Design Concepts for Engineers 5th edition Horenstein Solutions Manual

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Design Concepts for Engineers – 5th Edition

by Mark N. Horenstein

Instructor Resource Manual

Overview:

This manual is intended to serve as a guideline for the instructor teaching a course on engineering design while using the text *Design Concepts for Engineers, 5th Edition*. Given the very nature of design, most of the problems in the text are open ended and hence have no single solution. Thus many of the "solutions" in this manual are really just suggestions that are meant to help you as an instructor and motivate your students. Where they appear in the text, complete answers to analytical (non-design) problems are provided.

Coverage of Problems:

This manual does not cover every problem in the text, but only a representative sample from each topical section. Given the unfortunate proliferation of solution manual copies on the Internet and their widespread availability to students, I have reserved some problems without solution so that the instructor can, by using solved problems as template guidelines, construct similar solutions to those for which a solution is not provided. The richness of this manual can be greatly enhanced by contributions of users like you who contribute solutions to problems not currently covered. If you would like your solution of particular problem added to future renditions of this manual (with appropriate citation to you) or kept in a future Instructor-Only databank, feel free to mail your solution to the author at mnh@bu.edu. Contributions from your students are also most welcome.

CHAPTER 1 – WHAT IS ENGINEERING

This chapter contains no problems or exercises.

CHAPTER 2 – WHAT IS DESIGN

Solutions to Selected Problems

Problem 2.1 - *Develop a design concept for a mechanical device that will allow hands-free operation of an automobile based on the GPS system. Outline its basic form, key features, proposed method of construction, and prototyping plan. Consider size, weight, shape, safety factors, and ease of use.*

Some considerations for the design of a device to steer a car based on the GPS system:

1) The GPS data must be obtained electronically from the GPS tracker in the form of numbers that indicate latitude and longitude
2) The system must include detailed map data that indicates the GPS coordinates of roads, turns, intersections, plus a database of traffic lights and stop signs
3) The system must include an array of sensors to detect the proximity of other cars, pedestrians, bicycles, and obstacles, then use this information to determine whether or not it is safe for the car to proceed.
4) A dash mounted console is the best interface, as it will allow for easy viewing by the car's occupants.
5) The system must be fail-safe (failure of the system must stop the car, and indicate to the occupant that a live, human driver is needed.

Problem 2.2 - *Develop a concept for a device that will allow hands-free use of a mobile phone without the addition of accessories such as an earphone, microphone, or Blue-Tooth® headset. Your design should be based solely on a mechanical solution.*

Some possible methods for the design of a device for holding a mobile phone hands freer:

1) Headband that has phone clip. It positions phone next to user's chin.

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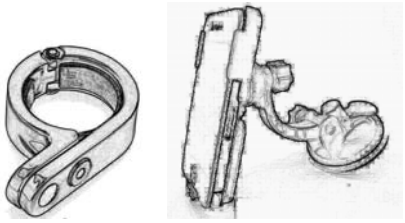
2) Wear phone on belt. A flexible hose is placed near microphone of mobile phone by clipping alongside the belt. The other end terminates in a speaking funnel clipped to a necklace worn around the user's neck.
3) A long bracket attached to a belt extends upward toward user's face. Mobile phone is mounted at end of bracket.
4) Develop a large, soft foam structure that can be cradled between the cheek and shoulder. Phone clips to this foam "pillow."

Problem 2.3 - *Design a device for recording design ideas that enter your mind while you are jogging. Your contraption should enable the runner to record notes while maintaining a steady gait.*

Some possible design strategies might include:
1) Voice activated (VOX) recording system with lapel microphone
2) Retrofit of earbud/microphone hands-free device that comes with most mobile phones.
3) Use of voice recorder usually present as part of native software in a mobile phone, with automatic activation upon pressing the button on a hands-free headset.

Problem 2.4 - *Design a device for securing a mobile phone to a bicycle. It should be universally adaptable to a wide variety of bicycles. Address safety and liability issues as part of your design.*

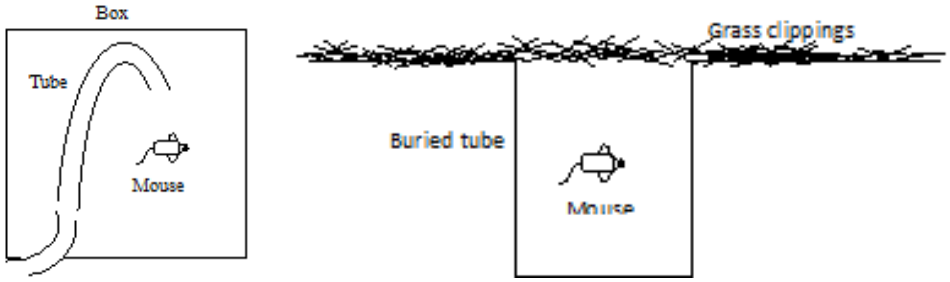
Several strategies come to mind. They might include:



1) Using a 3-D printer to make a dedicated box/bracket to hold the cell phone in a vertical position
2) Buying a commercial belt-holder for the phone, and then adapting it to a handlebar mount used for lights and reflectors, such as the one to the right.
3) Use a "suction cup" type mount, normally used for a car, and adapt it to a bracket such as the one shown to the right.

Problem 2.5 - *Develop at least three design concepts for a non-lethal mousetrap. Your device should be cost-competitive with an ordinary, spring-bale mousetrap.*

Some possible designs of a humane mousetrap:
1) Support a plastic shoebox on one end by a short stick. Tie piece of cheese to stick via string. Mouse grabs cheese, box falls on mouse and traps it.
2) Large box can be entered only by inside tube attached near bottom edge. (See figure below) Upper end of tube extends to top of box. Mouse falls down from end of tube and gets trapped in box.
3) Bury smooth-walled cylinder in ground. (Mouse cannot climb up the smooth walls.) Cover top of tube with grass clippings. Mouse falls through grass clippings into tube bottom.



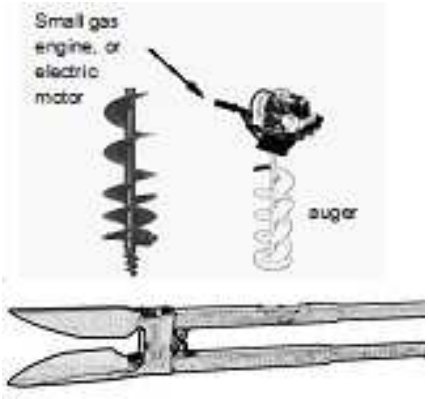
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Problem 2.6 - *Devise a concept for a powered device that can dig holes in the ground for the installation of fence posts. Sketch a prototype and outline a test plan for your design concept.*

It would be possible to have a large screw auger connected to a) small gas engine, or b) large HP electric (induction) motor, with handles and on/off switch to facilitate stop-and-go digging.

Alternatively, the device could be built with two "spoon" handles on either post, and an up/down ram and-separate/lift mechanism be used to dig the hole. Any test plan should include repeated use under easy, difficult, and extremely harsh conditions and soils.



Problem 2.7 - *Design a device that will allow the inside and outside surfaces of windows to be cleaned from the inside only. Compare the projected cost with that of a simple, handheld, squeegee-type window cleaner. Some possible schemes for the design of a window cleaning device:*

1) Outside squeegee held by magnets from the inside. (Requires that the window can be opened so that user can place squeegee against outside of window pane.)
2) Small sized, high-velocity hose nozzle that has rubber coupling that one can attach to bathroom/kitchen sink. (Inside window cleaned with conventional handheld squeegee. Requires that window can be opened so that hose can be passed through to outside.) The nozzle is attached to a long, bendable, flexible rod with handle for easy manipulation.
3) Develop a flying helicopter version of the "Roomba" (*www.iRobot.com*) autonomous, programmable robot. An onboard water tank provides water to squirt on windows.
4) Design a window that can be tilted in so as to provide access to outer side of pane.

Problem 2.8 - *Design a system for feeding pet fish automatically when the owner is out of town.*

Some ideas that could be put into the product:

- Automatic timer derived from automatic lamp timer (the kind used when people go on vacation)
- Rotating tray, located above the fish bowl/aquarium, with compartments that hold daily (or twice/thrice daily) portions of food.
- Above, but with a "Ferris wheel" type of arrangement.
- Large food reservoir, with scoop that comes down, traverses to fish bowl, and drops in the food.
- Immerseable packets that each open at a preset time.
- **"**Teabag" packets of food, each dangled above the aquarium, with each one dropped on a different day by automatic release.
- Hire the next door neighbor to feed the fish.

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Problem 2.9 – *Develop a concept for a spill-proof candle.*

Some design considerations for this problem:

- One obvious solution could be based on the "punching clown" approach, whereby the candle base is rounded at the bottom with a heavy weight.
- Another approach could be a spring-loaded holder on a heavy base.
- Yet a third could be based on a "gyroscope" mount with the candle mounted inside a gimbaled holder.



Problem 2.11 - *Design a device for conveying bricks to the top of a house for chimney repair. (The alternative is to carry them up a ladder by hand.)*

Some ideas that might be used for such a project:

- Motorized pulley system that can be attached to the top of the ladder, with counterweight; would need large weight to be used to replace bricks for downward travel.
- Conveyor belt type of arrangement that one could lean against the house.
- Small, portable crane with large bottom weight to hold the counterweight of the bricks.

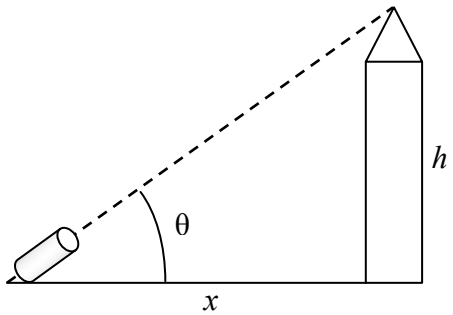


Problem 2.12 - *Design at least three different methods for measuring the height of a tall building.*

1) Use barometer to measure atmospheric pressure at top and bottom of building. Look up change in air pressure per unit height and use information to determine height.

2) Drop stone from roof and measure time to reach ground using stopwatch. (Two people communicating via mobile phone helpful—one on roof, one on ground.)

3) Use a surveyor's transit to determine the angle θ of inclination as sited to top of roof. Use Pythagorean Theorem to determine height h given known distance x. (See figure to right)



4) Convince the building manager to tell you the height by offering the barometer and stopwatch as gifts.

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Problem 2.16 - *Develop a concept for a public transportation system in which every traveler can ride a private vehicle on demand from any one station to any other.*

One Possible Solution:

a) Stations have docking platforms for vehicles the size of "Smart Cars." User card key required.
b) Onboard GPS keeps track of route, logs miles, and applies charges to user's account via radio link
c) User must return vehicle to another docking station in city; per-minute idle charges apply until vehicle is docked.

Another Possible Solution (motivated by the way some ski chair lifts operate:

a) Vehicles travel continuously along a set course, either by preset GPS navigation, or by moving from radio beacon to beacon
b) Vehicles can be stopped for a short time so that rider(s) can get on (or in)
c) Vehicle "catches up" to loop speed once underway.

Problem 2.19- *Design a system for parks-and-recreation personnel that would alert them when trash barrels need to be emptied. Such a system would eliminate needless trips to check for full barrels.*

The following issues would need to be resolved.

1) How to detect when any given barrel is full. Sensor methods might include: optical detector at rim; weighing the barrel, mechanical switch (with push-plate) that gets pushed when trash rises to its level.
2) How to send signals to central station. Methods might include: wireless notes ("motes") in an array; cell phone for each barrel; radio transmission over a dedicated *rf* band; infrared light flashing; squirrel messengers.
3) How to let the park attendants know the location of any given barrel. Methods might include: GPS in each barrel; database of known (preset) locations of barrels, with each given a number.

Problem 2.20 – *Develop a design concept for a system to measure the number of people passing through and airport security zone.*

Some design considerations for such a system might include:

- Choose method to detect people. Methods might include optical sensor, video detection, floor-mounted sensor plates, a toll-gate type of device that lets one person through at a time.
- The system would need to have an electronic time keeping system to keep track of time. A time stamp for each individual passage would be ideal, as then the data would comprise a much richer set.
- Consideration should be given to accommodating multiple lines, as this would be normal at a busy airport.

Problem 2.22 - *Design a system for automatically turning off an electric baking oven when a cake is done. The system must include a means for assessing the status of the cake.*

Classic method to determine when a cake is done: stick in a knife and see if it comes out clean.

Method 1

Devise moisture sensitive sensor tied to electrical switch box.

Method 2

Provide electronic scale inside oven. As cake bakes, water evaporates, weight is reduced. Keep track of percent change to determine when cake is done.

Method 3

Mechanical sensor that periodically touches top of cake and measures its "spring-iness". The firmness of the cake signals that its baking cycle is done.

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Problem 2.23 - *Design a system that will help a person locate misplaced eyeglasses*.
Some possible approaches:

- RF ID tag in glasses, with many sensors in the living area
- RF ID tag in glasses, with room scanner that would let the owner scan each room, one at a time.
- LED that activates upon receiving a coded radio or infrared signal
- Video camera in any given room, with image processing algorithm to detect the action of a person putting down glasses.

Problem 2.25 - *Design an electric light switch that will turn off lights if the room is vacated, but not sooner than some user-specified time interval.*

Designing a light switch of this type requires two things: A method to sense the presence of humans, and a lockout timer.

Suggestions for sensing people in the room:
Detect infrared rays emitted by warm bodies, detect motion via sound wave; detect motion via change in reflection of radio or microwave signals, detect change in image from small embedded camera, including image and/or shadows.

Suggestions for the lockout timer that starts when lack-of-people is detected:
Embedded microcontroller that starts timing and turns off lights a fixed time thereafter. Simple resistor-capacitor (*RC*) circuit that is activated and turns off lights when *C* is charged to a preset threshold. Mechanical switch that is driven by a motor and screw thread. Resets to zero when people again detected.

Problem 2.27 - *Devise a system for turning on home security lights when a person approaches the back door of a house. The system should have a way to distinguish between humans and stray animals to avoid unnecessary tripping.*

Designing a light switch of this type requires two things: A method to sense the presence of humans, and a way to distinguish from small animals

Suggestions for sensing people and not sensing small animals:

- Detect infrared rays emitted by warm bodies, but set threshold limit for how much is considered a “hit”;
- Detect motion via sound waves, and make wavelength longer than size of typical cat, squirrel, raccoon;
- Detect reflection of radio or microwave signals, with wavelength longer than size of typical cat, squirrel, raccoon;
- Analyze image from small infrared camera, detect motion of objects large enough to be humans while rejecting smaller sizes.

Problem 2.28 - *Design a system for turning off a stove-top burner when a pot of water has boiled. Such a system would be valuable for cooking rice or preparing hard-boiled eggs.*

Key components of such a system would be a temperature sensor and an electrically actuated valve (to turn off gas burner) or switch (to turn off electric burner). Ideas for temperature sensor include: bimetal strip (like traditional thermostat), thermocouple, optical thermometer, semiconductor diode (in an appropriate circuit), commercial temperature sensing integrated circuit. Each of these would have to be designed to a) be capable of immersion in water, and b) inert, so as not to affect the potable nature of the water.

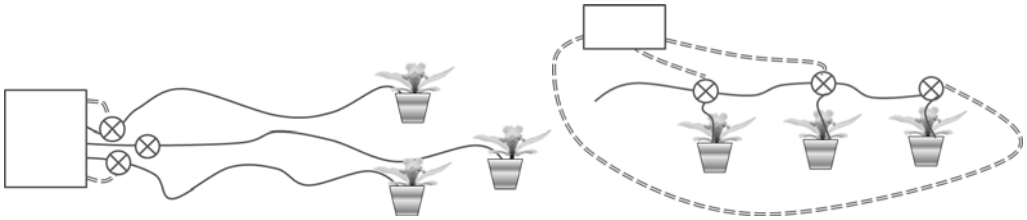
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Problem 2.30 - *Design a system that will automatically water houseplants when they are in need of moisture.*

Such a system would require several components: Continuous water supply (or large, fillable tank mounted on a high shelf so as to create pressure, and have enough water to last the entire time); moisture detectors embedded in the soil of each pot – the kind that emit an electrical signal proportional to percent moisture saturation; electrically-actuated water valves; one for each pot; flexible tubing to bring water to pots; master controller, such as a microcontroller, dedicated computer, or similar.

One key question to answer: Is it better to have a valved tube going from a central location to each individual pot, or to have a single tube with valves located at intervals, and wires going from the central location to each valve. There are cost/benefit tradeoffs to each method.

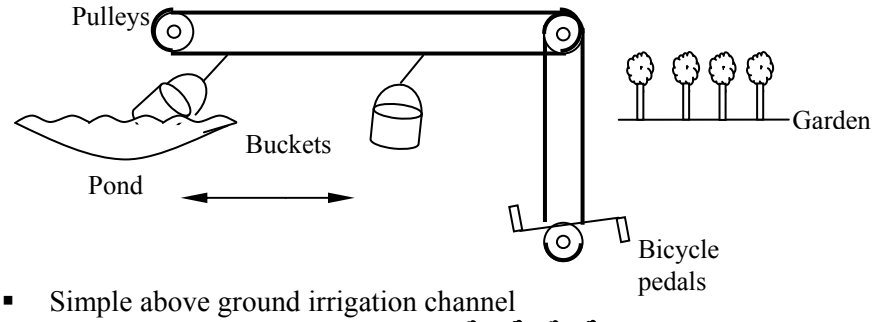


Method 1: Multiple Tubes Method 2: Multiple Wires

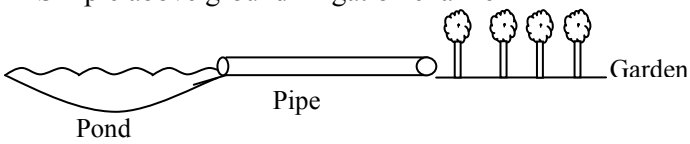
Problem 2.32 - *Design a solar-powered irrigation system that will bring water from a nearby pond to a back-yard vegetable garden.*

Some Possible Approaches:\

- Solar powered pump. Perhaps a 12-V portable pump and solar-recharged automobile storage battery?
- System of buckets and pulleys driven by a bicycle pedal system



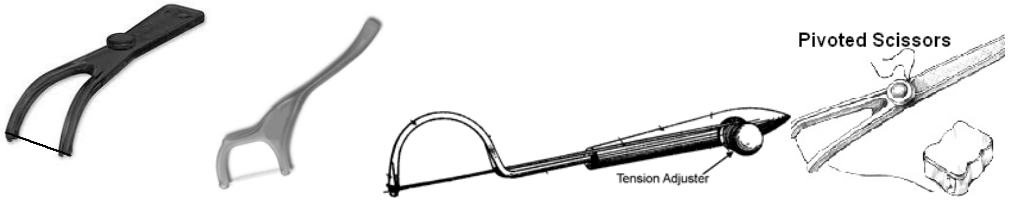
- Simple above ground irrigation channel



- Below-ground pipe moistens soil beneath plants. Water seeps up through soil to plant roots.
- Same as above but include "wicks" from below-ground water table to plant roots.

Problem 2.35 - *Design a device that will allow a one-armed individual to properly use dental floss.*

Some possible approaches:



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Problem 2.37 - *Design a method for counting the number of people who attend a football game. The stadium has a maximum capacity of 40,000 fans and eight entry gates.*

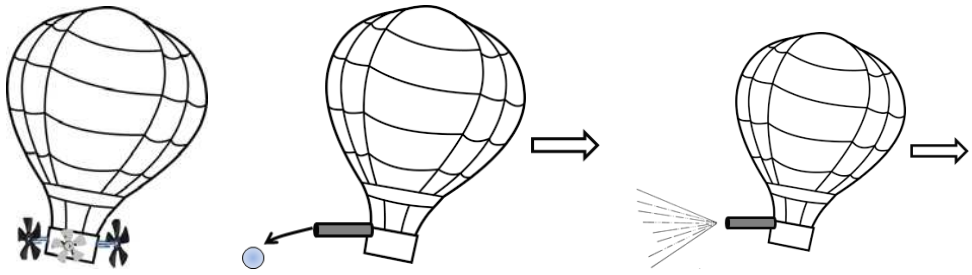
Some possible methods of counting people:

- Laser beam and detector on opposite sides of entry aisle to stadium (requires that people go single file)
- Take photos, use software imaging (e.g., Matlab toolbox) to identify and count people.
- Know ahead of time the percentage of people that buy vendor peanuts; get sales data from peanut vendors
- Measure amplitude of crown roar relative to empty stadium; assume it is proportional to number of attendees.
- Have detector underneath each seat/bench that sends data to central processor
- Count the number of tickets sold.

Problem 2.39 - *Design a system for automatically steering a hot-air balloon along a desired compass heading.*

Some design considerations for this problem:

- The system will require a compass that has an electronic output. For example, the fluxgate type of compass shown below produces voltage signals that indicate percentages of N/S and E/W headings.
- The compass derived heading signals can then be used to steer the balloon along a desired course. The latter could be derived from GPS (another electronic device), or simply dead reckoning and a desired compass heading.
- Possible methods to steer the balloon: Four fans on opposite sides of its two horizontal axes (requires battery operated power supplies, hopefully rechargeable; small sail that captures the wind when the latter is blowing in the correct direction, accompanied by a rudder; small water or gas jets to add horizontal motion (requires refillable reservoirs); eject weights in opposite direction of desired travel, to provide periodic directional force impulses to the balloon.



Problem 2.41 - *Design a system for automatically steering a tiller-controlled sailboat on a course that lies along a user-specified compass direction. Most small sailboats have a tiller (steering stick) in lieu of a steering wheel. Design for a simple boat that has no onboard electricity.*

Some possible design approaches might include:

1) Relying on wind direction to steer the boat, with small wind vane tied to tiller
2) Using compass heading (with battery-powered electronic compass)
3) Using user set direction and fixed course path.

Methods to move tiller might include: Rope and pulley system; hydraulic piston; rack and pinion system; weights and pulleys system.

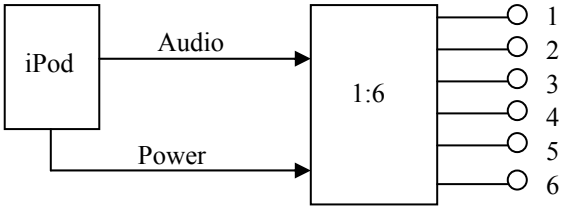
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Problem 2.42 - *Design a system that will allow a group of musicians to mix their sound channels to proper volume automatically without the need for a live sound technician.*

Requires more than just connecting all the headphones in parallel. Why? Because output amplifier of iPod/smartphone/MP3 player will be loaded down; volume will be too soft at each headphone.

- Use distribution (1-to-6) amplifier powered by iPod's battery



- Same as above but with AAA battery for 1:6 amplifier.
- Each of six headphones has its own battery powered amplifier.
- Wireless system using Blue Tooth.

Problem 2.43 - *Design a manually operated kitchen device that will crush aluminum and steel cans in preparation for recycling. Such a device would be helpful for households that practice recycling but have limited storage space.*

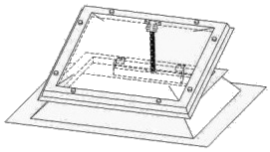
Some possible designs (most of which are commercially available) are shown below.



Problem 2.45 - *Develop the design concept for a device that will automatically close a skylight window when rain falls. The window should be closed partway when rainfall is light but should be closed completely when rainfall is moderate to heavy.*

Some design considerations. System will need:

a) method to detect presence of water (capacitive electrode sensor; weigh small container; optical sensor)
b) motorized closing system (e.g., see below);
c) measuring method of (a) that can deliver signal indicating how hard rain is falling.

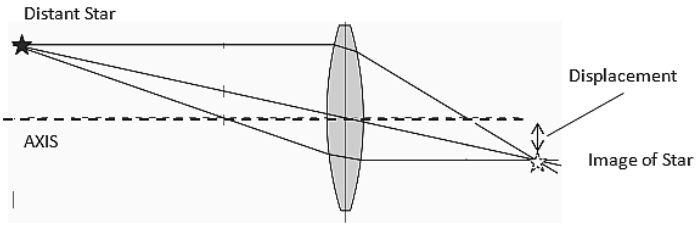


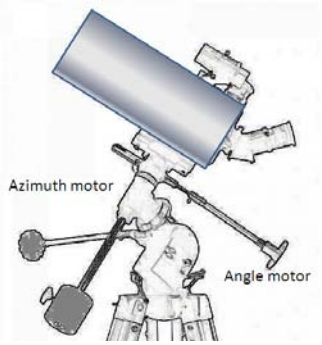
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Problem 2.46 - *Design an apparatus that will keep a telescope pointed at a distant star despite the rotation of the Earth.*

A requisite of this problem to find a distant star to be tracked. It will look like a point source to the telescope; viewing a point source through a lens will cause the focused point image to move when the axis of the lens is displaced from the line to the star, as shown below.





The focal plane displacement could be detected by an imaging camera, and software used to determine the displacement in the *x* and *y* directions. These signals could be used to move *x*-axis and *y*-axis motors to direct the axisof the telescope to the star.

Problem 2.47 - *Design a system for keeping solar panels pointed directly toward the sun as the earth rotates.*

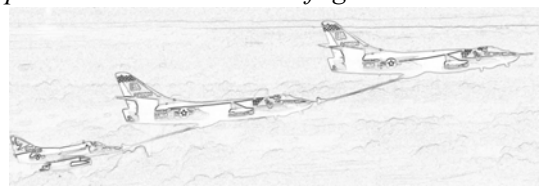
Some Possible Approaches:

- Align panels once during installation. Thereafter, two-axis, timed motors follow sun's zenith. Must return to "dawn" position each night.
- Photocell with maximum intensity detector.
- Mirror system with fixed panels where mirrors are tied to motor-driven, gimbaled mount with sun-tracking programming on two axes.

Problem 2.48 - *Devise a system for transferring people from one airplane to another while in flight.*

The possibilities are endless. Some ideas might include:

- Cable tether and "breeches buoy" type of harness
- Tube through which person is propelled
- Catapult person (wearing safety parachute in case of miss) into opening in fuselage of receiving plane



Problem 2.50 – *Design a system that can detect potholes in city streets and report location to repair crews.*

Here are several approaches and considerations:

Methods to collect data:

- Install cameras on the fronts of taxicabs to scan roadway as they go along
- Same as above, but utilize the public bus system
- Use per-intersection video surveillance footage to detect presence of potholes via image detection software
- Rely on reporting from individual drivers
- Install in numerous volunteer cars a "bump detection" sensor that sends SMS messages back to a central data collection point. Aggregate bump reports to pinpoint potholes
- Use high-resolution satellite data to discern presence of large potholes.
- Put video cameras atop the helmets of volunteer bike riders.

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Methods to transfer and use data:

- Via SMS messages
- Via radio
- Store data (e.g., USB flash drive) and collect manually at central station
- Have data acquisition at known locations; transfer data whenever detector passes beneath or beside one.

Problem 2.52 - *Design a system for detecting start-line violations for a horse race.*

Some Possible Approaches:

- Video camera and image recognition software. Taken from above track.
- Laser beam (low intensity) with detector across start line. Early crossing triggers camera to detect which horses have crossed too early, thereby violating the starting rules.
- Start the race with a lifting gate. This system prevents all starting line violations.

Problem 2.55 - *Design a can opener that performs two tasks: a) It must not allow metal slivers to fall into the can, and b) it must catch and hold the cut lid for subsequent hands-free disposal.*

Here are some ideas that could go into the design:

Cut along the edge of the rim, rather than on top of the lid.



Problem 2.56 - *Design a system for measuring and reporting accumulated snowfall and rainfall at a remote monitoring station. It must be capable of discriminating between the two types of precipitation.*

It should be possible to tell the difference between collected rain and snow using an optical method, because snow is opaque (more or less), whereas water is clear (more or less). Hence something that shines, e.g., a laser beam across a glass collection cylinder and measures transmitted light would be helpful. A good way to measure rainfall might be to weigh the collection cylinder, rather than rely on an optical method for detecting the height of collected water. Another method might be to measure the conductance and/or capacitance between two electrodes in contact with collected precipitation. Snow will have less bulk conductivity and a smaller dielectric constant (hence smaller capacitance).

Problem 2.61- *Design a robot for automatically walking a dog in a safe and reliable manner. The robot should require no human intervention other than setup.*

Some Possible Approaches:

- Buy an iRobot (*www.iRobot.com*) and equip it with GPS.
- Mobile phone equipped GPS.
- Oval track rail with moving card; leash attached (dog is inside track).
- Requires breakaway device in case of snags (anti-choking device).
- Walkway around shallow wall with "wall hugger" motorized car.
- Aerial balloon with onboard propellers and camera to send view to person at computer.

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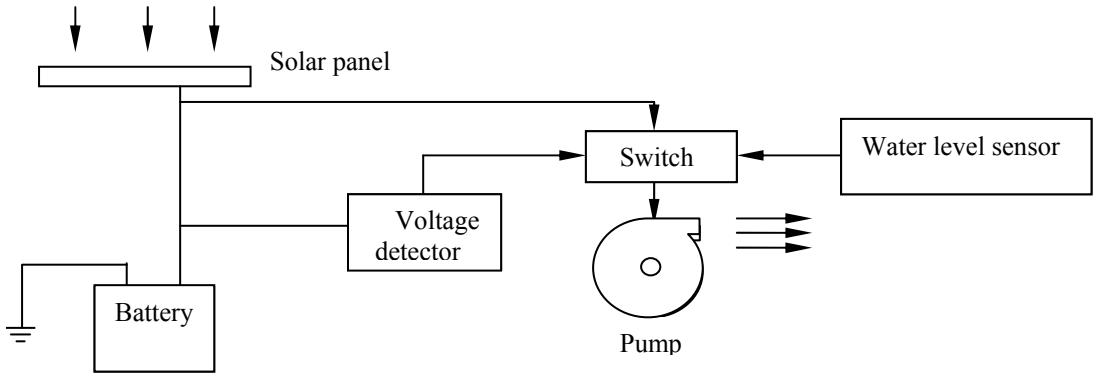
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- Fenced in walkway with moving (gentle) dog pusher.
- Trail dog behind a garbage truck. These vehicles move slowly, stop often, and could charge money (income for the city) for the service.
- Hire a smart cat to entice the dog along.

Problem 2.64 - *Design a system that will automatically pump out water from a small boat. One of the problems with many small, recreational boats is that they fill up with rainwater which must be pumped out after a storm. Your system may use an onboard storage battery, but it must then include a means for charging the battery during periods of sunlight. Note that a typical water pump uses more power than a small solar panel can provide.*

The following block diagram outlines one possible solar-based solution that addresses the following issues:

- Battery runs down in about an hour when powering water pump.
- Solar panel provides significant power only in bright sunlight.
- Sun is absent during storms when pumping is needed the most.
- System must therefore use an "after the storm" pump out strategy.
- Solar panel alone cannot provide sufficient power to turn pump (300 mA for solar cell vs. 10 A of current for the pump.) Hence the pump cannot be "on" when battery is being charged.



Notes:

- Voltage detector allows switch to close, connecting motor to battery, only when battery has a full change.
- Voltage detector disconnects pump from battery when battery is run down, so that solar panel can recharge it when sun comes out.
- Switch also can only close, thereby powering pump, when water level sensor indicates that boat is filled with water.

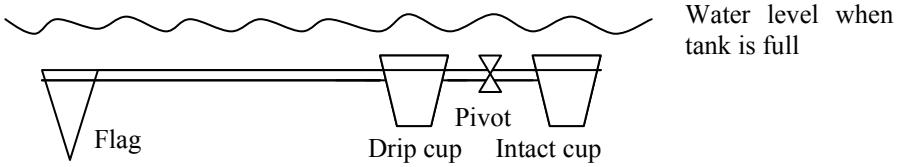
Problem 2.66 - *Design an inexpensive device that can alert a homeowner to a running toilet. If a common household toilet fails to fill its tank after flushing and is left "running", it can waste a considerable amount of water.*

Some Possible Approaches: **Note**! Solutions involving electric devices powered from a wall socket are not considered due to safety reasons (possibility of electric shock).

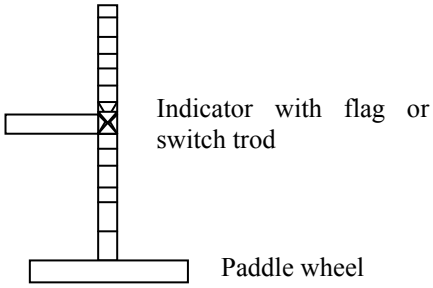
- Small float switch starts electrical timer when water level in tank goes down upon first flush. After a fixed time period (30 seconds?), if the bowl has not refilled, an alarm sounds.

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- A flag mounted on a pivoting arm is counterbalanced by two water receptacles on either side. One has a small drip hole in its bottom. If the tank has not refilled after a preset time, the flag pops up due to the weight of the receptacle without the drip hole.
- Have a small paddle wheel in the water stream. Turn a long screw shaft that raises an indicator. If the water runs for too long a time, the indicator a) becomes visible or b) triggers some sort of electrical circuit.



Problem 2.68 – *Design a method for alerting a driver the fraying and imminent breakage of a timing belt.*

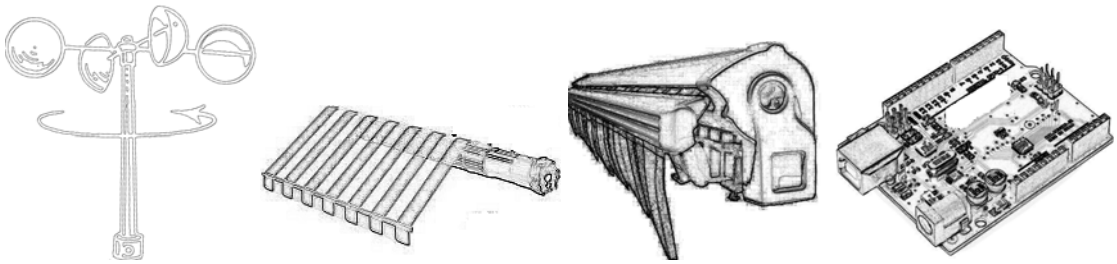
Some design approaches that come to mind:

- Have a sensor adjacent to the belt that can detect when wiped by fraying fibers.
- Use a small video camera and look for changes in image that might signify fraying.
- Shine an infrared light on the belt; have a sensor on the other side. Any changes in light might signify fraying.
- Develop an in belt tension sensor; any loosening of the tension could indicate a problem.

Problem 2.71 – *Devise a method for closing ornamental shade awnings when the wind becomes so high that it might damage the awnings.*

Some key components:

- Wind sensor (hotwire anemometer, rotating cups; small fan that runs dc generator with voltage proportional to wind speed)
- Motorized awning retractor.
- Microcontroller to receive wind data and activate motor when needed.



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Problem 2.74 - *Devise a system for tracking and reporting (at all times) the location of spent nuclear fuel rods being transported from a power plant to a long-term storage facility.*

Possible Solutions:

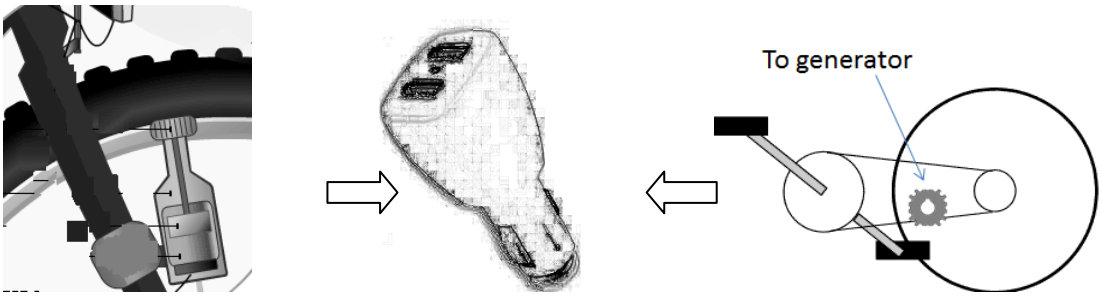
- GPS tracking device on each container.
- RF ID tag or bar code on each container that must be scanned and sent to central system by radio whenever location of container is changed. (Note: UPS and FEDEX, for example, use this method to track packages).
- Aerial surveillance via satellite.
- Always under human guard and video monitoring

  *Note: The radioactive nature of the rods is likely to upset sensitive electronics, so a simple system is essential.

Problem 2.76 – *Design a method to charge your phone from the pedal power of your bicycle.*

Several approached could work here:

- Standard headlamp generator with voltage regulator to keep voltage at 12-V required for "cigarette lighter" type of USB charger for phone.
- Generator connected to extra sprocket gear.



Problem 2.79 - *Design a system for automatically turning on an automobile's windshield wipers when it begins to rain.*

Some Possible Approaches:

- Two electrodes on the exterior of the car windshield are bridged by moisture, triggering wipers.
- Small water well on top of car roof; when it fills with water, electrodes sense it and trigger the wipers.
- Force sensitive touch pad on hood detects repetitious patter of rain, turns on wipers.
- Microphone senses sound pattern of falling rain, triggers wipers.

Problem 2.81 - *Challenge Problem: Design a handheld medicine dispenser for dispensing pills at specific times of the day. The unit is to be carried by an individual patient and must have sufficient capacity to hold medication for at least 1 day. The unit should open a compartment and should emit an audible or visual signal when it dispenses medication. The unit must be easy to load and should be easy to program.*

This product must consider several constraints and requirements:

- A patient may have as many as 3 or 4 pill regimens per day; hence if a week-long capacity is desired, that would require as many as, say, 28 separate compartments
- Many pills are large, hence the compartments must have ample space for multiple pills in each one.
- The device is likely to be used by the elderly, hence any audible alert must be sufficiently loud and include a volume control.
- The unit will require a display and touch buttons to facilitate programming. Alternatively, it could be programmable by connecting to a computer or smart phone. Wireless would be nice, but wired permissible.

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- The act of "dispensing" could mean many things. For one, it could mean that each compartment have a latched lid, with only one unlatching at the appropriate time. It could mean a light goes on next to the correct compartment, or a colored tab uncovered over the appropriate compartment.
- All compartments must be capable of being opened at the same time, so that the dosage(s) can be loaded all at once.
- The device will be hand-held, and thus must be battery operated and rechargeable. Ideally, the battery should last a week, but at minimum a day.
- Some sort of programmable clock is needed, hence a microcontroller of some sort, running timing software, is needed.

Problem 2.84 - *Challenge Problem: Design a system for identifying which electrical circuit breaker is associated with a given electrical outlet in a large building. The best system will be one that does not require the operator to move back and forth between the circuit-breaker panel and the locations of the outlets on the all of the building.*

- The breaker panel is often located at a location remote from the room where the outlets are located, hence something that doesn't require visualization is best.
- The circuit to be traced could be live, or it could not be energized. While the outlet can be tested to see if it's live, the system would have to work either way.
- Many buildings are wired in three phase, with a given outlet being part of one-in-three electrical circuits
- Radio frequency waves can travel over wires and simply be superimposed on the AC power voltage; hence *rf* could be used to inject a signal into an outlet, with a radio-type receiver moved from breaker to breaker until it picked up the signal. Capacitors can block the low-frequency AC power voltage while passing the high-frequency *rf* (the "impedance" of a capacitor goes down as the frequency of the signal goes up.)
- Same as above, but with audio signal.
- Mechanical solutions are probably not the way to go, although it would be worth investigating whether a vibrating audio-frequency signal (not electrical) can be sent down any given wire and detected at the breaker end.

Problem 2.87 - *Challenge Problem: Design a system that would allow a blind person to drive an automobile.*

This problem presents numerous challenges, but in principle could be made to work. Some of the key elements required would be:

- Navigation – probably GPS would be best
- Presence of other cars – a series of sonar-type sensors, light-reflection sensors, and/or cameras with real-time video processing (or all of these) would provide a map of other vehicles
- Traffic constraints – A combination of "following speed of other traffic" and character recognition of speed limit signs and image recognition of red/green/yellow lights would be needed
- A voice activated set of functions would be useful, as would a voice annunciator to inform the driver about what is going on.
- A method to let the car know about the desired destination.
- Real time traffic data (e.g., from Google Maps or MapQuest) indicating status of traffic along route.

Problem 2.91 - *Challenge Problem: Laser communication, or "laser-com," is a system by which digital data is sent from one location to another via a modulated laser beam. Laser-com systems are used whenever connections via wires, WIFI or fiber-optic cables are too expensive, not possible, or not desirable due to the possibility of unwanted eavesdropping by others. One of the principal drawbacks of laser-com systems is the difficulty in maintaining beam alignment when the sender and receiver are moving. Design a system that will automatically direct the communication beam sent by one vehicle toward another receiving vehicle.*

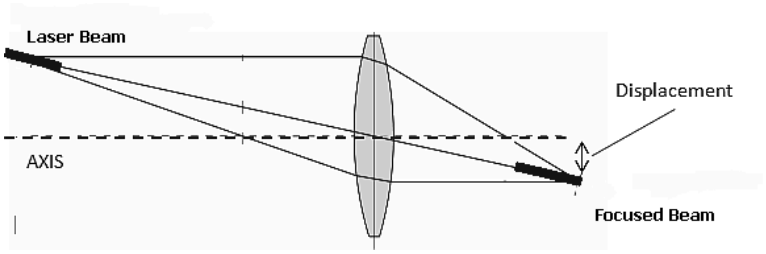
This product must consider several constraints and requirements. Here are some ideas:

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If the axis of a lens is aligned with the laser beam, its focused spot will also be on the axis. However, if the laser is not aligned with the axis, as in the figure below, its focused spot will be displaced in the focal plane.

The focal plane displacement could be detected by an imaging camera, and software used to determine the displacement in the *x* and *y* directions. These signals could be used to move *x*-axis and *y*-axis motors to direct the axis of the laser (on the right end of the figure) toward the axis, thereby lining it up with the axis of the other laser.



Problem 2.92 - *Challenge Problem: Design a concept for a two-way communication system that works via a modulated light beam. In this system, only a fixed ground station will emit a beam. The other participant in the link will be a moving person who will receive the beam and reflect a modified version back to the base station.*

The main issue is that one node of the communication system does not transmit radiation, and hence maintains camouflage and "stealth" operation. Here is one possible idea for making the system work. It involves a "master" station that sends out a directed laser or radio beam, and a "slave" station that does not transmit, but can only reflect back the beam to the master.

- Master station can encode its beam with digital information (e.g., pulse on and off to make a binary pulse train of digital data, for example).
- Slave station has detector that captures pulses from transmitter and decodes the information sent.
- Slave station has a mirror that can be turned on and off (at a rapid rate, electronically). When master is ready to send information from slave, it sends a code, then sends a continuous (not pulsed) beam to the slave. The slave then modulates its mirror, encoding the *reflected* beam with information sent back to the master. The latter received the reflected beam and decodes message from slave.

Note that only one node can send information at one time. This mode of operation is called "half duplex." Most of us are used to communicating over full duplex (talking on a cell phone), but in fact we use a half-duplex mode whenever we communicate with someone via text messaging.

Problem 2.99 - *Challenge Problem: Design a system to fulfill online food shopping orders.*

Such systems are no longer in the realm of fiction – robotic order fulfillment systems are starting to appear in many different industrial sectors. In any case, key components would include:

- The usual Web interface and database to receive and store orders.
- Robots capable of accepting navigation and gathering commands, as well as WiFi data from the customer order database.
- Staging area where orders placed in bins are kept prior to loading on trucks
- RF ID tags to or similar to put navigational data into truck's GPS, with a system to optimize the route so as to minimize travel time/distance (and hence fuel use)
- A video/optical inspection system for produce (which is not barcoded, typically) to enable the robot to select suitably ripe or intact fruits and vegetables.

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