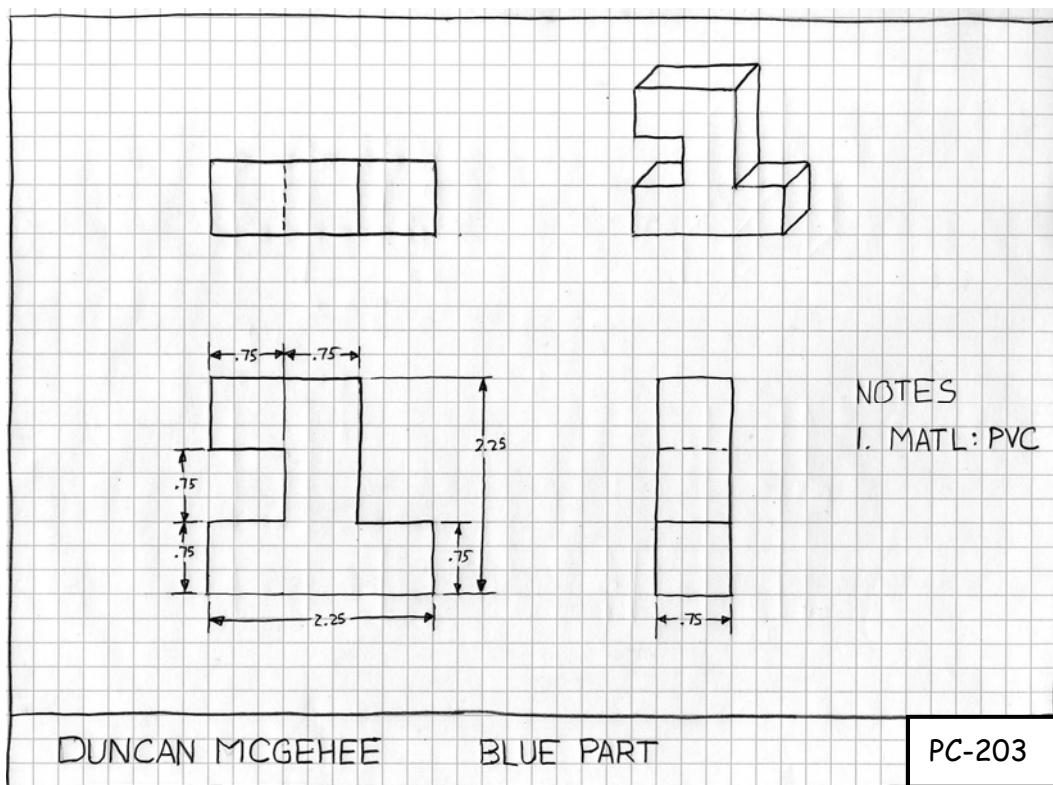


Figure 11 Detailed part drawing on quad-paper.