TESTS OF ENGINEERING APTITUDE, MATHEMATICS AND SCIENCE

Problem Statements & Background Information

TITLE: IRRIGATION WATER-LIFTING SYSTEMS

PROBLEM STATEMENT:
Your team has been hired to perform an analysis of irrigation water-lifting systems for use in developing countries.

BACKGROUND:
Irrigational water is considered a precious commodity throughout the world. Agriculture often places the heaviest demand on the world's water basins. Learning ways to conserve or transmit water efficiently can prove an important key element in utilizing these resources wisely.

In many communities throughout the world farmers are dependent on well water to irrigate their crops. The success or failure of their efforts can be as important as life or death to their families. In this problem, technologies for lifting irrigation water from wells will be analyzed. For that purpose, a range of traditional, modern, and intermediate technologies will be considered.

A chadouf is a traditional machine used to draw water from wells. It consists of a lever with a counter weight on one end and a container used to draw water connected to a rope on the other end. Below is a schematic diagram of a chadouf showing the dimensions of the device.

TEA-M+S TESTS OF ENGINEERING APTITUDE, MATHEMATICS AND SCIENCE

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According to the Columbia Electronic Encyclopedia, shaduf or shadoof in English or chadouf in French, is a primitive device used to lift water from a well or stream for irrigation purposes. Essentially the device consists of a long boom balanced across a horizontal support from 8 to 10 ft (2.4–3 m) above the ground. The beam has a long, thin end and a short, stubby end. From the long end a bucket or similar container is suspended, and on the shorter end there is a counterweight. The operator pulls on a rope that lowers the long end of the boom so that the bucket submerges and is filled with water. He then releases the rope, allowing the counterweight to raise the bucket to the desired level, and then empties the bucket and repeats the process. Shadufs can be used in a series where it is desired to raise water to a height exceeding the range of a single one. It has been suggested that the massive stones used in building the pyramids of Egypt were raised by an ancient variant of this device.

TITLE: FRICTION FORCE MEASUREMENTS WITH STRAIN GAGES

PROBLEM STATEMENT:
As a research team who studies friction and wear you have the task of designing a device to measure the friction force between a "pin" and a rotating disk. One common technique for such a measurement involves the use of strain gages attached to a cantilever beam. Your objective is to select the dimensions of the beam to achieve a suitable force measurement sensitivity as well as a suitable force measurement range.

BACKGROUND:
In many engineering applications, it is of interest to measure the forces that are exerted on bodies. Because all solid materials experience some degree of elastic deformation when subjected to a force or "load," the force can be detected by measuring the amount of deformation. Consider what happens to a flexible ruler when you bend it:

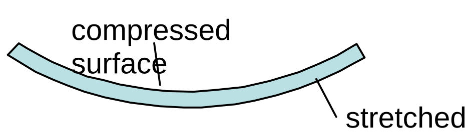

Figure 2-1: Bending of a plástic ruler.

In the case depicted above, the bottom surface of the ruler would be slightly stretched, while the top surface would be slightly compressed or shortened. Strain is defined to be the change in length divided by the original length. You can think of strain as the fractional change in length. Typically, strain values remain below of a few parts per thousand and are often in the range of a

JETS Your Pathway to Careers in Engineering few tens or hundreds of parts per million. A strain of 1 part per million is called one "micro strain." A positive strain amount of 1 micro strain means that the length of the object is 1.000001 times as long as its original length. That's not much of a change, but it is measurable with sensors called strain gages. Strain gages are small plastic patches that are adhesively mounted to the surface of an object. Inside the strain gage is a thin wire whose electrical resistance changes as its length changes. These changes in electrical resistance can be detected by connecting the strain gage within an appropriate electrical circuit. Usually a voltage output that is proportional to the strain is monitored.

TITLE: SOLAR MEASUREMENTS FROM EARTHLY LOCATIONS

PROBLEM STATEMENT:

Your engineering team has been assigned to make various types of calculations related to planets and the Sun.

BACKGROUND:

Several great astronomers of antiquity attempted to solve the problem of determining the dimensions of the earth, and other heavenly objects using earth-based observations. Most of the methods used by these astronomers were genuine, but not accurate enough. One of these methods employed a simpler mathematical technique, which led to a relatively more accurate calculation for the radius of the Earth. When traveling in Northern India, the Persian Scientist Biruni invoked a new way to measure the circumference of the earth. 'It does not require walking in deserts' he said, in recommending it. Instead you must climb a high mountain. Biruni measured[1] the height of his mountain to be approximately 300 meters [2], and the angle between the vertical and the farthest point to the horizon to be about 89.43°. He then calculated the radius and the circumference of the earth using this data and the simple principles of trigonometry. (See Figure 4.1)

Figure 4.1
1. He measured his mountain to be 625.5 cubits.
2. The cubit is the earliest unit of length, used in Egypt in the 3rd Dynasty (2800-2300 BC). It is the length of the arm from the elbow to the tip of the middle finger. The English cubit is 18 inches long (46 cm), but the Romans, Egyptians and Hebrews all had different lengths. Cubits are used in the Bible. The ark was 300 cubits long.

Let us do this for ourselves using the Biruni's method. We select a point on the top of a mountain, and then we measure the angle of depression. Once we measure the necessary distances and angles, we will calculate the length of the radius of the earth at the point of observation. A simplified model of this method is shown in Figure _ -1, where vertex A is the top of the mountain, C is at the base of the mountain, B is the projection of A at the base, and D is the horizon (the furthest point at the horizon that can be seen by an observer at A). (Hint: The line from the tip of the mountain to the farthest point on the horizon is tangential to the earth's surface.

TITLE: ORBITAL MECHANICS

PROBLEM STATEMENT:
Your engineering team has been asked to assist NASA in placing a new earth observation satellite into geo-synchronous orbit. You will launch the satellite into a 200-mile parking orbit, check out all the systems, and then boost the satellite into its final orbit using on-board thrusters.

BACKGROUND:
As you research the problem, you learn that the physical principles and mathematical equations that describe satellite motion had been developed by Johannes Kepler in the early 1600's. Kepler had been studying the motion of the planets around the sun, but the same equations apply to the motion of a satellite around the earth.

The first of Kepler's three laws of motion states that all planets move in elliptical orbits around the sun with the sun as one focus of the ellipse. A circle is a special case of an ellipse, with both axes equal in length, and the focus at the center of the circle. For our preliminary studies, we assume that the earth is a perfect circle with radius (Re) equal to 4,000 miles. The parking orbit is at an additional 200 miles above the surface of the earth. The distance from the center of the earth to the circular orbit of the satellite is designated (Rc). The velocity of a satellite in a circular orbit is designated (Vc).

TITLE: NANOTECHNOLOGY PROCESSES

PROBLEM STATEMENT:

Your engineering team has been given the task of analyzing a nanotechnology process for producing wafers.

A single crystal of pure silicon is slowly pulled from a vat of molten silicon. Thin wafers are then cut from the "boule" and a reference flat edge is ground off to identify the orientation of the crystal structure. Next, an insulating layer of silicon dioxide is created on the surface and polished. The thickness of the oxide surface is measured using an optical technique based on the index of refraction. A photoresist material is spun onto the surface before being exposed to UV light through a mask of the desired pattern. The surface is then etched through the oxide and a metal conductor surface is deposited by sputtering. This whole process must be temperature controlled occurs under a vacuum in a clean room.

DEFINITIONS:

Vat	A large container for holding liquids.
Boule	A rod/pear shaped synthetically formed mass (as sapphire or silicon) with the atomic structure of a seamless crystal. Boule often refers to a large single crystal Si rod immediately after the growth by pulling it slowly from a vat.
Ingot	Refers to large single-crystal Si rod after it has been taken off of the growth chamber and shaved on one side to mark the crystal orientation.
Slurry	A watery mixture of insoluble matter often used in chemical-mechanical polishing technique to create extremely flat surfaces.
Monomer	The molecular unit that joins with similar units to form a polymer, or the subunit of a protein composed of several such units loosely associated with one another.
I-line	Spectral line at 365 nanometers used in lithography printing method, or a high-intensity line at 365 nm in the spectrum of UV (ultraviolet).

TITLE: ROADWAY DESIGN

PROBLEM STATEMENT:
Roadways are a combination of horizontal and vertical planes that consist o straight sections, called tangents, connected together with curves of varying length. Horizontal curves go left or right and are designed for sight distance, super elevation and driver comfort at the posted speed. Vertical curves can be a sag or crest are designed for sight distance. Parameters for the elements of horizontal curves and vertical curves are primarily based upon speed.

Each roadway also has what is know as a normal pavement cross slope, which is needed to facilitate drainage of water off the pavement. A normal cross slope is usually sloped at 0.016 away from the crown at the centerline of the roadway. For horizontal curves, the normal pavement cross slope of the outside lane will transition upward to create a banked or super elevated section to a maximum cross slope of 0.083. The super elevated section is designed for driver comfort and to keep the vehicle from skidding outward and possibly crashing.

TITLE: NUCLEAR ENGINEERING

PROBLEM STATEMENT:
Your engineering group has been asked to investigate radiation properties of Radon. Also, you have been asked to investigate some design parameters of power generation using nuclear reactors.

BACKGROUND:
You perhaps know that the three types of ionizing radiation are the alpha (α) particle, the beta (β) particle, and the gamma (γ) ray. We speak of ionizing radiation because ionization is one result of the interactions of these three forms of radiation with matter. Ionization is the mechanism of radiation damage, and we are especially concerned when the damage is to living tissue. We review the physics of these three forms:

The α-particle is a helium nucleus, having a charge of +2 and a mass of 4.0026 atomic mass units (amu).

The β-particle is like an electron. It is produced with relativistic speeds. The rest mass is that of an electron.

The γ-ray is electromagnetic radiation whose wavelength is shorter and energy greater than some of the other forms of electromagnetic radiation—light, radio waves, and microwaves.

The α-particle is easily stopped by matter. A sheet of thick paper is generally adequate. The energy of the α-particle is therefore deposited in a very small volume, creating localized damage. This can be good if you wish to damage something like cancer cells, but bad if you damage healthy tissue. The local damage is so severe that the affected area may not recover.

The β-particle is also easily stopped by matter. A few sheets of aluminum foil will do the job. Like the α-particle, energy is deposited throughout a small volume, causing concentrated damage, though not as much as that caused by the α-particle.

The γ-ray is not easily stopped by matter. So the localized energy deposition is small in comparison to that of charged particles, but you cannot block out γ-rays too well. A single γ-ray is called a <u>photon</u>.

So the mechanisms of interaction and the consequent effects have both beneficial and harmful aspects. As engineers, we learn to manage radiation to use the Laws of Nature to our advantage.

In particular, we use radiation where there is a need to operate on a microscopic scale. We cannot change the natural laws—we can only adapt ourselves to them.

TITLE: **COMPRESSOR APPLICATIONS**

PROBLEM STATEMENT:
You are working at a food manufacturing company as a manufacturing engineer. Currently, the plant's compressed air system is operating near its capacity. Because of this, and the rising energy costs, your engineering group has been assigned to investigate the system for possible improvements.

BACKGROUND:
Compressed air systems are used in virtually all manufacturing plants for a variety of applications. Compressed air is created by a central air compressor(s) in the plant, and is delivered to the usage points via piping. There are a few different types of air compressors, with one of the most common types being a rotary screw compressor. Two large screws are rotated by the motor, trapping air between the screws. The air becomes compressed which results in an increased air pressure. This compressed air is then capable of performing work.

Compressed air can be used for a variety of applications and has many advantages. Compressed air is used for a host of motion control and actuators in assembly lines. For instance it can be used to control gates to direct the flow of product, clamps to hold products in fixtures during assembly, robotic grippers can be air operated, and it can provide motion by moving air cylinders. Some power tools can be powered via compressed air instead of electricity, such as pumps, drills, screwdrivers, and grinders. Air tools (also called pneumatic tools) are often desired because they are lighter for operators to hold, which reduces the ergonomic risk to an operator, and are often quieter. They are also less of an explosion risk for hazardous environments. Compressed air is also often directly used as well, such as blowing off waste chips from drilling or machining operations, drying products before labels are applied, or moving small parts on feeder lines in assembly operations.

While compressed air has many uses and advantages, it is expensive to create because of the energy and maintenance costs associated with operating the air compressors. Since compressed air systems serve a critical or even irreplaceable role, it is prudent that the system is operated efficiently. Some of the efficiency issues that need to be constantly considered are checking the system for any leaks, making sure the compressor is operating at peak performance, assuring that compressed air is being used prudently, and regulating the pressure at those locations that don't require the maximum system pressure.

DISCLAIMER

The following are the preliminary problem statements and initial background for the 2005 TEAMS competition. Actual problems may be edited and expanded in the actual TEAMS exam, however the overall thrust of the problems will remain. In addition, one problem will be completely eliminated for a total of 8 problems (each with 10 multiple choice questions). The order of the problems may not remain the same. Students are encouraged to research the general problem topics and terms they are unfamiliar with in preparation for the competition.

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