Section Four — Systems and Mechanisms

Systems

It's often handy to think of a device as a "system".

A system has various parts that work together to perform a set function.

In D&T systems may include the use of mechanisms, electronics, pneumatics and structures.

Systems can be broken down into three simple elements: Input, Process and Output.

Subsystems — Small components of a Larger System

1) All complex systems can be broken down into a number of smaller systems, called subsystems.

2) A simple example of this is a bicycle. As a whole system it has an input — movement of your legs, a process — turning the pedals, which link to the wheels, and an output — forward motion.

You can break it down further into smaller subsystems like this:

- Wheels and frame — a structural subsystem.
- Pedals and gears — a mechanical subsystem.
- Breaking system — a mechanical or pneumatic subsystem.

Mechanical Systems — Systems that Use Mechanisms

1) In Resistant Materials you need to look in detail at mechanical systems.

2) All mechanical systems have mechanisms which transform an input motion and force into a desired output motion and force.

3) They will be designed so that you can gain some advantage from using them — in other words they make something easier for you to do. This idea is known as 'mechanical advantage'.

4) For example, a car jack lets you lift up a car, a job you couldn't do without it (unless you're Super lift-cars-without-a-jack Man). The mechanism gives you an advantage.

Motion — Different ways of looking at How Things Move

In this section you will be looking at a number of different mechanisms, many of which are designed to change one type of motion into another.

You need to understand four different types of motion:

1) **Linear Motion** — moving in a straight line.
2) **Rotary Motion** — moving in a circle, e.g., a wheel.
3) **Oscillating Motion** — moving backwards and forwards in an arc, e.g., a swing.
4) **Reciprocating Motion** — moving backwards and forwards in a straight line.

Do your ears hang low, can you oscillate them to and fro...

So the idea is — devices have an overall function, but you can break down this big system into small subsystems — each doing a specific task. It's a bit like football — you've got strikers, midfielders, defenders and the goalie, all doing different jobs, but with the overall aim of winning the game.

Gear Mechanisms

The 'process' part of a system could include one or more mechanisms. The next few pages are dedicated to making sure you know about all the main kinds of mechanism. First up — gears...

Gears are toothed wheels which interlock (or mesh) together as a way of transmitting rotary motion.

Gear Train — Linking Gears Together

Where two or more gears are linked together it is called a gear train.

The DRIVER GEAR, turned by hand or motor (the input), turns the driven gear (the output). Both will automatically turn in different directions. If the driver is turning clockwise, the driven will turn anticlockwise and vice versa.

By using a third gear called an IDLER, the driver and the driven gears will both turn in the same direction. The size of the idler will not alter the speed of the other two gears.

A COMPOUND gear train is where more than one gear is fixed to the same shaft. This is handy because it lets you change the gear ratio easily.

Gears can change the Type and Direction of Motion

RACK AND PINION gears are used to turn rotary motion into linear motion. The pinion, a round gear, is turned to move a flat gear, the rack.

A WORM DRIVE AND WORM WHEEL change the direction of rotation through 90°.

The worm drive (the driver) only has one tooth and will turn much faster than the worm wheel, which with many teeth will turn very slowly.

BEVEL GEARS also change the direction of rotation through 90°.

The teeth are angled at 45° so the gears fit together at right angles.

Have no fears, dry those tears, it's a wonderful page all about gears...

For a gear enthusiast like myself this is a very special page. Just look at those beautiful, greasy, perfectly-crafted lumps of spinning metal — rrrrrmm... Anyway, even if they don't excite you, you still need to learn them all. There's nothing difficult here, just 7 gear types to sketch and learn.
Belt Drives, Chains and Pulleys

And the fun continues on page 36 with exciting stories about belt drives, chains, and pulleys...

Belt Drive — Transfer of Power and Movement

1) A belt drive transfers power and movement from one rotating shaft to another.
2) Belt drives are used in pillar drills. The flexible belt links the motor to the drill shaft, and can be put in different positions to make the drill turn faster or slower.

Chain and Sprocket — Transfer of Power and Movement

1) A common example of a chain and sprocket mechanism is on a bike. There are two sprockets (toothed wheels) linked with a chain, made up from loads of links.
3) This has the advantage that it can't slip like a belt drive could.

Velocity Ratio — To Work Out Speeds

1) With both of the above systems, if you alter the size of the wheels or sprockets, you change the speed that they turn.
2) The relationship between the two is summed up by the velocity ratio.
3) With both systems, simple formulas will help you calculate the velocities:

Belt Drives

\[
\text{RPM of driven pulley} = \frac{\text{RPM of driver pulley} \times \text{diameter of driver pulley}}{\text{diameter of driven pulley}}
\]

Chain and Sprockets

Velocity ratio = \frac{\text{Number of teeth on driven sprocket}}{\text{Number of teeth on driver sprocket}}

Pulleys — Can help gain Mechanical Advantage

1) Pulleys are another way to gain mechanical advantage when lifting a load.
2) One pulley on its own will not make a load lighter, but it will reverse the direction of the force required. You will be able to lift the load by pulling.
3) If set up in the correct way pulleys can make things appear a lot lighter than they actually are. For example, one fixed pulley and one moving pulley (a block and tackle) will mean you only need half the force.

Baby don't break my heart, pulleys stay and we can work it out...

Make sure you learn those formulas. Make up a few simple examples (and sketch them) and try out the formulas on them — they make a lot more sense when you try them with actual numbers. I'm going to make myself a lovely cup of tea now because I reckon I deserve one.

Cams and Cranks

Cams — Change Rotary Motion into Reciprocating Motion

1) A cam is a mechanism that converts rotary motion into reciprocating motion.
2) The cam mechanism has two main parts — the cam itself and the follower.
3) The cam is a rotating shape that comes in many different shapes and sizes.
4) The follower follows the shape of the cam. It may simply rest on the cam, or it may have a small wheel to reduce friction.

Here are a few basic cam shapes that you need to be able to recognise:

- **Circular Cam** — Also called offset or eccentric — produces a uniform reciprocating motion.

- **Parabolic Cam** — For half of the revolution the follower will not move, then it will gently rise, and then suddenly drop. It will only work in one direction.

- **Tangential Cam** — Has four sides (the stick out). For each turn of the cam the follower will rise and suddenly fall four times. This cam shape will also only work in one direction.

Crank and Slider — as seen in Pistons

1) This mechanism can be found in steam engines. The reciprocating motion of a piston is turned into rotational motion.
2) Both parts are joined together with a connecting rod. The mechanism won't work unless the red can move at both ends.

Revision can be tough, but I know you can do it...

Cams turn rotation into reciprocating motion. Cranks can do the same and they can also do the opposite.
Levers and Links

Levers are used to help move or lift things. There are three different types of lever that you will need to know about.

First Class Lever — Pivot in the Middle
1) All first class levers have the pivot between the effort and the load.
2) By using this type of lever a large load can be lifted using a smaller effort — the lever can give you a mechanical advantage.
3) As you move the pivot closer to the load it becomes easier to lift.

Second Class Lever — Load in the Middle
1) Here the pivot is at one end of the lever and the effort is at the other end.
2) Again the closer you put the pivot and the load, the easier it is to lift.

Third Class Lever — Effort in the Middle
1) In a third class lever the effort is in between the load and the pivot.
2) Third class levers can be things like fishing rods, cricket bats and garden spades.
3) Moving the effort and pivot apart makes it easier to move/lift the load.

Double-Acting Levers — First Class Levers Joined Together
Sometimes levers can be joined together. A double-acting lever is when you have two first class levers hinged together at the pivot point. A common example of this is a pair of scissors.

Links Connect Different Parts of a Mechanism
A link is something that connects different parts of a mechanism together. Here’s a few common examples:
1) Simple links can:
   * transfer forces and
   * change the direction of motion.
   In this example the input and output motions are in opposite directions.
2) A bell crank changes the direction of a force through 90°.
3) Lazy tongs use loads of levers linked together.

Revision Summary for Section Four

OK, so mechanisms probably wasn’t the most fascinating topic you’ve ever read about. But it wasn’t too bad... and it’s pretty easy, really. It’s not very hard, so there’s no excuse for not learning all the examples in this section. There’s nearly always a mechanisms question in the exam. You might have to incorporate a particular mechanism into a design and for this you need to know a range of examples, what they do and how they do it. Anyway, enough of me rambling... GET ON WITH THESE QUESTIONS.

1) Describe the three elements that any system can be broken down into.
2) Some large systems can be split into smaller systems. What are the smaller systems called?
3) Describe three subsystems of a bicycle.
4) What is mechanical advantage?
5) List and describe, with the aid of simple diagrams, four different types of motion.
6) Give a simple explanation of what gears do.
7) What is a gear train?
8) What is the difference between a driven gear and a driver gear?
9) Describe the purpose of an idler gear.
10) What happens if you change the size of an idler gear?
11) Explain the term ‘gear ratio’ and give an example of how it is calculated.
12) What’s the advantage of using a compound gear train?
13) Sketch a rack and pinion gear mechanism. Describe the motion involved.
14) Which turns faster — a worm drive or a worm wheel? Explain your answer.
15) What does a bevel gear do?
16) Explain what a belt drive is and give a simple example.
17) What is the advantage of a chain and sprocket mechanism?
18) What does ‘velocity ratio’ mean?
19) How can a pulley system give you mechanical advantage? Draw an example.
20) Briefly describe a cam mechanism.
21) Sketch and describe four different cam shapes.
22) Which cam shapes can only rotate in one direction?
23) Give an example of where you might find a crank.
24) Where might you find a crank and slider mechanism?
25) Sketch and describe a first class lever, and give an example.
26) Sketch and describe a second class lever, and give an example.
27) Sketch and describe a third class lever, and give an example.
28) What is a double-acting lever?
29) Write a simple definition of a link.
30) What two things can a link do?
31) Sketch a bell crank and describe what it does.
32) Sketch a pair of lazy tongs.

Treat me bad, do me wrong, just say you'll never lever me...
That sounds like a song doesn't it. Don't know which one though. If you think you know, send your answer to me at... err actually, don't bother — I don't really care. Anyway, it's another easy page. As usual, the best way to learn is to scribble (and sketch) what you remember until you know it all.