Question 1:
A Swiss Army knife can be thought of as consisting of numerous independent physical elements, or chunks, capable of performing a myriad of independent functional elements that include slicing, screwing, sawing, poking, and picking, just to name a few. These chunks include blades, screwdrivers, scissors, awls, toothpicks, and, depending on the model and price, as many as forty other handy instruments, each with its own specific purpose.

Each of its chunks implements one functional element, and the functional interactions between these chunks are minimized. However, two important interactions remain between chunks: 1) the blades must each interface to the knife body chunk, and 2) each blade requires clearance from the side to access the fingernail dents. In spite of these interactions which require some detail design attention, the Swiss Army knife provides a nearly perfect example of a modular architecture.

Modular product architecture has the following advantages:

- 1. Product Change—Modularity allows product changes to be made to a few isolated functional elements without affecting the design of other chunks. This enables the firm to minimize the physical changes required to achieve a functional product change.

- 2. Product Variety—Products built around modular product architectures can be easily varied.

- 3. Component Standardization—The manufacturing firm can decrease unit manufacturing costs by using the same component or chunk in multiple products.

- 4. Product Development Management—Modularity minimizes the coordination efforts between teams tasked with designing independent chunks.

Modular product architecture has the following disadvantage:

Product Performance—Modularity inhibits the performance gains possible through the practice of function sharing between physical elements.

It is interesting to consider what the more integral architecture alternative might be like. Perhaps a single-bladed tool that can do everything?
Question 3:

Advantages:

- • The relatively integral architecture might enable greater acceleration due to the lighter weight.

- • The relatively integral architecture might create an aesthetic quality to distinguish it versus other motorcycles.

- • The relatively integral architecture allows for function sharing and nesting that minimizes material use, reducing one aspect of the manufacturing cost.

Disadvantages:

- • The relatively integral architecture would require a greater number of physical changes in order to achieve functional changes for upgrades, add-ons, adaptation, wear, consumption, flexibility in use, or re-use.

- • The relatively integral architecture would increase the effort and cost required to provide product variety in response to customer orders.

- • The relatively integral architecture is probably non-standard compared to BMW's other motorcycles. Therefore, the chunk must be produced in relatively small volumes and cost/quality might be adversely affected.

- • The relatively integral architecture will require greater integration, conflict resolution, and coordination during the detail design phase of the development.

- • The relatively integral architecture would make it difficult to allocate the detailed design of the structural support function and the power conversion function to different teams or suppliers.

- • The relatively integral architecture would make it difficult to implement a design change in one functional element without also making a change in the other functional element.

Manufacturing:

The more modular approach would most likely cost less to manufacture because it uses standardized components which can be manufactured in volume. In addition, the performance requirements for the relatively integral transmission might demand more expensive materials or manufacturing processes that would offset any savings due to reduced material usage.
Question 4:

For this exercise, a General Electric model 2-9167A telephone base was disassembled. A schematic of the physical elements is shown below.

There are a number of important notes to make about the architecture of this telephone. First, we can describe its modularity; it has a relatively integral architecture. We notice that there are many functions which all interrelate in the telephone. For instance, the buttons, while integrated with the plastic housing, are also intimately connected to the circuitry which itself is all very interconnected. Most likely, the development team was attempting to better the performance of the telephone by integrating many parts together. However, we do notice some modularity. Modularity is evident in components such as the memory buttons, the receiver switch, and the slide switches, all of which can be found on other GE phones. By standardizing these parts, GE can make other products with these parts and achieve economies of scale. It would seem that the development team was less interested with issues such as upgrades, add-ons, and wear, since when a phone becomes worn or obsolete the entire unit is generally replaced rather than a portion. Thus, modularity is less important for the exterior.

Although the phone is rather integrated, several chunks can be identified. Keypad circuitry is contained on a single board separate from the main circuitry on the back of the phone, thus identifying two possible chunks. However, since the circuit elements are probably arranged somewhat differently from phone to phone, they can be considered a chunk because their basic composition most likely remains essentially the same throughout GE's low-end telephone products and therefore GE engineers probably designed these circuits as a standard chunk or module. The exterior can be considered a chunk because there are several components which must blend and fit together to achieve the desired styling and ergonomics. The jack interfaces are also a chunk because they are standardized to fit existing phone cables. Finally, the ringer is isolated as its own chunk, perhaps to reduce the likelihood of incidental interactions such as vibration with other chunks.

An alternative architecture might arrange the keypad circuitry and the buttons into a single chunk. Possibly all of the switches, jacks, and buttons could be considered as a single chunk. My guess is that the GE team wished to design a product that appeared integral from the outside but used modularity inside.
Question 5:

Product variety can certainly be achieved in a number of ways. On the one hand, it is possible to create a large variety of products using no modularity at all—but this is difficult and does not work in many cases. For example, most injection molding shops generally do not exploit the concept of modularity at all, yet they produce a high variety line of one-piece moldings. They use unique tooling for each product and the results are highly integrated. Another way to achieve product variety is through flexible manufacturing systems, where the variety is accomplished by programming the machines to create different products. While these strategies are successful, they are less appropriate for a complex line of electromechanical assembled products.

Modularity allows a manufacturer to obtain high product variety using relatively few standard modules. For example, Sony produces a small number of different tape transport mechanisms for their Walkman line. They add variety to the line by using different casings, electronics, and feature options along with one of the standard tape transports. This modular strategy allows Sony to produce the most complex component (the tape mechanism) in high volumes. Another example is provided by the Swatch example described in the chapter.

For the molding shop described above to utilize the principle of modularity, they might design mold tooling for a line of products such that they can interchange components of the mold to create slightly different moldings, comprising the product line.
Question 6:

Analysis of two corkscrew designs: a traditional corkscrew and a "big wings" corkscrew.

"TRADITIONAL" CORKSCREW

<table>
<thead>
<tr>
<th>Category</th>
<th>Level of Importance</th>
<th>Explanation of Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Quality of the User Interfaces</td>
<td>Low</td>
<td>The user can guess how to use this corkscrew by looking at it, but there is no guidance as to where to place the sharp tip to best remove the cork.</td>
</tr>
<tr>
<td>2. Emotional Appeal</td>
<td>Medium</td>
<td>This corkscrew has no excitement; it’s just a bit and a handle.</td>
</tr>
<tr>
<td>3. Ability to Maintain and Repair the Product</td>
<td>High</td>
<td>This criterion does not apply because no corkscrew should require repair or maintenance. This corkscrew is easy to clean, however.</td>
</tr>
<tr>
<td>4. Appropriate Use of Resources</td>
<td>Low</td>
<td>This corkscrew obviously has no frivolous features. It does, however, under-utilize resources: there could be a placement guide.</td>
</tr>
<tr>
<td>5. Product Differentiation</td>
<td>Medium</td>
<td>This product is so simple and common as to almost be a commodity.</td>
</tr>
</tbody>
</table>
"BIG WINGS" CORKSCREW

<table>
<thead>
<tr>
<th>Category</th>
<th>Level of Importance</th>
<th>Explanation of Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Quality of the User Interfaces</td>
<td>Low - Medium - High</td>
<td>As with all corkscrews, use is easily communicated. Here the extra large handles make it clear where to grip.</td>
</tr>
<tr>
<td>2. Emotional Appeal</td>
<td></td>
<td>Corkscrews don’t have high status appeal, but this design creates pleasure. The large handles look inviting and the sheer black construction has a &quot;high tech&quot; appeal. It’s a conversation piece.</td>
</tr>
<tr>
<td>3. Ability to Maintain and Repair the Product</td>
<td></td>
<td>If you have to clean it, this corkscrew is well designed. Repair does not apply.</td>
</tr>
<tr>
<td>4. Appropriate Use of Resources</td>
<td></td>
<td>Expending more plastic to make large and grippable handles and turn-piece is well conceived, especially for arthritis sufferers and the rest of us who have trouble opening bottles.</td>
</tr>
<tr>
<td>5. Product Differentiation</td>
<td></td>
<td>No other corkscrew looks this inviting. It’s even differentiated by color.</td>
</tr>
</tbody>
</table>
A travel mug is very simple and is obviously a product for which industrial design has a huge importance. Its "technology" is very basic and the design aspects that relate to the user interface are the key to the product success. Ergonomics are central because you want the product to be as unobtrusive, easy to handle, and safe to use as possible. Aesthetics also play a major role in differentiating the product. When I started drawing the sketches I could hardly think of an "inside-out" approach. I was basically paying attention to the shape of the product, to its look and feel, and to the ease of using and carrying it. The "outside-in, function-follows-form" seemed to be the appropriate one. However, when I came to nailing down the design I realized that I had to be sure that these "forms" fulfilled several functions. These functions are basically:

1. Mug holds liquid
2. Mug allows drinking
3. Mug is portable
4. Mug prevents liquid from spilling
This list of functions could be translated into a series of physical elements that formed the mug

1. Hole to pour the liquid and container

2. Hole, straw, air vent...to allow drinking

3. Handle or carrying device

4. Cover

I checked the designs using this "inside-out/form-follows function" approach to be sure all the functional requirements were covered. In fact, the different designs in the market could be graded according to how many and how well these requirements were met, independently of their user-interface. So, both approaches were complementary and played a role in helping me to understand the product requirements and come up with concept sketches.
Question 8:

The following table lists some firms with strong corporate identities along with some of the mechanisms these firms have used to achieve this identity.

<table>
<thead>
<tr>
<th>Firm</th>
<th>Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercedes-Benz</td>
<td>The grill on a Mercedes automobile has retained some of the same characteristics for decades. The &quot;star&quot; logo is also a strong point of consistency. Such design elements are one way of establishing and maintaining a corporate identity.</td>
</tr>
<tr>
<td>Hewlett-Packard</td>
<td>Although Hewlett-Packard (HP) does not have a strongly recognizable &quot;design language&quot; like Mercedes, its products create a consistent impression of being highly engineered, rugged, and powerful.</td>
</tr>
<tr>
<td>Apple Computer</td>
<td>Apple creates its corporate identity in part by using industrial design that is fun, different, and even whimsical at times. Apple also employs a consistent design language that includes &quot;surface interest&quot; (bulges, tears, dimples, patterns); consistent semantics for controls and displays; and sculpted forms.</td>
</tr>
<tr>
<td>The Stanley Works</td>
<td>Stanley’s identity is mostly derived from the use of the color yellow on its tools and packaging.</td>
</tr>
</tbody>
</table>
Question 9:

The cause-and-effect relationship between manufacturing cost and ID can be illustrated with a few simple examples. If the product’s design requires a more expensive/exotic material, this will increase the cost. If the product requires a more complex geometry or a difficult finish or color this may drive up the tooling costs. If the involvement of ID can reduce part count or make the product easier to assemble, this would reduce the cost. The examples of this relationship are numerous and obvious.

A more intricate relationship intertwines the complete lifecycle costs of the product and ID. The pertinent cost would be the combination of manufacturing costs, direct cost for ID (salary, supplies, and overhead), and time cost (possible economic penalties for a longer lead time). An industrial designer could reduce this overall cost if he or she was able to make timely, sufficient reductions in manufacturing cost to balance out the cost required to actually perform the ID. These reductions could come in the way of reduced part count, simplified design, or a process change (e.g., using injection molding instead of casting a part). An industrial designer would add to the overall production cost if he or she was unable to reduce the manufacturing costs sufficiently.

It appears more important to expand the question and discuss the overall profitability of the product with relation to the ID. The ID expenditure could then be justified with "increased product appeal and greater customer satisfaction through additional or better features, strong brand identity, and product differentiation. These benefits would translate into price premium and/or increased market share".
Question 10:

Industrial designers focus their attention on the outward features of a product. They have expertise in the areas of ergonomic needs and aesthetic needs. The ergonomic needs address the ease of use, ease of maintenance, and safety issues. The aesthetic needs address the external appearance of the product. Therefore, products that would not benefit from ID involvement must not have these needs. These products would demonstrate the following attributes:

• no user interface
• very little maintenance required
• no safety concerns from a design standpoint
• not seen by the customer

One product group that meets these criteria are products that are internal components to a larger end user product, i.e., a hard disk drive for a computer or a drive shaft for an automobile. The end user of the computer or the automobile would not experience any benefits of ID. However, if the assembly worker is defined as the user, even these products would benefit from ID. One goal may be to make the component easier to assemble into the product by making the component features indicate the correct orientation. I conclude that any product group will benefit from ID involvement in the development process on some level if the group considers all the interactions the product will have over its lifetime.