2014 Paper, Model Answers

Question 1

01. By their definition, non-renewable energy sources (e.g. Coal, Gas, Oil, Uranium) are finite and will eventually be depleted. As a relatively small island compared to the rest of the World the UK has limited supplies of oil, but has recently discovered shale gas which may provide energy security in the medium term. We have a great deal of coal in the UK but no uranium, which is imported.

From an environmental/sustainability standpoint, it is advantageous to take advantage of clean forms of energy generation where possible. Wind, tidal and solar power can all be harnessed to reduce fossil fuel dependency which will slow the rate at which non-renewable energy sources will be drained and reduce the overall impact on the environment. The process of transporting fossil fuels to power stations in itself also further contributes towards air pollution and global warming.

Unfortunately the availability of clean energy sources tends to fluctuate – the sun isn't always visible, the wind doesn't always blow and so forth. As such, there will always be a demand on fossil fuels to make up the shortfall.

From a financial perspective, as technologies that underpin traditional generation methods such as coal and gas are well developed and reliable, and while the cost associated with their initial construction is high, this can be quickly recovered throughout the life of the plant. As their popularity increases, solar panels and wind turbines become cheaper to manufacture, but are still beyond the reach of many British households for small-scale micro-generation.

02. Electric vehicles can come in several forms, such as scooters, cars and trains.

Advantages

Traditional cars continue to burn fossil fuel when sat still as the engine idles over. While the amount of fuel an individual vehicle consumes is miniscule, when this effect is happening on millions of vehicles sat in traffic all around the World simultaneously, the compound effect is substantial. Electric cars (or hybrids such as the Toyota Prius) use no energy when they are sat still, reducing the amount of air pollution.

Electric cars make little to no sound when operating, as they are not exploding fuel on order to drive. While this reduction in noise pollution makes for a more pleasant environment, there can be a downside in terms of road safety. There have been incidents where pedestrians have walked in front of electric vehicles that are pulling out of parking spaces, as they don't hear them. As a consequence, laws are being drafted by the EU to stipulate that EVs have to make a sound, when moving at low speeds to help protect pedestrians.

Disadvantages

Manufacturing batteries is an industrial process which involves processing large amounts of chemicals in order to make them. This in itself contributes towards global warming.

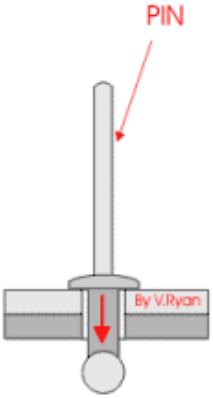
Some feel that overhead power lines for electric trains spoil the landscape. There have also been instances where people are electrocuted by the lines (e.g. by flying kites into them, with long fishing poles, etc). Additionally, electric trains are unable to operate on lines which aren't electrified, necessitating costly upgrades wherever it is desired to operate them.

Any battery has a finite lifetime, and battery performance (i.e. charge capacity) will suffer over time. Eventually, spent batteries will either need to be recycled or sent to landfill depending on the technology available at the time. Range is a current limiting factor with electric cars, as only the most expensive models enjoy ranges of over 100 miles.

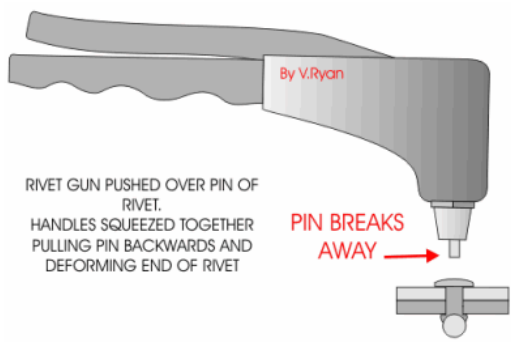
While new ultra-capacitor batteries are in development, charge time for an electric car is typically lengthy (8 hrs+) compared to a diesel/petrol/LPG vehicle which can be re-filled in a few minutes. Charging stations are starting to appear in supermarkets and shopping centres, but are not consistently available nationwide at the current time.

<u>Question 2</u>

03. First joining method is pop-riveting, used to join two pieces of sheet aluminium together. I'd start by clamping the two pieces together, then drill a hole slightly larger than the size of the rivet through the two sheets.

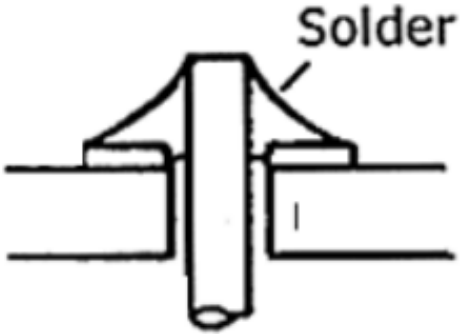


Next, I'd place the rivet through the hole, ensuring it was all the way in.



I'd then push the rivet pliers onto the pin and pull the handles to deform the bottom end of the rivet (locking it in place) and breaking off the pin on the rivet.

The second method is soldering, which is used in plumbing and electronics. In this example, I will be bonding the leg of an electronic component to the copper track on a PCB through the use of a soldering iron, heated to around 300℃. If required, the copper track can be rubbed with wire-wool prior to soldering to remove any oxidation. The leg and track are heated with the iron for around 3s and then the solder (usually pre-fluxed) is inserted so that it flows cleanly over the component leg and track to form a peak. The soldering iron is then removed, and the component leg trimmed with a side-cutter.



(Note: Question only asks for advantages when making mechanical parts)

04. Wastage is the process of starting with a block/sheet of material (metal in this question) and removing unwanted areas to produce the desired part using different

tools. This could include drilling, using a hacksaw, filing, or the use of a water-jet cutter or milling machine. The advantages of wastage are that if working on a small scale, many of the hand tools are readily affordable and require little training to use to make simple parts. If manufacturing on a large scale (e.g. using a plasma-cutter or waterjet), high precision is available. On a mass-production scale, using tools such as a blanking press allows for high volume parts to be punched out of sheet metal at high speed and with a consistent quality output. This would be convenient for making gears.

Redistribution/deformation is the method by which a material's shape is changed through mechanical methods – the mass of the resulting workpiece is unchanged. This is less wasteful than using a wastage method (although in theory, the wasted parts can be collected, melted and re-cycled). Industrial machinery for these can be configured to work with the majority of metals, and processes such as extrusion could be used to create drive-shafts or frames for parts to be connected to during the fabrication process. The lack of waste makes this an advantage over attempting to form similar parts by milling, for instance. Another advantage of using deformation methods is the strength of the finished product – the grain structure of a

Question 3

05. I will consider the design of a vehicle engine. One destructive test would be to run the engine as full speed on a simulated load night and day until it fails. Once this happens, the engine can be dismantled and the responsible part(s) can be identified post-mortem, then re-engineered to increase strength/remove design flaws before the process is repeated. This can happen several times to help create an optimized design.

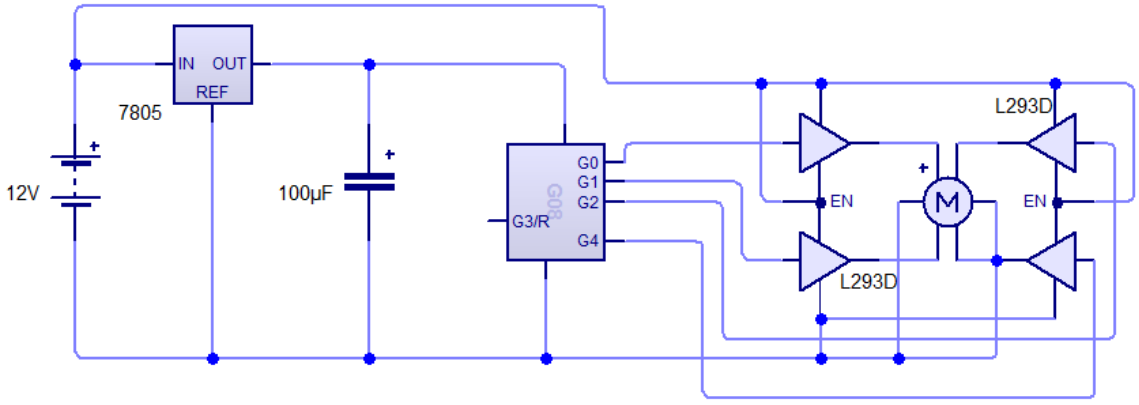
Another product might be a vacuum cleaner. A destructive test could be to put the cleaner at the top of a flight of carpeted stairs, then to have a tester drag it down the stairs to that it bounces down each step. This can be repeated until the housing breaks, when the failing component can be identified. As with the previous example, this can be re-engineered and the process repeated to improve the product before commercial release.

06. Non-destructive testing is where testing is undertaken without damaging the product/part itself. A product such as a part of a jet turbine could be tested with infra-red imaging. This is where a special camera is used, which renders the heat radiated as an image on a display, using different colours to represent different temperatures. Any areas of the turbine which are becoming hotter than they are designed to can be quickly identified, and the underlying causes identified and rectified without having to break the turbine.

Another product could be a multimeter for use in a lab. The housing could undergo a visual inspection before being boxed for shipping. This could either be performed by inspectors looking over the product's exterior for scratches, imperfections in the plastic, or excess flashing on the housing, possibly aided by a magnifying glass to provide better resolution.

Question 4

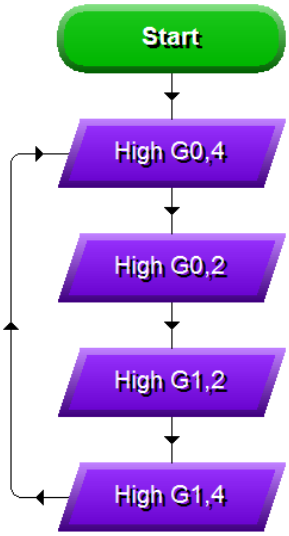
07. My first idea for a stepper control circuit would look like this:



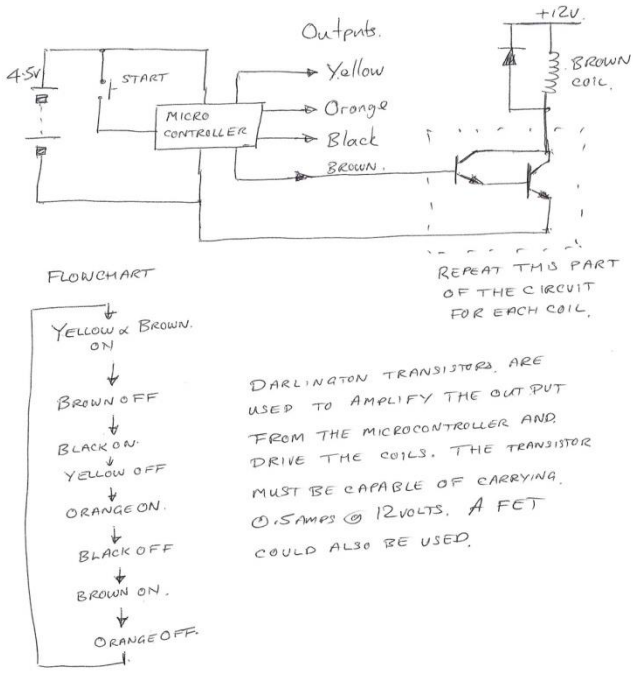
By using an standard L293d H-bridge, the coils can be energised in any order by the use of a program on the PIC chip. I would connect the coils in the following order:

0 - Yellow
1 - Orange
2 - Black
4 - Brown

My program could look like this (if needed, I could use a short pause of a few milliseconds to slow the motor).

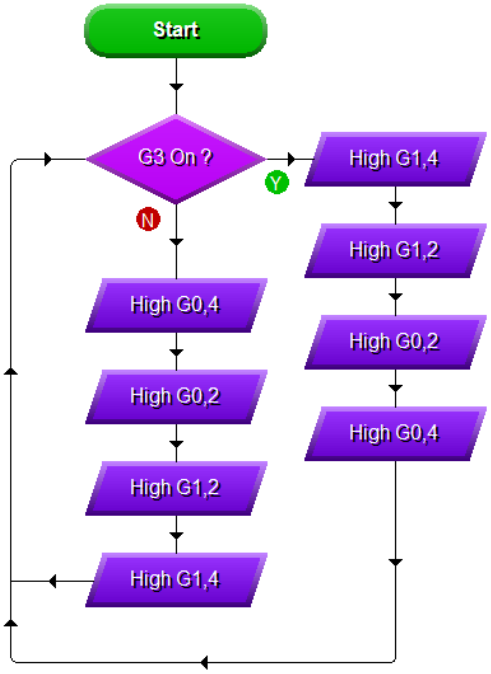


The second idea uses a series of transistors set up as Darlington pairs (to amplify the output current)…



Each coil has a flyback diode in conjunction with the coil, so that any back-EMF is fed back into the coil, rather than being allowed to damage the transistors.

08. To reverse either of the above two solutions, I would simply need to reverse the sequence in which the coils are energised (so the sequence order would go 4-3-2-1-4 etc). To allow this to happen at any point, I would add a PTM switch as a digital input to the PIC, and modify my program as follows:

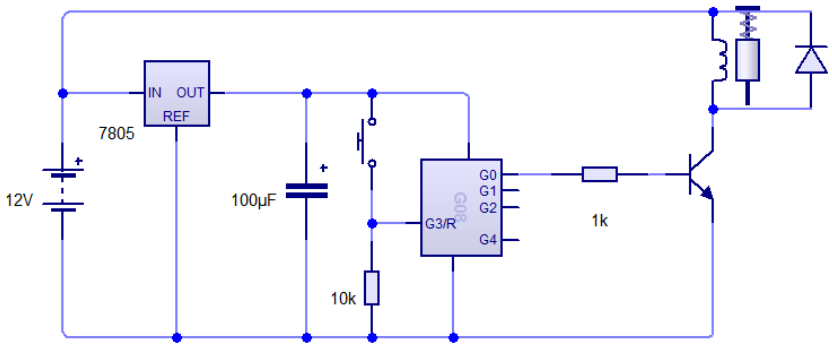


09. In a PIC program, an input in a control program is listened for at specific points in a program, leading to appropriate actions being taken at that point in time. They involve some type of logical comparison (e.g. Is input 1 on?). In my previous program for instance, I only check the state of my input after each complete step.

An interrupt is triggered when a certain condition is met at <u>any time</u> in a program, and causes a specific set of instructions to be executed, before (optionally) returning to the point in the program prior to the interrupt. This could be relevant in a safety system on a robotic arm for instance. If a user breaks the light beam 'cage' surrounding the arm, an interrupt could be triggered to immediately cease all movement and sound an audio/visual alarm.

<u>Question 5</u>

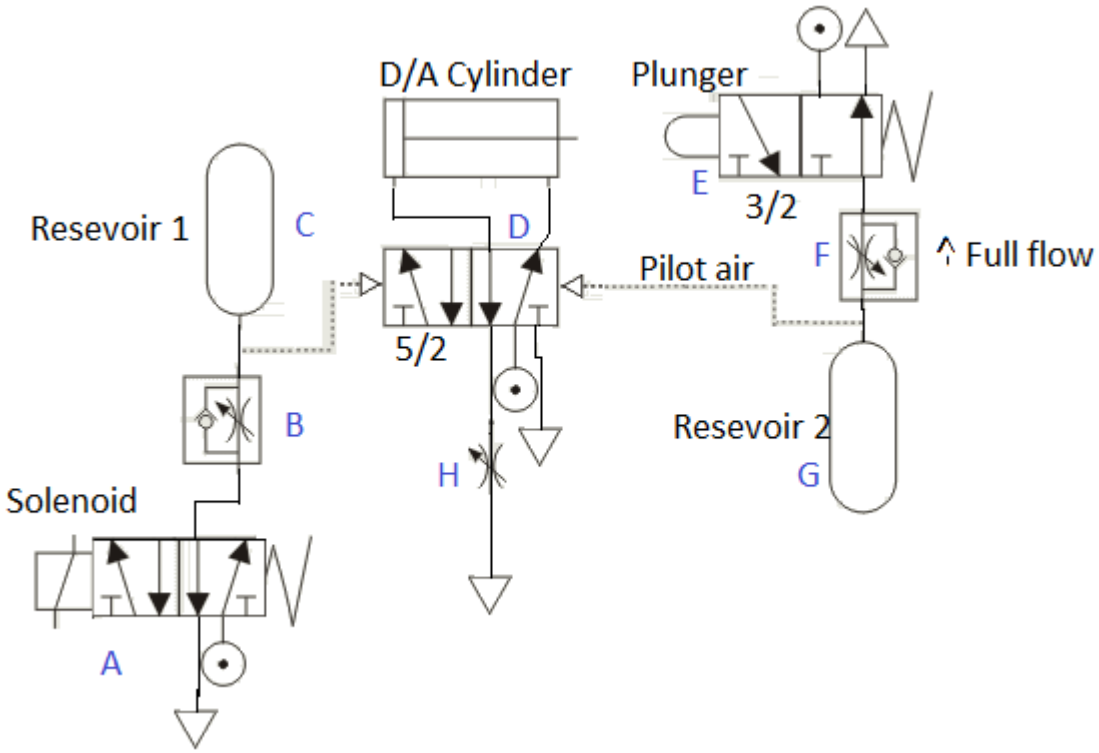
10. This system consists of two parts. A small PIC circuit with a simple program to energise the solenoid on the pneumatic circuit when the PTM is **momentarily** pressed, and the pneumatic system. *(Note: If the question had said that the pneumatics were needed when a switch was held down, a push-button activator could have been used in place of the PIC and solenoid!)*.



When the PTM is pushed, the PIC program energises the solenoid for 10s, pushing the 5/2 valve (A) into its second position, sending air slowly through the full-flow restrictor (B) which fills up reservoir C. If the restrictor is set correctly, it would take 5 seconds for the pressure to rise to the correct value to operate the five port valve (D).

When this switches over it goes to the left of the D/A cylinder making it extend quickly. The cylinder rod operates the push button valve E, this sends air slowly through F and taking 20 seconds to fill up G and operate the 5 port valve sending it

back to the start position. Air goes to the right hand side of the D/A cylinder sending it back in but only slowly because the air can only escape slowly from the left hand side of the cylinder because of H.



11. The primary advantage of using pneumatics in industry is the ability to exert larger forces than can be easily achieved using the equivalent electronic part. This said, in order to provide higher level of force one would need to move towards a hydraulic system instead.

Pneumatics also offers a safer (and cleaner) system then their hydraulic equivalents; a burst airline will only produce air. A hydraulic system will emit high-pressure oil. An exposed electrical wire could represent a shock risk. This can make pneumatic systems desirable in hazardous situations.

Compared to electric systems such as stepper motors, pneumatic systems offer less accuracy in terms of providing precise positional movement. More sophisticated pneumatic systems typically require electronic control systems (e.g. solenoids) in order to make them work autonomously. They tend to be slower moving than electronic control systems.

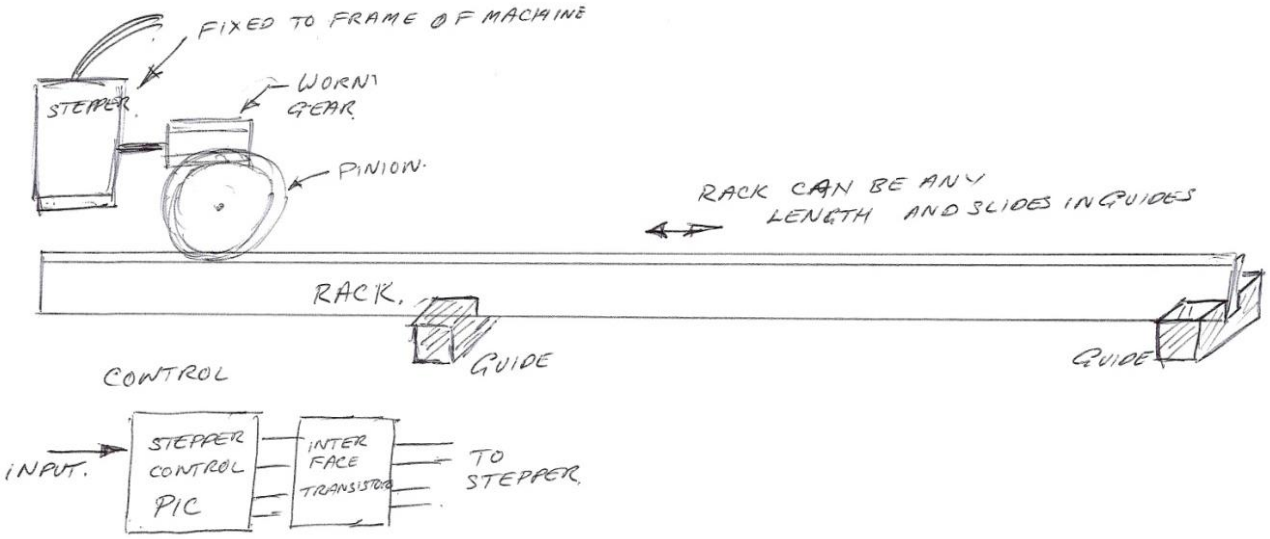
Pneumatic systems are costly to initially implement, as a compressor is needed, as well as airlines and valves. They are considered more environmentally friendly than hydraulic systems due to not using oil to transmit force.

Question 6

12. The stepper motor drives a worm which drives a pinion which moves a rack. The stepper and gears are fixed in place so the rack will move and move the component of the machine. The guide makes sure the rack goes in a straight line.

If the teeth on the gears are 2mm each tooth will move the rack 2mm. The stepper motor will produce 200 steps per revolution so one step will move the rack 1/200th of 2mm or 0.01mm.

The stepper motor is driven by a PIC which provides the sequence for the coils and the input tells the stepper motor how many steps are needed.



13. In areas such shopping centres, electrical systems tend to be used to operate sliding doors. This is likely because electricity is already available to power the door, the door will not be excessively heavy, and it would negate the need to have a compressor, valves, cylinders and air lines installed in order to provide the desired movement. It would also work quietly, whereas a pneumatic system could be very loud and unpleasant for shoppers to experience. Additional advantages would be that a range of input, process and output components can be brought ‘off the shelf’ already and would (presumably) be cost-effective to implement. The electrically controlled system would need some sort of mechanism (e.g. rack and pinion, chain and sprocket) building to move the door. Another advantage of electronic systems is be that detecting the end of travel (and if someone is caught in the doorway as it closes) can be easily detected with different sensors. Logic can be programmed and optimised easily with a PIC or PLC.

Pneumatics would allow the door to be driven directly, negating the need to produce a separate mechanism – this would facilitate a simpler system design. The exerted force *could* be far greater (if the door in question was for a bank vault, for instance). If all the exhausts and compressor were located on the roof of the building in question, the operation of the system could be almost silent. It is probable that in order to ensure safe operation, the system would need to be interfaced with some electronics to provide sensor input.