Sample Problem 1

Boats are often tied to docks via mooring lines to keep them from drifting away. While a boat is moored, it is possible for water to collect in the hull through precipitation or from splashing of waves.

This water is often removed from the boat via a bilge pump. The inlet suction line is positioned in the lowest point of the hull and water is pumped out of the boat.

You work for a company that is developing innovative automatic bilge pumps for small vessels.

You should complete the following tasks. ***Please note there are approximate time after each task.***

a. Develop a list of requirements (constraints and criteria) for the bilge pump. Include units and targets for the requirements. *Hint: The requirements should be expressed as "shall statements".* (10 minutes)

b. You are given a populated morphological chart (see Figure 1), generate conceptual designs including sketches and descriptions as needed. Discuss the process of using the morphological chart (~30 minutes).

Function \ Solution	Mechanical	Fluid	Pneumatic	Electrical
Capture Energy	Linear Spring Torsional Spring Pendulum Elastic Band Spring-Mass-Damper	Hydraulic Head Turbine	Propellor Vanes Cup	Solar Panel
Transform Energy	Crank Shaft Gears Belt/Sprocket Four Bar Linkage Cam Rack and Pinon	Hydraulic Piston Hydraulic Impellor	Pneumatic Piston Pneumatic Impellor	Generator
Import Fluid	Lift Wheel (rotary) Archimedes Screw Carousel	Suction Siphon	Suction Siphon	
Channel Fluid	Conveyor Lift Archimedes Screw	Tube Funnel Open Channel V-notch	Jet	
Energize Fluid	Reciprocating Pump Screw Pump Rotary Pump Electric Motor	Water Column	Vaporize Jet Pump	Electric Pump
Eject Fluid	Lift	Pressure Jet	Pressure Jet	
Inhibit Back Flow	Flapper Valve Ball Valve Butterfly Valve			
Separate Debris	Screen Filter Permeable Membrane	Float Skim Vortex		

Figure 1. Populated morphological chart for bilge pumps.

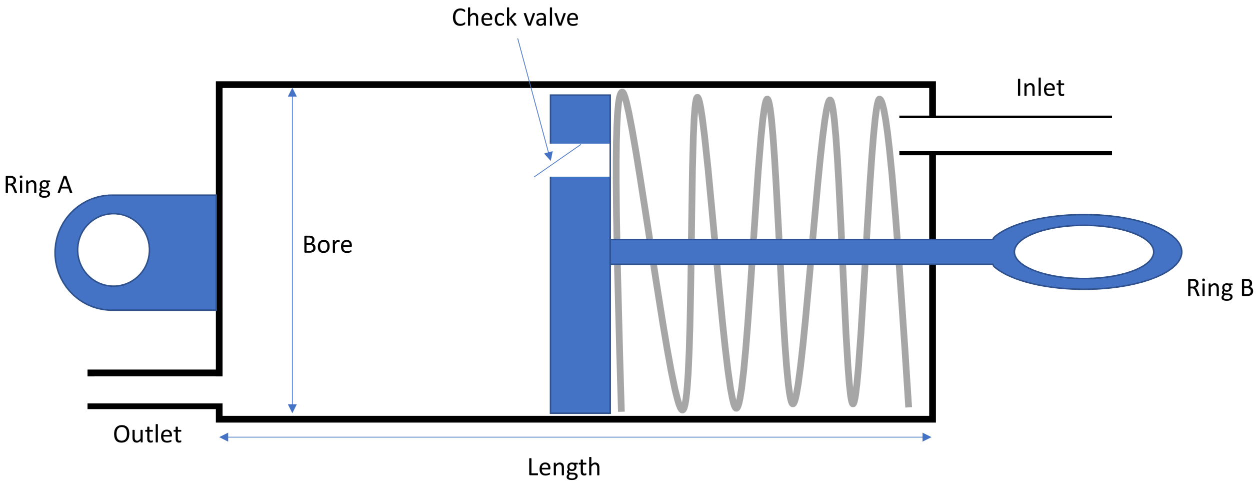
c. Perform a selection of your conceptual design, show your reasoning using appropriate analysis and any selection tools and methods. (~30 minutes).

d. For the kinematic bilge pump determine the size of the spring. (45 minutes).

The pump is powered through the kinematic energy and motion of the boat relative to the (see Figure 2).

Figure 2. Bilge pump in line with mooring lines connection boat to dock.

A diagram of the bilge pump is shown in Figure 3. The compression spring is determined to be a critical component in the design.



The specifications of this pump are:

- This pump is designed to last 10 years
- The maximum force on the pump is 5000 Newtons
- The pump is capable of pumping approximately 1400 liters per 24 hours.
- The Bore of the pump is 5 centimeters
- The Length of the pump body is 200 centimeters

Determine the following:

- Wire diameter, spring diameter, and number of coils. State your assumptions.
- Approximately how many strokes per hour does the pump need to achieve the flow rate.
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Use equations, tables, and diagrams are provided on the following pages.

Sample Problem 2

NASA would like to design a field deployable satellite antenna to send to the Moon or Mars. The satellite dish itself is readily available and is deployable, but the supporting structure needs to be designed. You are asked to design a structure for minimum mass and easy assembly capable of supporting a mass P of 5 Kg from a point 30meters above the ground level. Gravity on the moon is 1/6 the gravity on Earth (0.166g), and on Mars is 0.38g of the gravity on Earth. Since there is no wind on the moon and very low density air on Mars, the main issue is positioning the structure and elevating the mass. Furthermore, for ease of transportation, NASA decided that the system can be stored and transported in up to two (2) boxes each with a dimension of 20cm x 10cm x 10cm is the maximum size that the structure should fit in.

a. Fully define the problem as you understand it.
b. Come up with several conceptual designs
c. Select a design and show your reasoning for the selection.
d. Determine which is the critical component on your design, what failure may happen, and what should you do to design against the failure. Perform a detailed design/analysis of that component.

In general, if you use a tool, please write a short justification for the use of that particular tool.

Sample problem 3

Boats are often stored under boat houses and lifted out of the water via boat lifts. An image of the boat lift is included below for reference. A design package is included at the end of the test for reference.
The boat lift pictured below is affixed to the boar house beams and a cradle is raised and lowered via a cable and pulley system.
The boat is positioned over the cradle and a motor and gear combination rotates a drum to perform the lifting operation.

Task 1: You are given an initial list of requirements (see Table 1). Some of these requirements may be poorly written, incomplete, ambiguous, or expressed incorrectly. Please identify the requirement (using the ReqID), discuss the issue(s), and rewrite the requirement to address these issues. In addition, please add or delete requirements to specify the design more fully. Please include justification for the requirements.

ReqID	Requirement
1	The system must be capable of lifting Malibu Boat Model 25 LSV.
2	Must be made of aluminum.
3	The system must be safe.
4	Must integrate with existing boat houses.
5	The system must operate quickly.
6	Be easy to use.

Task 2: Given the current configuration of the lift on Page 15 of this exam. Identify components and sub-systems that may present a failure in the system.

You are expected to identify at least 3 potential failures within the system for each failure present the following:

- Please identify the component(s) or system: Please identify the component No. and Item Description (page from the Bill of Materials on Page 13)
- The failure that may occur
- Engineering decisions and analysis/testing would be completed to address this concern.

Note: you are not expected to address the failures, but rather communicate the potential concerns.

Task 3: For the Snatch Blocks (Item 13 on Page 13) and Dead Head Brackets (Items 14 on Page 13) complete the following. A diagram is included on Page 19.

- Draw a free body diagram of the components.
- Discuss the loads and boundary conditions during lifting
- Identify the assumptions
- Discuss in detail the analysis and the key components that must be considered to ensure a successful design solution.

Task 4. Complete an analysis to size the motor required to lift a boat.
Assume the consumer desires to lift a Malibu Boat Model 25 LSV (specifications on page 26).

The typical lifting process includes the following:

- The driver of the boat remains in the boat
- The lifting operation should be completed in 2 minutes
- The boat is desired to be lifted a total of 1 meter to ensure it is out of the water.

Assume the motor is a NEMA 56 type. Using the catalog page provided on page 27, select the motor for the design. Please state any assumptions that you have made. Include any diagrams and equations used to size the motor.

Please show all your work. A diagram of the motor assembly and winch mechanism are included on pages 21 and 22. There are other diagrams that may be useful as well.

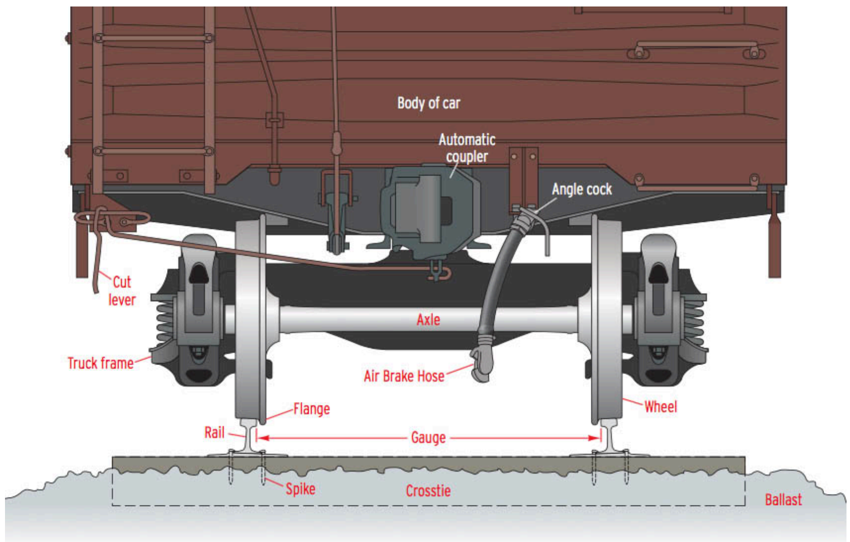
Note: Do not consider electric circuit and control.

Sample Problem 4

Problem Statement

Design and develop a system for measuring the rolling resistance of model train freight cars on straight and curved track.

Examples of both the cars and the track are provided below.



Stage 1: Problem Formulation

Part 1.1: Formulate the problem and identify requirements for the testing system.

Part 1.2: Explore the solution space and identify conceptual alternatives to accomplish the design task.

Part 1.3: Identify technical risks associated with the alternatives and down select to a single solution. Show the logics and justify the selection.

Stage 2: Analysis, Evaluation

Part 2.1: Perform back of the envelope calculations and supporting analysis. Please be sure to provide equations.

Part 2.2: Based on the back of the envelop calculations specify details associated with the systems. Discuss details associated with your chosen design solution.

Stage 3: Use of the system

Part 3.1: Define the procedure for usage of the systems and associated experiment .

Part 3.2: Identify areas of error and variation on the experiment.