June 2013 – Model Solution

1.1. Industrial Waste. This is produced as an effect of certain industrial processes. For instance, manufacturing tables from hardwood will produce a great deal of sawdust and offcuts as a consequence of the wastage methods (removing wood with tools to form the desired shapes) that are used by carpentry machinery (e.g. lathes). While wood is a renewable material, hardwoods are often slow-growing, and it is questionable as to whether new stock can be grown as quickly as the trees are cut down. In areas such as the rainforests, wildlife depend on the trees for their livelihood. Wood waste can be burnt or sold as animal bedding, so doesn't need to contribute to landfill – in any event, it is also biodegradable.

Sound. Manufacturing methods can be very loud (especially those working with pneumatic airlines or moving around large amounts of metal. If the sound can be heard in the nearby area, this will startle wildlife, and reduce the biodiversity of the surrounding area. There is also a human impact, as homes are unlikely to be built near a factory which is known to produce a great deal of noise. There may also be long-term health effects for both people and animals from extended exposure to noise.

CO_2 – Car manufacturers use large amounts of electrical power to drive the hydraulic and robotic systems that move car chassis' around, as well as using large amounts of plastics for fittings and trims. CO_2 is produced by fossil fuel powered electricity stations and the cracking process for oil. While both of these are secondary sources of pollution, the automotive industry indirectly contribute to this. The consequence of high levels of CO_2 are global warming over the long-term. Climate change may cause drought and famine around the World, which World-leaders seek to avoid.

Visual – If factories are able to be built anywhere with no regulation, it would be easy to spoil the natural landscape. This is why towns and cities have designated industrial parks to keep heavy industry in designated zones. Over industrialisation of areas of outstanding natural beauty will lead to an unattractive landscape, and humans would sooner not settle in areas where there are nearby unsightly factories.

1.2. Oil does not easily adhere to machinery, and where used in machinery, is usually stored in a sump, then pumped around the friction generating parts (e.g. gears) where is lubricates and draws heat away, is passed through a cooling system (e.g. car radiator), and back to the sump ready to be re-circulated. When the machinery is turned off, the oil slowly drains back into the sump, meaning that the next time the machine is cold-started, there will be a short period where the parts are unprotected until the oil starts to circulate again.

Grease is a semi-solid liquid, and is used on machinery which can only be lubricated infrequently (e.g. a hinge on a window, or inside the CV joint on a car wheel). It provides immediate cold-start protection, and can be easily applied by (gloved) hand.

Rubber seals on machinery that are starting to wear out will retain grease more easily than they will retain oil, due to the increased viscosity of grease.

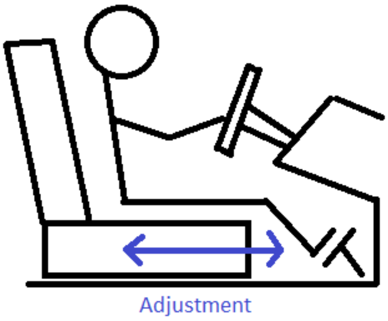
2.1. A bridge is a very large object. As such, it will not be manufactured as a single part, but instead as individual large parts which are brought together as the construction site, and then assembled with plant machinery (e.g. cranes). The eventual site of the bridge itself will almost certainly have limited (or more likely, none) manufacturing facilities, which is another reason to assemble the bridge on site. To make large parts from steel and concrete will require access to large quantities of power and substantial amounts of specialist equipment, which will be difficult to source in potentially remote locations.

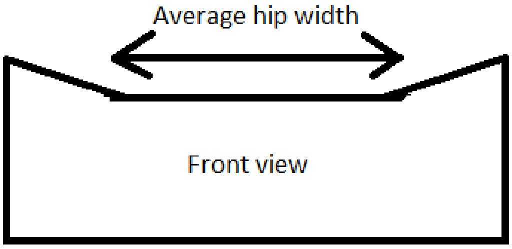
By bringing together parts from different locations, the best possible parts can be sourced from individual companies who specialise in the different aspects that need to be considered (e.g. road surface, rivets, steel beams). Transporting the bridge parts a few at a time by road can be achieved by the use of HGVs (40T weight limit), and rail.

Making parts off-site will also accelerate production, as multiple sites can work on the creation of different parts

2.2. With the aid of annotated sketches describe how anthropometric data is used when deciding on two adjustment requirements and two design requirements of a driver's seat. *(4 x 4 marks)*

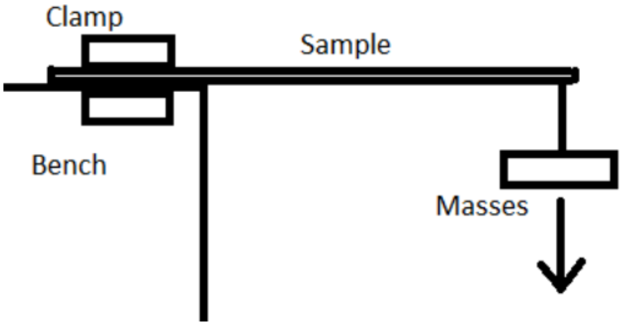
The range of thigh lengths of >17 year old males and females would need to be considered, as this will inform the adjustment of the distance between the seat and the steering wheel. If the seat cannot be brought far enough forward, shorter drivers would struggle to operate the pedals safely. If it doesn't go far enough back, taller drivers won't be able to comfortably drive the car.



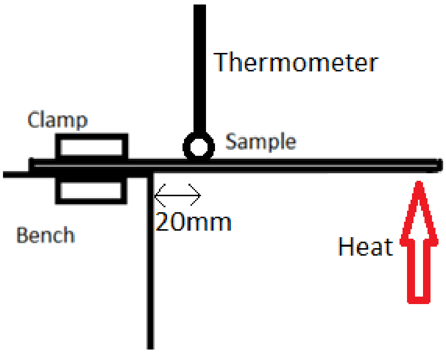


The range of hip-width of >17 year old males and females would need to be considered, as this will inform the width of the seats themselves. Modern car-seats are often ergonomically designed, with elevated sections towards the edges of the seats, to reduce the amount of movement of the body of the driver when turning corners. If the seats are designed too widely, the ergonomic design won't provide any support. If they are too thin, larger drivers may find them uncomfortable to sit in.

3.1. To measure flexiblity of metal samples, I would obtain 200mm x 20mm x 1mm samples of each material, and use a G-clamp to secure each sample so that it hangs 150mm off the edge of a table top. I would then incrementally suspend masses (200g at a time) from the end of the sample. After each mass is added, I would measure the distance that the end of the sample has moved down by until the sample either snapped, or moved more than 45˚ from horizontal.



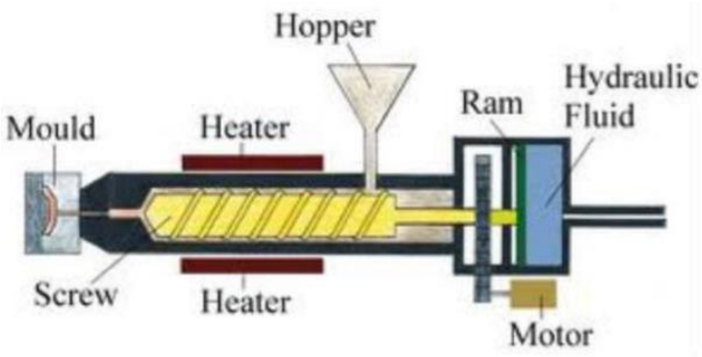
Each displacement would be recorded on a spreadsheet. Once the test was completed, I would plot a line graph with a line for each material, so that the relative resistance to bending forces could be compared easily.



Thermal Conductivity could be measured by taking the same-sized samples (minus the hole) as for the previous test, and clamping them as before. A thermometer can then be placed 20mm from the edge of the table, and a starting reading taken after 2 minutes (to allow the thermometer to calibrate). A Bunsen burner can then be placed at the end of the sample, and the temperature change recorded every 15s, and recorded onto a spreadsheet.

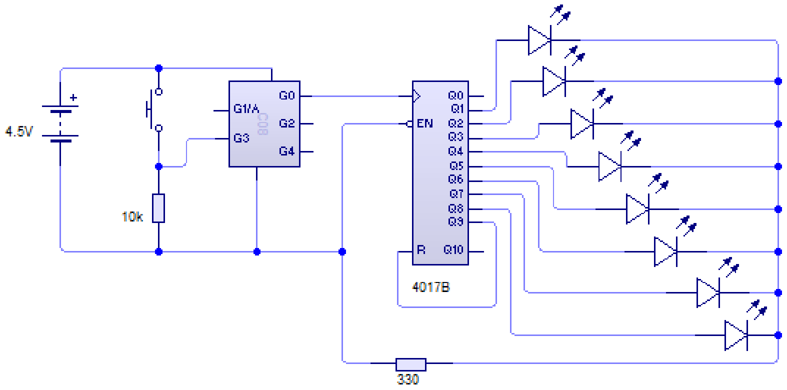
Once the test was completed, I would plot a line graph with a line for each material, so that the relative conductivity can be seen side by side.

3.2. To make large quantities of the pictured gear, a method such as 3D printing would not be suitable, as it will not build sufficiently quickly as to be practical. Instead, injection moulding would allow the gear to made from ABS. I chose this material, as it is known for durability, and so would be suitably hardwearing.



The mould itself would need to be cast from a metal such as steel (or aluminium for a smaller number of parts, which would reduce cost, but not last as long). The mould in question could probably manufacture several gears at once. A hopper is filled with granules of the thermoplastic to be used (e.g. ABS), which are released into the main chamber. They are driven along towards the mould by an Archimedean screw, passing along a heated section, which melts the plastic to its molten state. The plastic is driven into the mould under pressure, and then allowed to cool. Once set, the mould is opened, and the gear body can be removed. The gear would then need any excess flashing or sprue trimming off before shipping to the customer.

4.1. A decade counter IC would be used, connected to the PIC output…



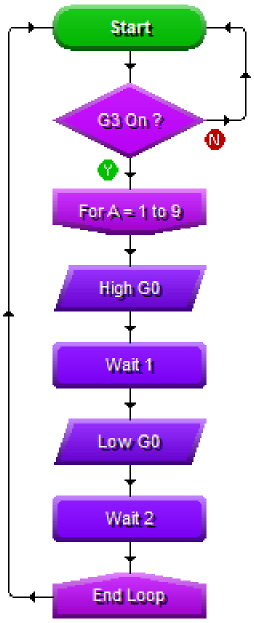
4.2. The PIC program would work as follows:

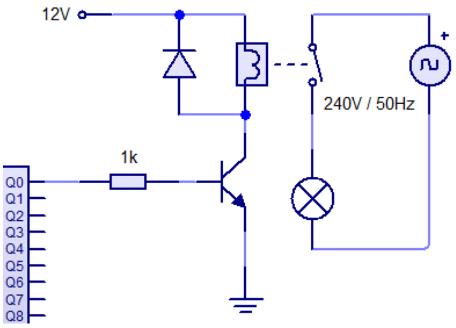
The program starts by repeatedly checking to see in the digital input has been pressed. As soon as it detects the input, a loop is started, which will happen 9 times.

The first iteration of the loop will made the first LED illuminate (output 0 on the decade counter isn't connected to anything).

The next 7 will illuminate the LEDs on the decade outputs, and the last iteration will trigger the reset pin, effectively turning off all the LEDs.

Once this process has completed, the program resets, ready to repeat the process when required.





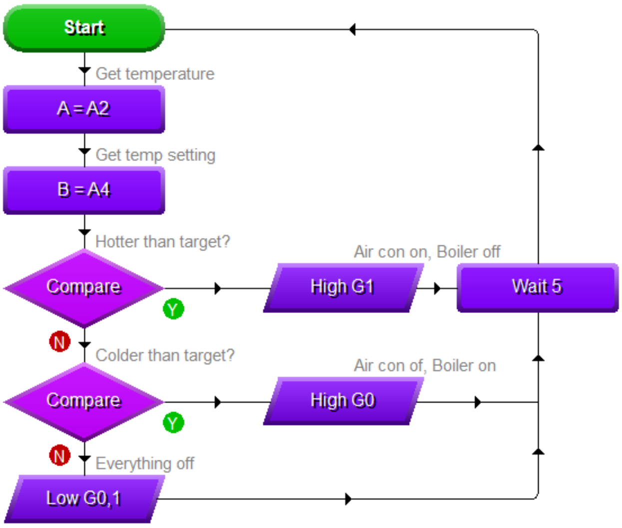
4.3. To convert one of the LEDs to a 240V AC power supply, a relay would be needed (driven by a high-power NPN transistor) and with a flyback diode for protection. This is because the AC power source should not be connected directly to the DC power.

5.1. To control the temperature, this flowchart could be used. An analogue input pin has a thermistor connected to it, and the result is stored in a variable, A.

A potentiometer is used to set the target temperature, and the analogue value is stored in B.

If A > B, then the boiler is turned on and the A/C off.

If B > A, the A/C is turned on, and the boiler off.

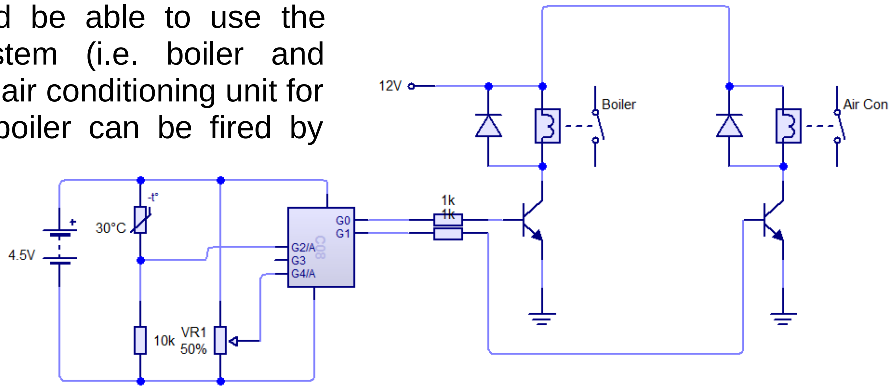


If A = B, then everything is turned off.

Once the action has been taken, there is a 5 minute delay before the process repeats, so that the system is not constantly switching.

5.2. The control circuit would be able to use the house's central heating system (i.e. boiler and radiators) for warming, and an air conditioning unit for cooling when required. The boiler can be fired by wiring a relay into the back of the control unit.

Premium A/C units have external inputs that can be triggered by closing pairs of contacts on their control unit. To achieve this electronically, I'd use a SPST relay.



If a single room were being heated (as opposed to a house in the question), I could take a 2kW electric fan heater, and energise this through the relay, and take a standard oscillating fan through the other.

By using the circuit drawn above, the desired temperature can be selected (the input would need calibration, so that target values could be written on to the housing the pot was placed into, and these could be interpreted by the PIC to ensure the correct temperature is achieved.

The thermistor would also need to be calibrated through experiment, again to ensure that the system was accurate. This could be done by submerging the tip of the thermistor in a cup of water with an accurate thermometer in it, then slowly heating the water and recording the analogue values for each temperature. From this, a formula could be derived for all input values.

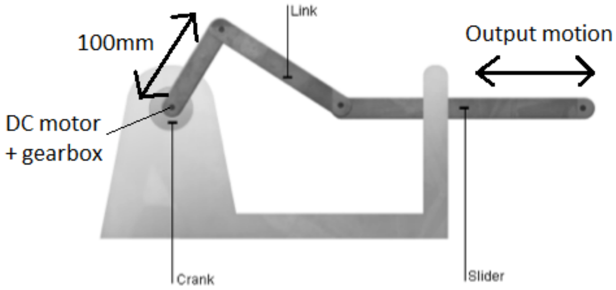
5.3. Insulating a house carries a number of benefits for the homeowner:

a. Lower heating bills – If heat is less able to escape through the roof, windows or walls, then less energy will need to expended in order to maintain the target temperature for the home.

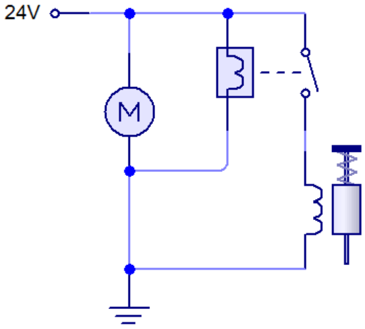
b. Warmer / Cooler house – If well insulated, then in hot weather, the interior of the house will absorb less heat, and the opposite effect will be observed in cold weather, making the house more comfortable.

c. Faster heating – As the heat loss will be lower in a well-insulated house, the speed at which the house can be brought up to the desired temperature when the heating is turned on will be accelerated.

6.1. This could be achieved with a double-acting pneumatic cylinder, or a rack and pinion gear with microswitches at either end. I will show how to do this with a crank, link and slider, connected to a 24V DC motor, and powered by a 24V DC power supply.

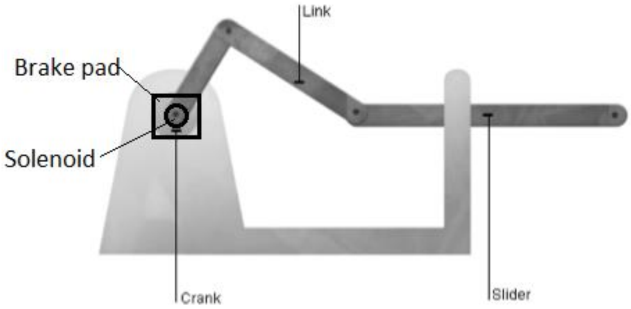


By setting the crank arm to 100mm, the output motion will be limited to 200mm.



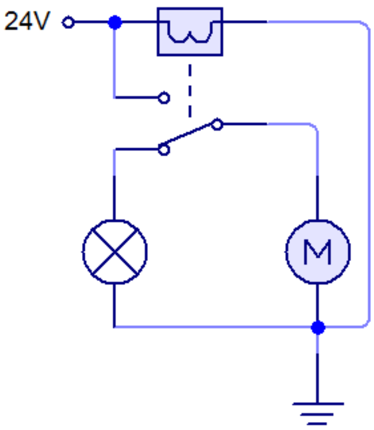
6.2. Method 1: To stop the motor shaft spinning, I would first need to identify when the power has been removed. This would be accomplished by the use of a relay, as shown in this sketch.

Here, when power is supplied, the relay closes, and a spring-return solenoid with a brake pad mounted to the end of the plunger arm is retracted, allowing the motor to spin.



When the power is cut, the relay contacts will open, causing the solenoid to return to its rest position, applying pressure to the pivot area of the crank.

This in turn applies friction to the crank, transferring the kinetic energy into heat energy and so slowing the DC motor shaft.



Method 2: The power loss would be detected by a relay as per the first method. This time though, when the relay loses power, the second thrown of the SPDT relay would change the circuit, so that the DC motor would be short circuited through a low-value resistor, which would provide a rapid braking effect.

The inductance created by the motor as it slows and spins in One Direction will power the motor in the opposite direction, causing braking to occur.

As in the short-term a large amount of current will be temporarily drawn, I was initially tempted to use a low value resistor (e.g. 2r2), but for reliability, I have used a filament bulb, which I feel is better designed to handle the short term current spike. It may or may not light up during braking, depending on the size of the motor being used.