All about Printing

The year 1826 marked the beginning of photographic printing when the Frenchman Joseph Nicéphore Niépce invented a primitive way of recording a photographic image and transferring it, using a conventional ink-based printing process, to paper. Ironically, ink was there at the very beginning of photography, and today it has become resurgent through inkjet technology.

Right: *Nicéphore Niépce's 'View from the Window at Gras', considered to be the first permanently captured image.*

Niépce pre-dated fellow-countryman Louis Daguerre's polished metal photographic imaging process that was invented in 1839, called the Daguerrotype, and Englishman William Henry Fox Talbot's calotype silver chemistry-based process invented in 1840 that produced photographic images on paper.

For more than a hundred years, many further developments of silver-halide chemistry went on to dominate photographic film and printing, and indeed wet-process silver chemistry is still the main process used by mini-labs and professional processing labs owing to its relative speed and the low cost.

But of course, options for the contemporary digital photographer are by no means limited to wet-process printing, and there is no longer any need for a second exposure stage from a negative (or positive) original on film. Instead, digital image data is fed to an electromechanical printing device to produce the final printed image.

Two technologies, in particular, are now in widespread use, both in homes and offices as well as photographers' studios: dye-sublimation, dye-sub for short, and inkjet. These technologies can be packaged in much more compact and affordable hardware than those heavy, industrial wet processors - hardware that can sit on your desk and even be taken out and used on location, using a battery.

Dye-sublimation

The dye-sublimation process is fast, its costs have been steadily reduced and it's popular as a simple and convenient method of producing small and medium-sized colour prints.

A thermal process literally heats a thin plastic film impregnated with coloured dye, rendering dots of yellow, magenta and cyan dye from the film onto the paper. Each dye colour is applied in turn, which requires the paper to be over-printed three times. In order to protect the delicate dyes from moisture and physical damage, a clear plastic oversheet is laid down and this also provides a shiny surface finish, which can be compared with conventional glossy prints.

Photographically, dye-sub prints can vary quite widely in print quality. The need to print the image over three passes makes the registration of each pass critical in order to produce a sharp, contrasty, image and, as the cost of dye-sub printer hardware has been steadily reduced, some dye-sub printers do a better job than others.

Another issue with dye-sub print quality is that black and grey tones are produced entirely from coloured dyes. Achieving neutral tones this way is quite challenging. A dye-sub print has a characteristic quality of its own compared to conventional or inkjet prints. Perhaps

more concerning is evidence from independent testing that indicates poor light fastness, or resistance to fading by prolonged exposure to light.

But it's not all bad news for dye-sub printing. Unlike inkjet technology (explained in the next section), there is usually no ambiguity about the cost per print; dye-sub print cartridges usually come with a matching pack of paper. Print quality from dye-sub is also largely free from the graininess that is associated with poor-quality inkjet prints. With their protective top layer, dye-sub prints are admirably impervious to water spillages and other surface damage. Print speed is usually as fast or faster than comparable inkjet printers, though dye-sub printers are often mechanically noisy while in use and more expensive per print.

Dye-sub printers earn their place in the market for simplicity and convenience but they aren't nearly as versatile as inkjet printers. With dye-sub you are often limited to one set size of print, or a small selection of other pre-set sizes. The majority of consumer dye-sub printers produce prints no larger than 6x4 inches. Dye-sub printers aren't designed to be used with cheap plain paper so you can't print letters to your bank manager as well as print your holiday snaps using the same hardware.

Inkjet

After a shaky start, dogged with image quality reservations and doubts over resistance to fading, inkjet printing technology is now the leading photo printing technology except for high-volume photo print production. Inkjet has become the favoured printing process for archival and large-format photo printing and its versatility has enabled inkjet to dominate the home and small office market, with printers able to produce good-quality photos as well as business and graphic documents printed onto a wide variety of media.

The best inkjet printers, combined with great leaps in the technology of inkjet printer inks, means that inkjet printers are now routinely used for high-quality fine art archival printing, both of photographs and photographed works of art, such as paintings and sketches. At the other end of the market, inkjet printers are competing hard with dye-sub technology offering convenience and immediacy in the form of portable mini-printers designed to produce 6x4 inch type photo prints.

Inkjet's versatility is unparalleled. The same printer that produced a blow-up print of your latest photographic masterpiece on a variety of gloss, matt, semi-matt/gloss photo papers, can also print diagrams and charts on plain paper and card - as well as those letters to your bank manager. Inkjet technology is even used in the food industry, from labelling of foodstuffs, to printing photographic images onto cakes using food dyes instead of ink.

Print fade resistance has been improved markedly during recent years, though the subject of cheap third-party inks, which I'll deal with separately, can mean that users' experiences may not be as good as they should be.

But what lies at the core of the popularity of inkjet for photo printing is its ability to produce excellent photo-quality results, quickly and conveniently. The cost of inkjet printers has dropped in recent years, especially ‘All in One' or ‘Multifunctional' devices that combine a flatbed scanner with a printer. In fact, more multifunctional units are sold now than single-function printers.

Inkjet printing involves firing microscopic droplets of ink, usually water-based, as small as one picolitre, or a 10-12 litre, onto the surface of the print media. More technically

sophisticated inkjet printers are able to lay down droplets of different sizes to improve the definition and tonality of prints. Inkjet printer ink is not just coloured water and photographic paper bears little relation to the sheets that go into a copier machine. An inkjet printer lays down millions of these microscopic droplets of ink to build the smooth and rich tonal qualities that make a photo-realistic print. The way that those drops of ink behave when they land on the surface of the paper has a big influence on the colour, contrast, tonality and sharpness of the final print.

Ideally, each droplet of ink should create a well-defined spot of the correct size. Drops that overlap should not bleed into each other, corrupting colour in the process. The chemistry of the ink means that the colouring agent, which can be either a dissolved dye or a pigment in suspension, is just one of a team of ingredients that affect the surface tension of the liquid, its viscosity, its resistant to oxidation, how well it keeps pigment particles from crashing out of suspension, and much more.

The ink needs to be resistant to chemical reaction with the surface of the paper, as well as resistant to fading, both by visible light and UV, and chemical agents in the air, such as ozone, for example. Batch to batch consistency is essential too. Add to all that the growing expectation of tolerance to water exposure of a finished print and you begin to realise just how complex the engineering of inkjet printer ink is.

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Pigment-based ink drops sit on the paper's surface.

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There are two basic types of inkjet printer ink: **dye-based** and **pigmented**. Dye-based ink is formed using relatively small ink molecules that are completely dissolved in the water that is the usual solvent for consumer inkjet printers. Pigmented inks are formed by microscopic solid particles of coloured material that are in suspension. The correct ink type must be used with the correct printer model, otherwise the printer could be damaged.

Dye-based inks produce very high-quality results when printed onto micro-porous surfaces. You might think that a porous surface wouldn't exhibit a shiny glossy finish, but because the porosity is so microscopic, the surface can be almost mirror-shiny. The characteristics of a micro-porous media mean that when dye ink droplets land, they don't spread very far and they dry very quickly. This preserves the density of the colour and the definition of printed details very well and the glossy shine of the paper is unaffected.

This type of surface does not do much to protect the ink and in the early days the combination of dye-based ink and high-shine glossy papers added up to short print lives. But all the printer manufacturers are now claiming print longevity of several decades and even a hundred years if extra storage precautions are taken.

One type of photo media that is less fashionable than it used to be is swellable polymer surface photo paper. When inks were less resistant to fading, this type of paper was popular because it absorbed the ink into its polymer surface, sealing it in after drying and so protecting it from oxidation. But there were several drawbacks. This type of paper needs to be handled with care straight after printing and can take hours to dry completely. The polymer coating is not as resistant to water spillage or physical abrasion compared with micro-porous papers and the glossy finishes are not as shiny as micro-porous papers are.

They can exhibit less uniform surface shine, too, with unprinted or white areas shinier than areas that have been heavily covered with ink.

Pigmented inks are naturally more resistant to fading because the colour is sealed into microscopic solid particles, sometimes individually coated with a protective polymer layer. Unlike dyes, pigmented inks lie on the surface of the media that they have been printed onto instead of being absorbed. If the media has a high shine, pigmented inks can cause the shine to be dulled where there is a lot of ink laid down, causing an unpleasant variable

shine effect. Some pigment ink printers have a solution to this, variously called a gloss optimiser. This means the print has a uniform layer of ink, with clear ink being printed over areas that need little or no coloured ink.

Pigmented inks dry more slowly than dyes, but they are more suitable for printing on matt or plain paper surfaces, producing sharper details and deeper colours. Combined with specially coated papers made from high-quality wood pulp or cotton fibres, pigmented inkjet printers are the printers of choice among professional photographers producing so-called giclée prints for public exhibition or for archival work.

Print Heads

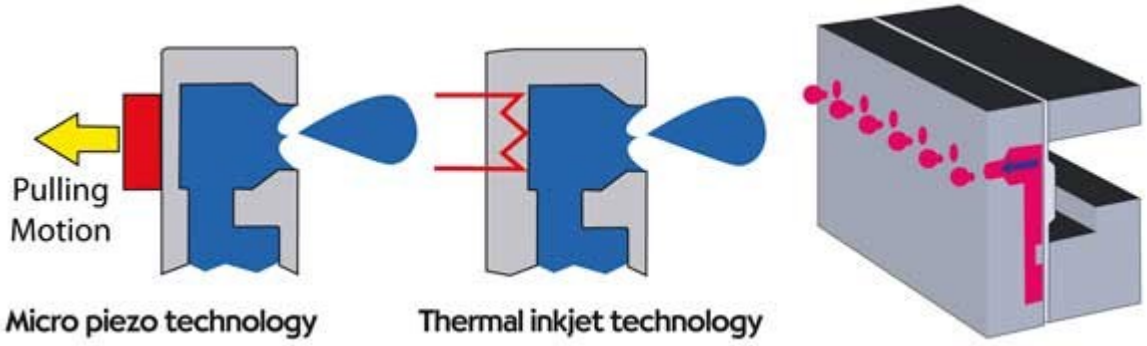
There are two main types of inkjet print head. They both incorporate tiny nozzles, through which ink drops are fired in precise doses many hundreds or even thousands of times per second. The most widespread way of firing the ink out of the print head is thermally. The chamber behind the nozzle is filled with ink, a heater vaporises the ink and this causes it to expand and escape via the nozzle, where it cools and forms a droplet before it reaches the media surface.

Some printers, notably those made by Epson, use piezo technology. Pass a current over a piezo material and it changes shape. This forms the basis for a microscopic piezo pump behind each nozzle in the print head. The ink is not heated this time. Manufacturers using both types of print head variously claim that theirs is superior. But both types deliver very good results, though thermal heads do seem to be used in printers that are physically faster.

Incidentally, some printers incorporate their print heads in their disposable ink cartridges. Others have permanent print heads, which can only be replaced by the manufacturer's service department and is often not economical. Kodak, some HP printers and some Canon printers have user-replaceable print heads that are independent of the ink cartridge, though in normal service you should not need to replace them.

Print Head Mechanisms

So how does the print head work?



Two main mechanisms lie behind the operation of inkjet print heads - thermal or ‘bubble' jet and micro piezo. The former works by heating the ink, vaporising it, causing it to expand through the nozzle. Piezo electro-mechanically squeezes the ink through the nozzle without heating it.

In diagram form you can see how an Epson micro-piezo print head is constructed. Channels form into chambers behind each nozzle and when a current passes through the piezo material it deforms, squeezing the chamber and expels a droplet of ink.

How Many Inks Do You Need?

An inkjet photo printer used to earn its ‘photo quality' tag because it offered additional inks to the standard cyan, magenta, yellow and, usually, photo black hues. These additional ‘photo' inks were lighter shades of cyan and magenta and were designed to refine the gradation of mid-tones and reduce the graininess of areas that required complex dot dithering to produce subtle tones, especially skin tones. And these photo inks certainly made a difference.

These days, many photo printers comfortably earn their ‘photo' credentials without extra photo inks. Manufacturers have achieved high-quality photo print quality with a standard set of inks through improved dithering of more and smaller ink dots. Good examples of photo printers that have extra photo inks do hold a critical advantage in photo print quality terms, but the gap is much closer than it used to be.

Higher-spec printers do tend to stick with added photo inks and lately you will find two or three greyscale inks included as well. These greyscale inks are provided to improve the neutrality of grey tones and to produce really good black and white prints.

Professional-style inkjet printers will also offer photo black and matt black inks. These aren't normally used at the same time. Matt black ink is used for printing on matt surface fine art papers and delivers a much deeper density on this kind of media surface. Photo black is laid down more sparingly and retains its shine on glossy finish papers better. One tip - many printers waste a fair bit of ink when switching between matt and photo black cartridges because the ink channels need to be flushed through the print head each time the switch is performed.

Cartridge Choices

Inkjet printers can be divided into three categories when it comes to ink cartridge design. The first type is a cartridge that not only incorporates reservoirs for the ink, but also houses the print head. In one sense, this arrangement is good because you get a brand new print head each time you replace the cartridge. However, historically, these types of cartridge have been expensive to replace and some argue that a permanent print head is often of higher quality and better specification, enabling faster and better-quality printing.

The second type of cartridge only contains the inks. These are cheaper to replace than those with integrated print heads but when one colour

is depleted, the cartridge may still contain a considerable amount of ink in the remaining colours.

The third type is the single ink cartridge. As its name implies, only one colour ink is contained and you only need to replace it once it has been depleted, theoretically saving yourself ink. There is a snag with this assumption because when you change a single ink cartridge, the print head must be primed and this usually involves priming all the cartridges, so ink does actually get wasted. In order to avoid the ‘domino' effect - when replacing one cartridge empties a near-empty neighbouring cartridge, etc. - it's advisable to replace any nearly empty cartridges at the same time as an empty one.

Some cartridges, notably with some Canon models, have transparent reservoirs, revealing exactly how much ink is visibly remaining. Others, notably Epson, have cartridges that log their use and prevent further operation once the ink has exceeded an estimated level. This is enabled by an on-cartridge chip and is important for Epson printers because they use a piezo electric print head that is vulnerable to air-locks if the cartridge runs dry.

Inks

If you choose to value inkjet printer ink by the millilitre, you might be shocked by how expensive it is compared to a variety of liquid commodities on the market. This, and the real cost in replenishing the ink for your inkjet printer, has naturally driven many of us to explore cheaper alternatives, such as refills and cheaper third-party cartridges from sources independent of the printer manufacturer.

Do independent third-party ink manufacturers have the necessary chemical engineering expertise to produce an alternative ink to that produced by the printer manufacturers? There is plenty of evidence to suggest that many third-party inks are inferior, so it's a risk to use them.

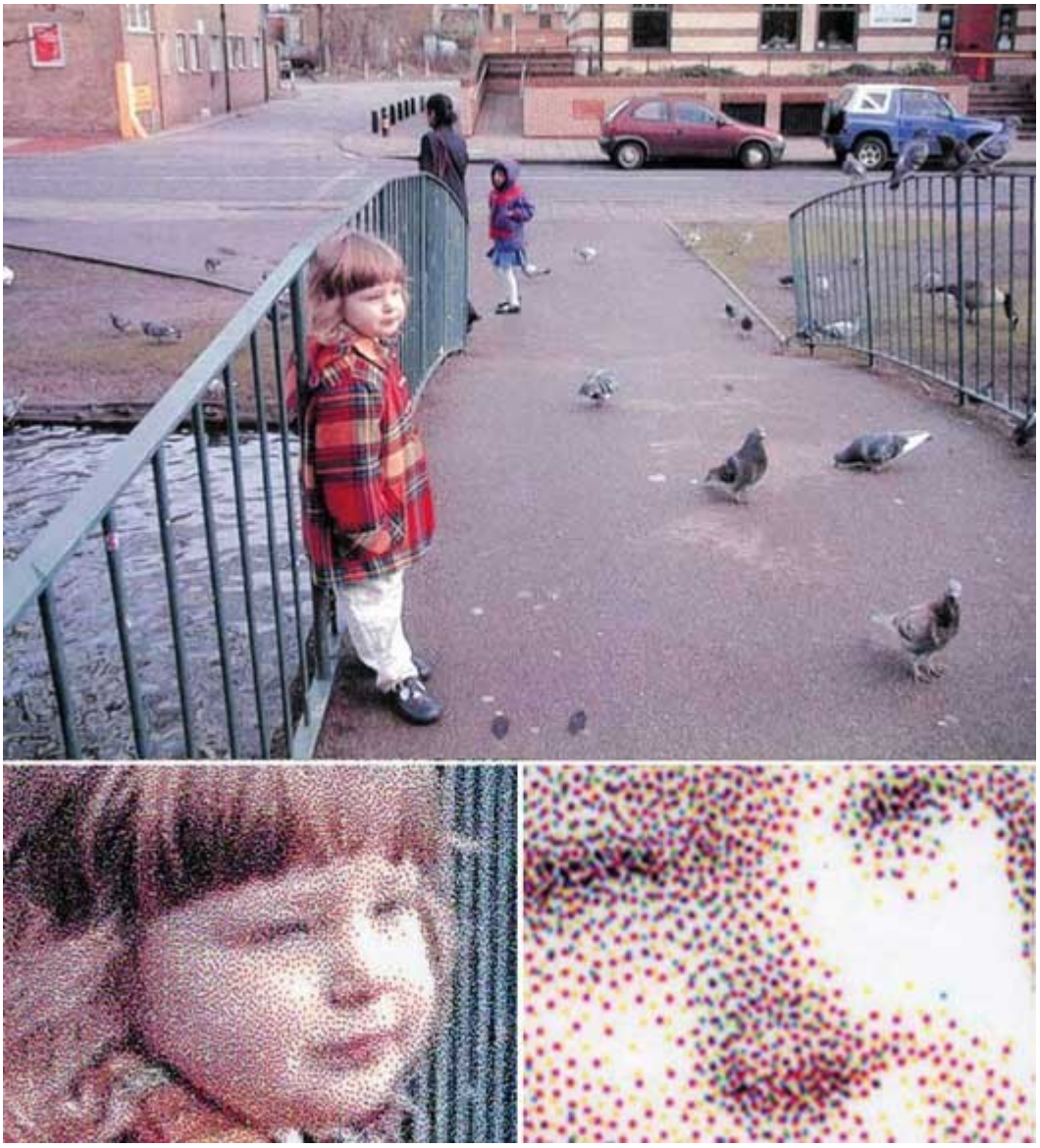
Printer manufacturers have to tailor the formulation of their inks to suit the particular technological needs of their printer hardware. These formulations are optimised for image colour stability, uniformity and minimal wear and tear on the delicate print heads, keeping them from getting blocked or worn out. Independent testers have, in the majority of tests, discovered that cheap third-party inks don't produce the same colours as the original manufacturer inks and they aren't as resistant to fading, sometimes by staggering degrees - with image stability measured in months instead of decades exhibited by original inks. One third-party ink brand even provided a dye-based replacement ink for a printer that required a pigment-type ink. This is akin to putting petrol into the tank of a car that required diesel. It's even more risky if the replacement cartridge incorporates a recycled print head, as you simply have no idea what its history is.

Are there any dependable third-party inks? It's difficult to say no, because there might be. But, as yet, there isn't enough testing of third-party inks to make any sensible recommendations, though there are some specialist suppliers of inks for converting photo printers to use such inks exclusively in bulk, and users do report good results. But these inks aren't aimed at ordinary casual users.

It's easy to feel like you're being ripped-off by printer manufacturers when comparing the cost of original and third-party inks. But many third-party ink suppliers have none of the chemical engineering backup required to produce consistently high-quality inks for your

specific printer. Much of the cheap ink on the market affords the vendors very high margins, too. So who's really ripping off whom?

I'd also argue that the valuing ink by the millilitre is missing the point. Besides the hard work that goes into making that liquid consistent in colour, resistant to fading and sympathetic to the smooth running of your printer, the ink is carefully packaged in its cartridge and costed into the lifetime of the printer. We demand cheap printers, so the manufacturer needs to recoup some of the original hardware cost through the consumables, including ink. Unfortunately, this means that more frequent use of your printer leaves you penalised as there are no established ways of rewarding heavier users with discounted ink beyond the supply, by some manufacturers, of larger-capacity ink cartridges.



This medium close-up (bottom left) of a typical inkjet print reveals the dot-dithering that makes up the printed detail that represents the image on the paper. Magnified further (bottom right) and you can see the individual dots of cyan, magenta and yellow ink formed as droplets of ink fired from the print head hit the surface of the paper.

Independent Photo Papers

My advice is to steer clear of third-party inks unless you are sure they suit your needs without any risk to your printer. But third-party photo papers are a different matter. There is relatively little risk in damaging your printer through using third-party papers though achieving perfect results can be a challenge. This is because the printer needs a ‘profile' based on a complex model of the colour characteristics of a given printer, its inks and a specific paper type.

By using papers recommended by the printer manufacturer, it's likely that the software installed with your printer, called a printer driver, will contain the correct profiles for these papers when used with that printer and the manufacturer's recommended inks. Changing just one element will likely invalidate the accuracy of a profile. But it's different with third-party papers because profiles for these papers are rarely supplied by the paper manufacturer. It's a difficult task to produce profiles for the hundreds of printer models.

Colour Management

Colour is an incredibly complex property, made even more complicated by the different ways it is captured to form an image in the camera, processed by the camera, edited and adjusted by the photographer and then output onto paper by a printer. For a start, cameras capture image detail in pixels with varying levels of red, green and blue (RGB). Printing involves laying down dots in the complementary colours of cyan, magenta and yellow that should, at a normal viewing distance and under neutral lighting, look the same as the original scene. Some printers also add in red, green, blue and various shades of black.

To maintain colour accuracy, a system of colour management is critical. In theory, what you see on your computer screen should be a close match to what you see in the printed version. But displays need to be calibrated correctly, as do printers. Even a display that has been calibrated will require re-calibrating, after time. So my first bit of advice is - invest in a monitor display calibrator. They are as little as £60 and are worth their weight in gold. If you don't calibrate your monitor, even if you happen to get a reasonable match between your monitor display and your printed output, the colours in the image file may look different when loaded into others' displays.

If you use photo paper supplied by the printer manufacturer, a generalised calibration, or profile, of that paper will often be included in the printer driver for your printer. If you want to change the ink or paper to something non-standard, you will need to calibrate the printer and produce a new profile based on the characteristics of the new media. If you are lucky, the paper manufacturer will have a database of pre-prepared profiles you can download that will address your particular printer make and model when used with their papers. If this is not available or you want to produce an even closer profile calibration, do-it-yourself printer profiling is the next step. You can do this by using a profiling service or buying the kit to do the whole process yourself.

A profiling service will send you a set of colour charts to print out. You post these prints back to the service and they will use their hardware to analyse the colour in the charts and generate an ICC colour profile, which is a data file that you install into your printer driver and, hey presto, you should see accurate colour once again. Printer profiling hardware is more expensive than monitor calibrating hardware, but if you do enough printing and often

use different types of paper, it can pay for itself quite quickly.

Without colour management, you may get a good looking view of your images on your PC screen like this and they may even happen to print well.

But send your image to someone else and because your colour calibration could be out, this is what they and anyone else with a correctly calibrated system may see when opening your images.

Print Quality Problems

Metamerism and Bronzing

Two of the most noticeable quality imperfections that relate to inkjet printers are metamerism and bronzing. **Metamerism** is where the neutrality of tones, especially grey tones, is affected markedly when the lighting used to view the print is altered. This is most characteristic with printers using pigmented inks when printing b&w images. Just by moving the print from one room to another you can see that the warmth of the tones changes; sometimes it can seem the print has a faint magenta or blue tint. Improvements in inks have steadily eroded this problem, but I still see it at galleries and exhibitions. Maintaining accurate calibration of the printer through colour-management profiling can help.

Bronzing is specifically concerned with glossy and semi-glossy papers. Again, it's mainly a manifestation of pigment ink printers. When the ink dries on the shiny surface of the paper, it can create optically refractive layers that result in a reddish gold variation in the surface shine when viewed under bright light from various angles. Improved ink layering has reduced this problem considerably, but if you can't get good results on gloss paper, use matt surface paper instead.

Tips For Running Smoothly

Pointers to help you to do your prints justice

Don't make a critical evaluation of the colour in an inkjet print until the ink has fully dried and the colour has stabilised. This can take up to 24 hours depending on the type of ink and paper used.

If your printer uses pigmented inks, then when installing a new ink cartridge, give it a gentle shake for a few seconds to ensure that there is no settling of the pigment particles.

Don't try to squeeze out that extra millilitre of ink from an ink cartridge by running excessively past the low ink warning. Some printers with permanent print heads can be rendered inoperable if air gets into the print head.

Always double check that the printer driver or on-printer setting, if using a stand-alone printer, is set correctly for a specific brand and type of paper. Two photo papers of identical appearance from different manufacturers may deliver very different results despite maintaining identical printer settings.

If your printer supports both ‘photo black' and ‘matt black' ink cartridges, be aware that each time the printer switches between them, ink wastage occurs while the ink channels and nozzles are flushed. Matt black ink is required when printing onto fine art papers that invariably have a matt surface finish.

Periodically, print a nozzle-test print to ensure that you won't waste a valuable sheet of photo paper through clogged nozzles and banding.

When switching off your printer, use your printer's on/off button. It may seem obvious, but sometimes it may seem more convenient to use the mains wall socket power switch. But this prevents the printer from parking the head correctly, and so sealing the head nozzles so that they don't dry out when left exposed for long periods.

What Size Printer?

Finally, we come to the important job of choosing a printer. First, you should consider the maximum size of print you are likely to need to print yourself. If you are content with A4 as the limit, there is a huge choice available. You may also want to consider an all-in-one printer, which is basically a printer with a built-in flatbed scanner. Or if you are only interested in printing 6x4ins, you can opt for a mini printer. Though these can be very convenient to use, be warned that in the long run and especially if you are printing large batches of prints, using a commercial photofinishing service in the high street or online will work out cheaper.

The choice becomes a lot smaller when you go beyond A4. There are not much more than half a dozen A3 printers from Canon, Epson and HP. If you may want to print on relatively stiff card, check to see if this is supported by the printer via a straight, or nearly straight, paper path. Many quality printers also use paper in large rolls – it can work out quite economically but only if all the paper is used for the prints themselves. The physical sizes of these printers varies a fair bit too. Ink type supported is also an important factor. Once you have a shortlist, try to get hold of reviews or hook up with other users of the printers you are interested in, maybe via the web, and hopefully the best printer for you will reveal itself!