Lighting for domestic, commercial And industrial installations

This has been designed by Paul Webb to help you in your studies if you require assistance please see your tutors

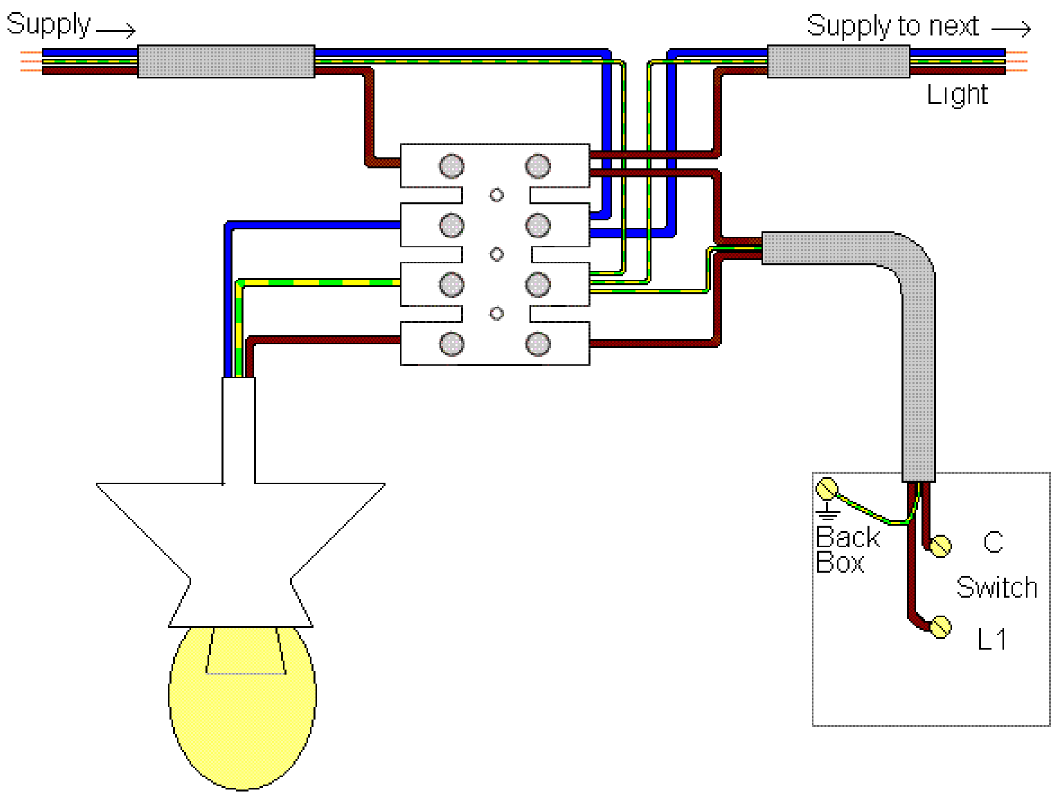
content

Lighting installations are a major part of every electrical installation; this is a complete installation guide covering installation, hints and tips, Types of fitting. Lamps and control, and the science of illumination.

Domestic installations

Where lighting is used in domestic properties, houses and flats, the twin and earth cables are installed by drilling holes through the joists of the building to points usually situated in the centre of the room, the ceiling is normally plasterboard.

The type of wiring system is called three plate as ceiling roses are used to connect three twin and earth cables which provide a feed, supply to next room and a switch line.

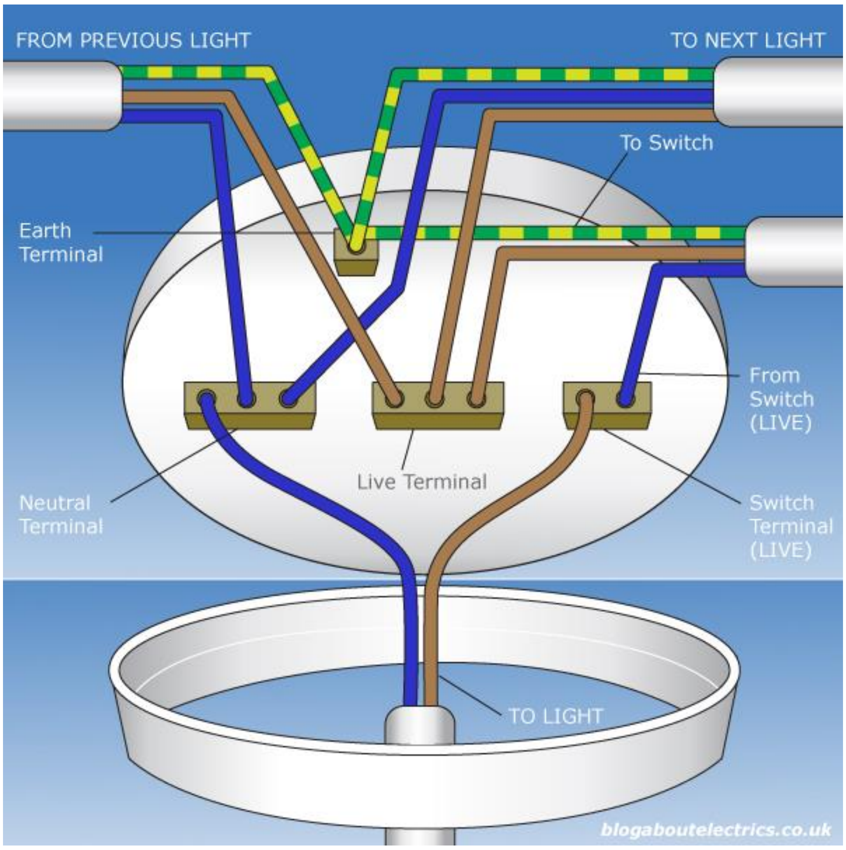


Installation method

The best practical solution is to wire from the consumer unit to the nearest room, this allows for cable length to be minimised and gives least amount of waste cable.

Once first fix is carried out, each room will have three cables centrally positioned, the last room will only have two cables as there is no supply needed to the next room.

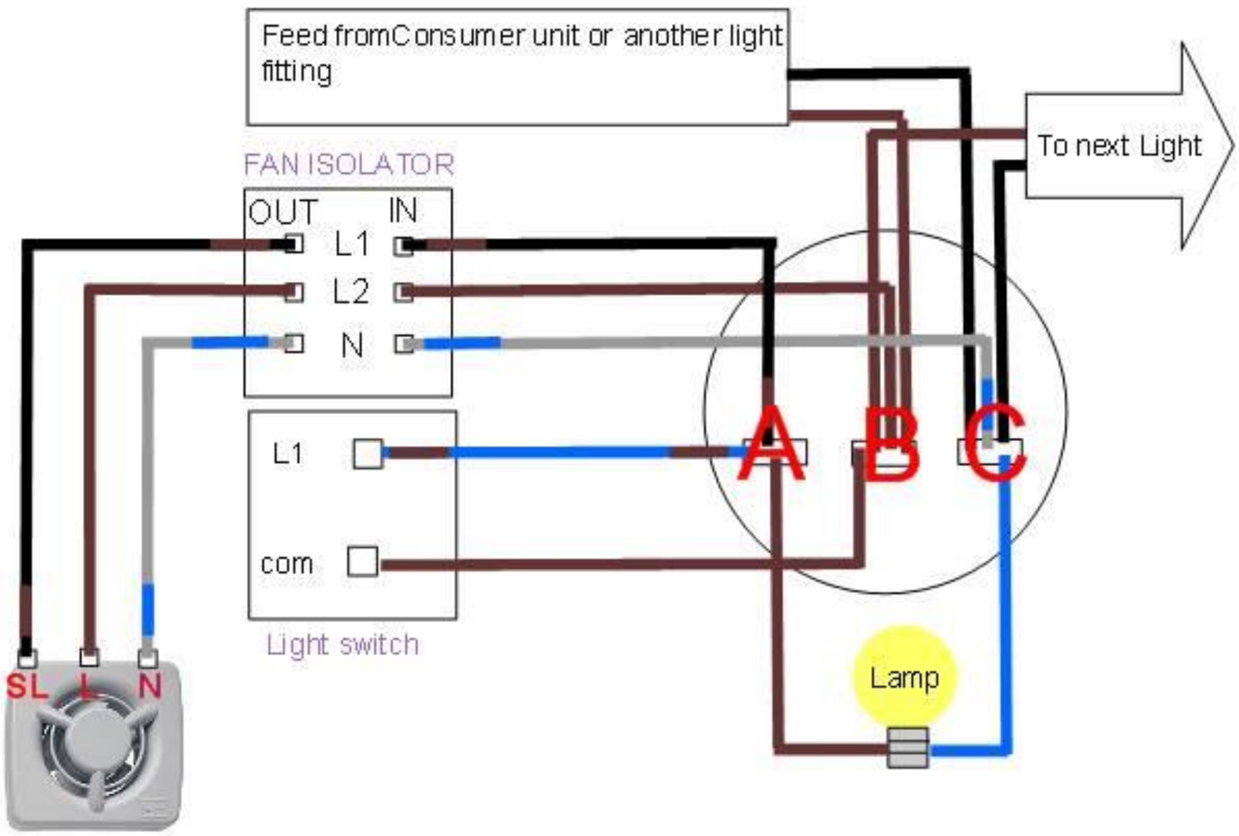
It is common practice to install two circuits, upstairs and downstairs, if exterior garden lighting is carried out this must be RCD protected and will generally be wired as a separate circuit, individual porch lighting and bathroom lights must be protected by a residual current device of 30 milliamp.



Where showers are installed it is usual for condensation to produce a damp interior, building regulation state that this should be removed either by a window or by a fan.

Fan wiring

Most fans will require an overrun , this is a facility which has a timer mechanism built into the electronic control circuit of the fan unit.
To wire to a fan unit, it will need three cores, a main supply for the timer, a switched live for the fan to start when the light is switched and of course a neutral.
A three core and earth cable is taken to an isolator and then to the timed fan unit, follow the wiring diagram as shown. The light switch if installed within the bathroom must be pull cord type.

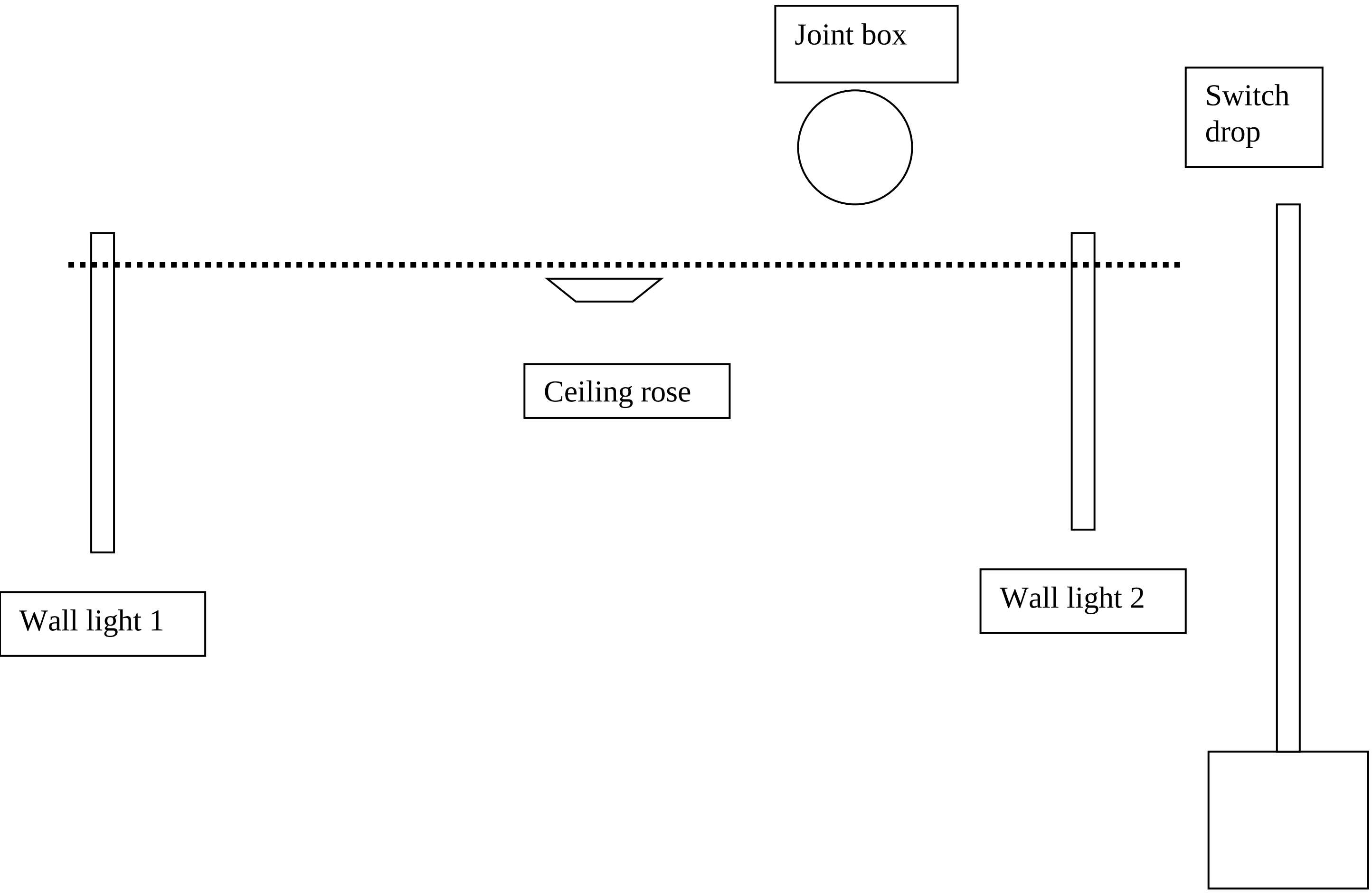


Three plate lighting conversions

Installing wall lights

In some installations it may be necessary for the installation of low wattage wall mounted lighting to be installed.
The supply should be taken from the three plate ceiling rose and adapted as per the drawings shown, note cables must be installed in safe zones in accordance with part p of the building regulations.

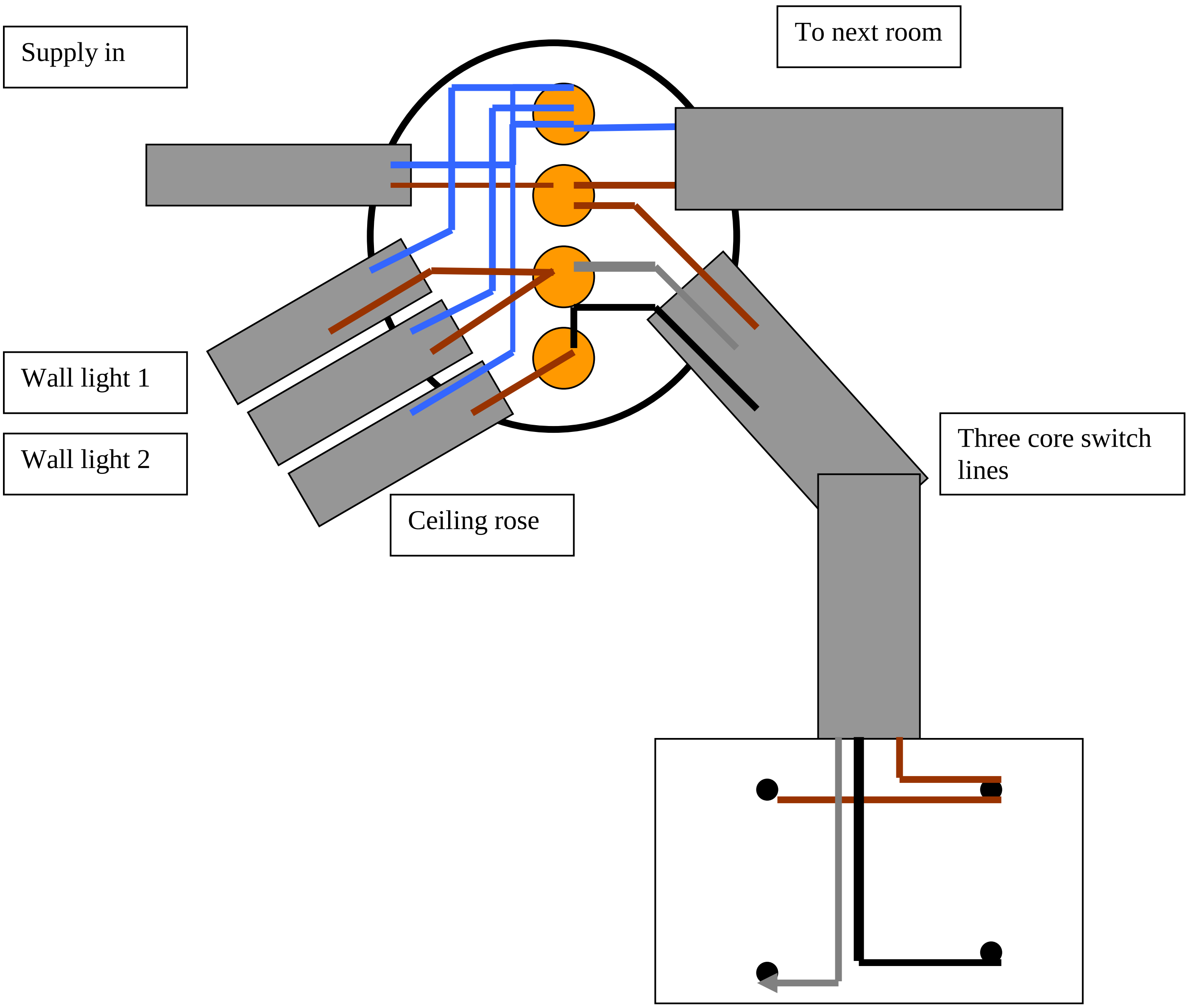
Drawing 1- position of wall chases



Method of installation

Ask the client for the position of wall lights, lift the flooring above the room and lift boards above ceiling rose and switch positions.
Chase both wall lights vertically until chase is above ceiling height, cables must have protection by capping to prevent damage from nails, screws etc.
Remove original twin and earth cable from light switch and replace with three core cable, install through joists until it can be terminated into joint box.
Install twin cables from wall light positions to joint box.
Remove final twin cables from ceiling rose and place in joint box as feed in and supply to next room as shown in wiring diagram.

Wiring diagram

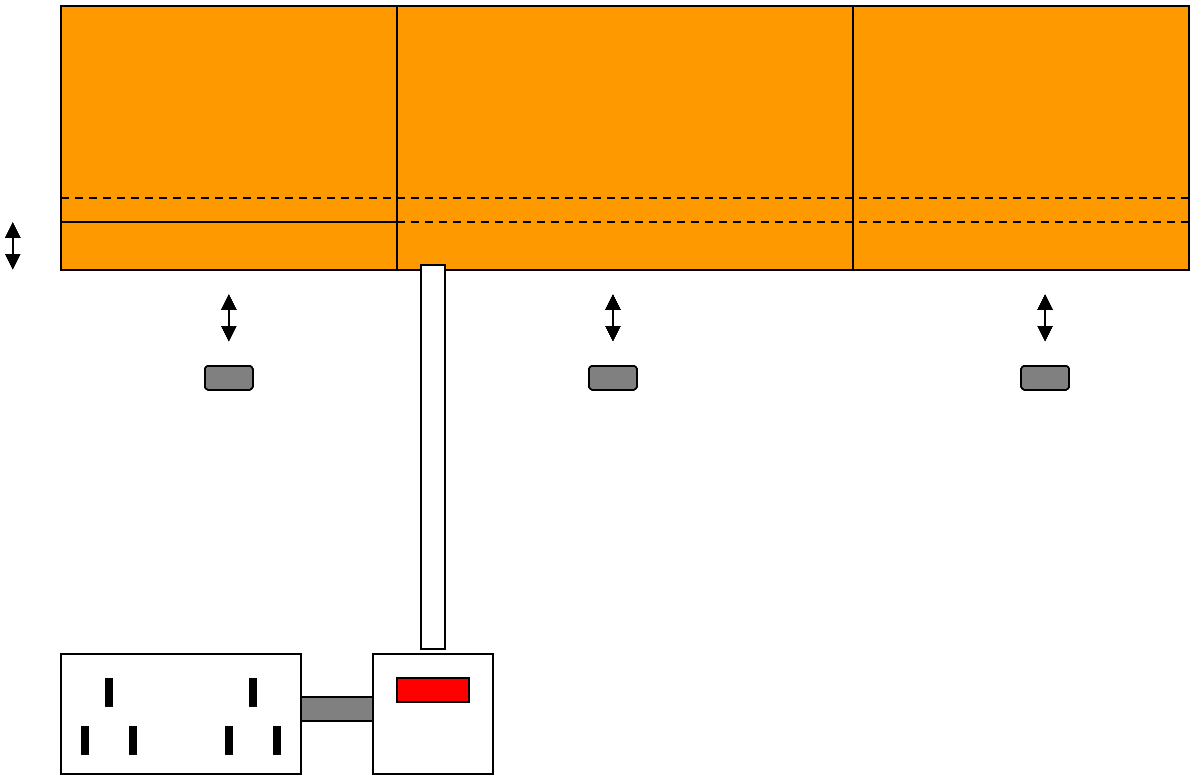


For clarity, circuit protective conductors have been omitted; these are usually terminated into a 16A connector block inside the joint box.
Note that the five neutral conductors may take practice to terminate into the joint box terminal, however there is the fact that the ceiling rose and both wall lights will each have just three cores to terminate.
The use of a two gang switch uses a small link cable between the common terminals of each switch.

Kitchen cupboard or display lighting

Many modern kitchens have under cupboard lighting, either as a decorative product or to be used as a secondary form of surface lighting for cooking. With the use of LED`S as a light source that produces little heat, these are ideal for this type of installation.

Installation diagram



Method of installation

As you will require space within the cupboard it is best to build a frame which can be used as a base for joint boxes and LED lights, this is shown by dotted lines, use a non flammable lid as a surface for inside the cupboard.

Install a switched fused spur as the supply for the lighting, it will also act as a switch, the feed being taken from the nearest double socket, remember to fuse down to 3A as the lighting will only require local protection and isolation for maintenance purposes.

The 1.5mm^2 twin cable will be installed from switch fused spur to joint box inside the cupboard; this must have mechanical protection in accordance with part p of the building regulations.

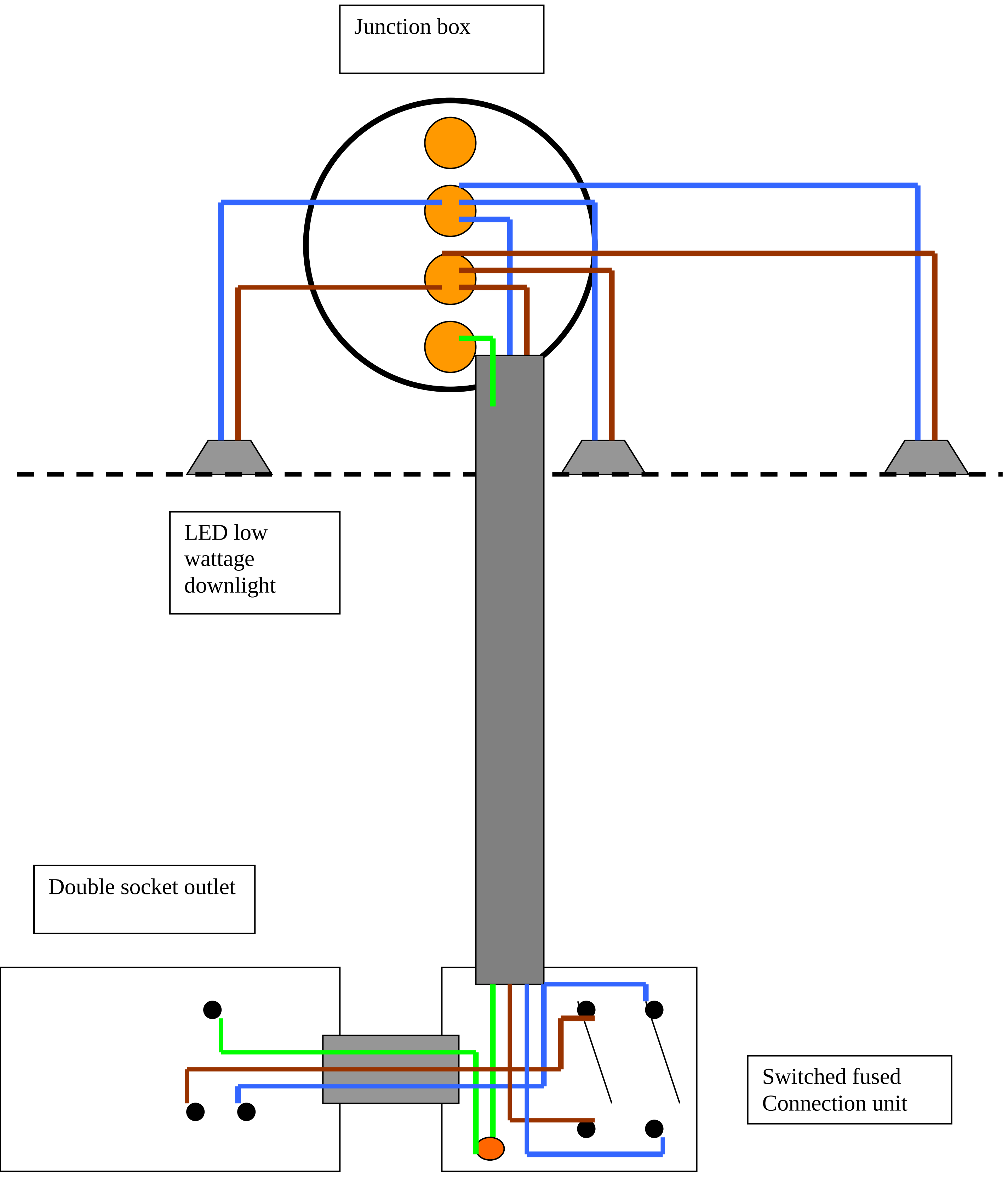
The twin cable from socket to spur will be a 2.5mm^2 and must be connected to the supply side of the spur, ensure that both neutral and line cables are connected to the correct terminals, this is to ensure polarity and isolation is correct.

Using the template provided with the light fittings, cut the holes out of the cupboard base unit , if transformers are used screw round spring holders to the back of the unit, then fit the lamps and fix in position using the spring grip toggles.

Test the fixed wiring by carrying out insulation resistance and continuity tests, ensure polarity is correct.

Do not perform an insulation test on the light fittings as this could damage the lamps

Wiring diagram

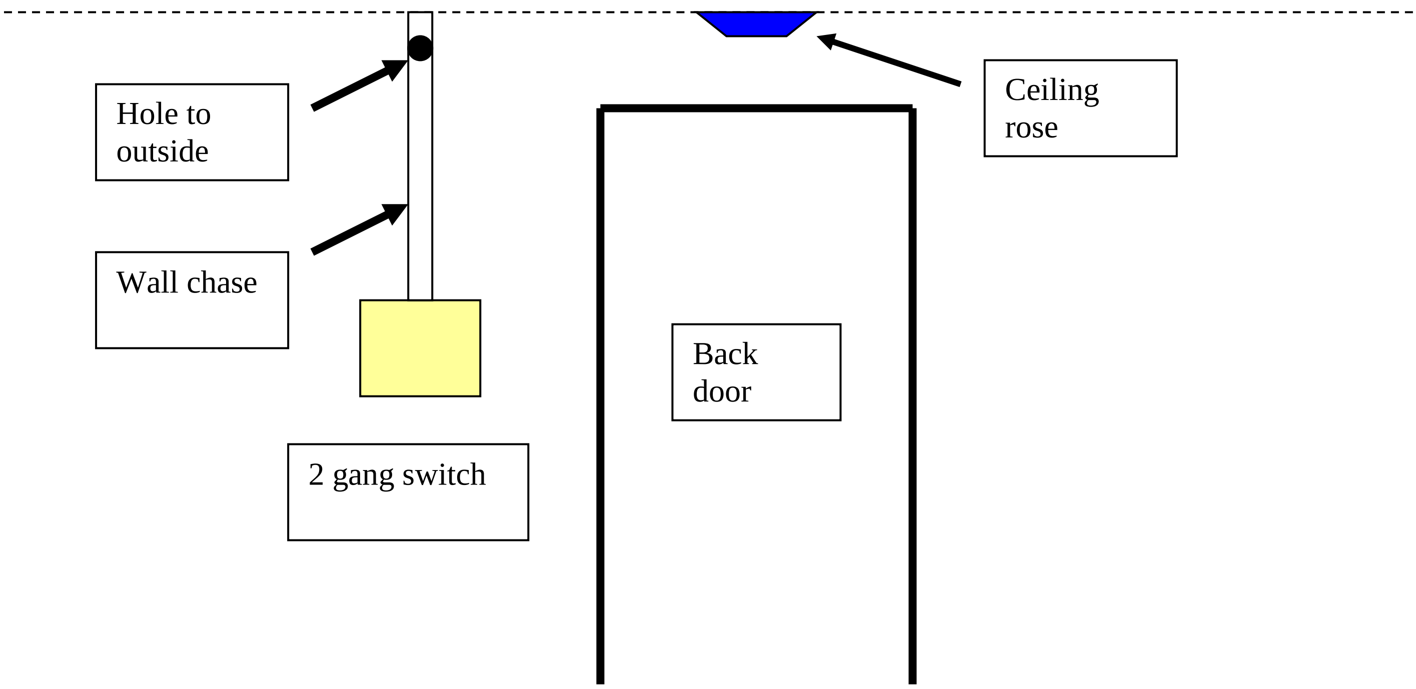


External light supply

This is probably the most common three plate conversion, in domestic properties outside lighting for security purposes has become a must for households, it must be installed so that it is a convenience, rather than a nuisance to others.

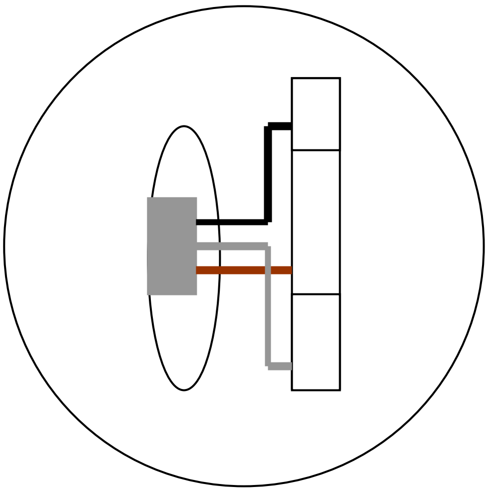
Installation diagram

Interior exit to garden

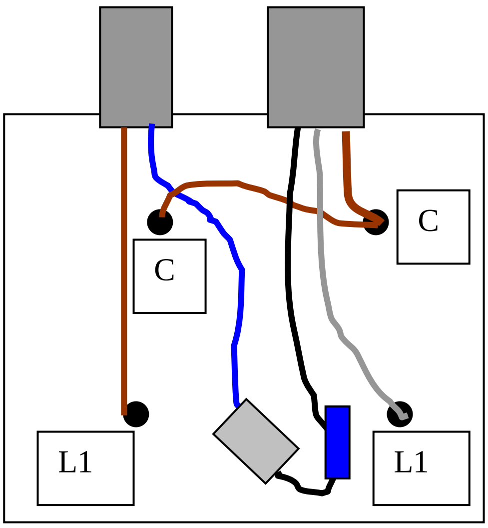


Internal method of installation

Isolate the lighting circuit, remove the original switch to passage light, cut a wall chase large enough for a three core twin cable.
Lift floorboards above ceiling rose and switch, remove two core twin cable and replace with three core, provide mechanical protection for this cable, drill a hole large enough for a twin cable to the exterior of the building, install to switch box, you should now have both a three core and a twin cable in the switch box.
Install the three core to the ceiling rose as shown below

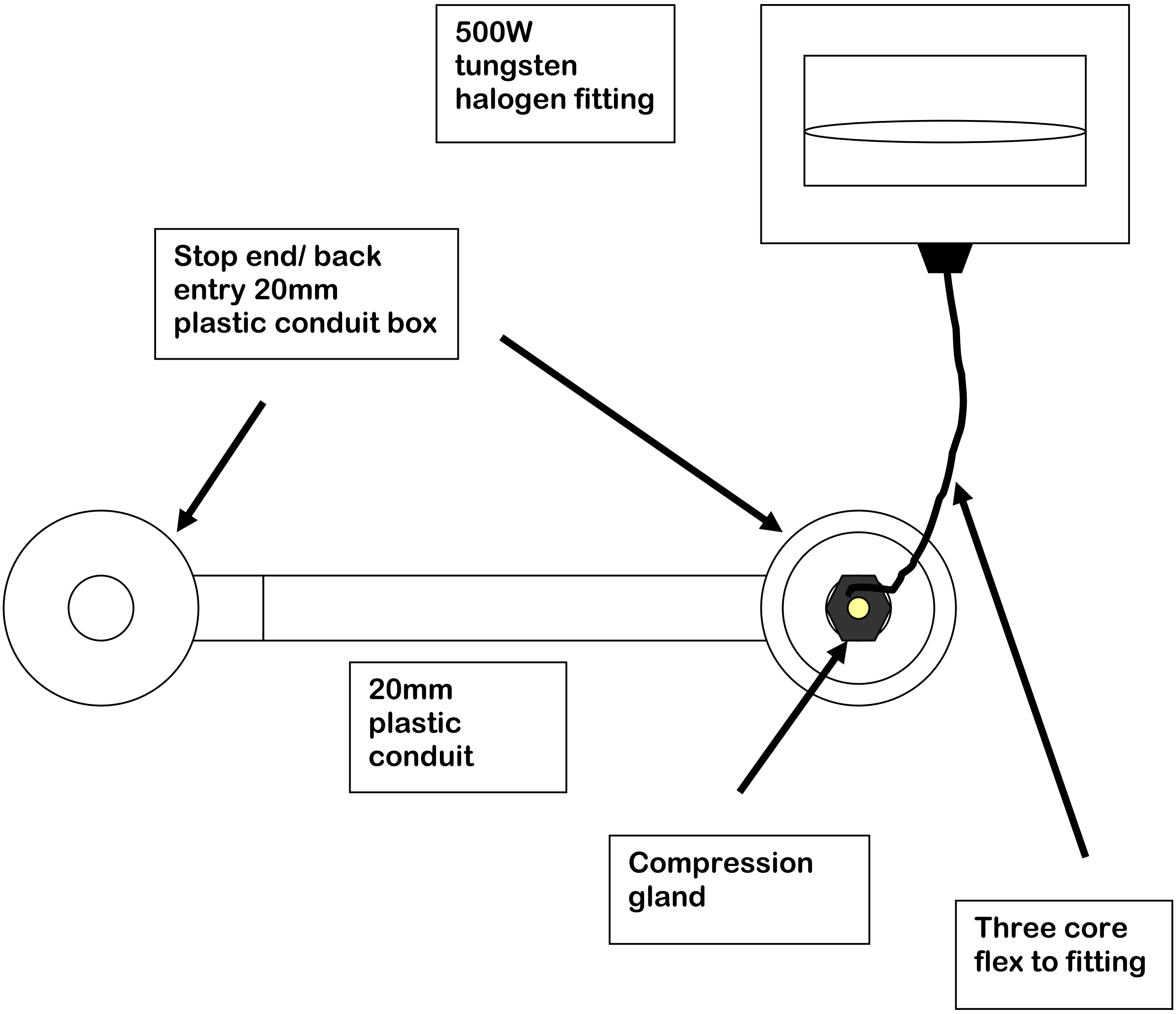


The black core is used as a neutral, colour this blue using sleeving to comply with BS7671, the grey is used as a switch line to the passage light and the brown is used as a live supply,



A two gang switch is connected as shown above, install a small link between common terminals, use a connector block to join black three core conductor to blue conductor of external light fitting.
Circuit protective conductors must be terminated to both switches and lights.

External installation



Fill hole with expanding foam and fix conduit box to wall, use silicon sealant around boxes to prevent water penetration, ensure that box lids have gaskets fitted, pass twin cable through conduit and connect light fitting flex to twin cable

using a connector block, cover the connector with insulation tape, tighten compression gland, before connecting light fitting test using continuity tester and carry out insulation resistance test,

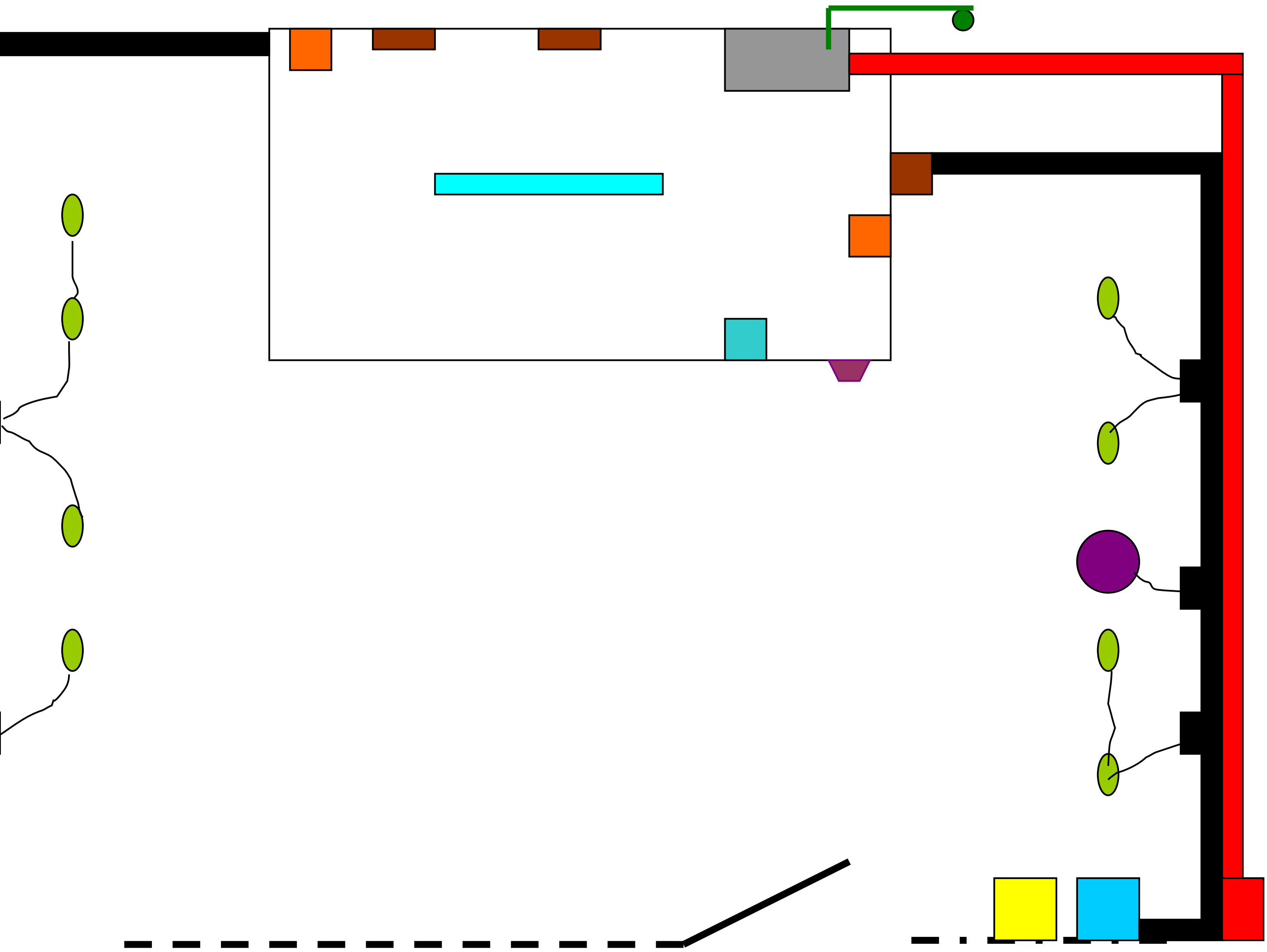
PIR controlled floodlight

Most modern outside garden floodlights are controlled using passive infra red detectors, animals can be a nuisance as they can be detected, adjusting the control will alleviate this problem.

Domestic garden lighting

One installation which gets overlooked is garden lighting, it can become an excellent business for electricians.
External lighting must be protected by a residual current device, the best advice is to supply a shed with a supply for freezer, sockets, lights water features etc.

Installation diagram



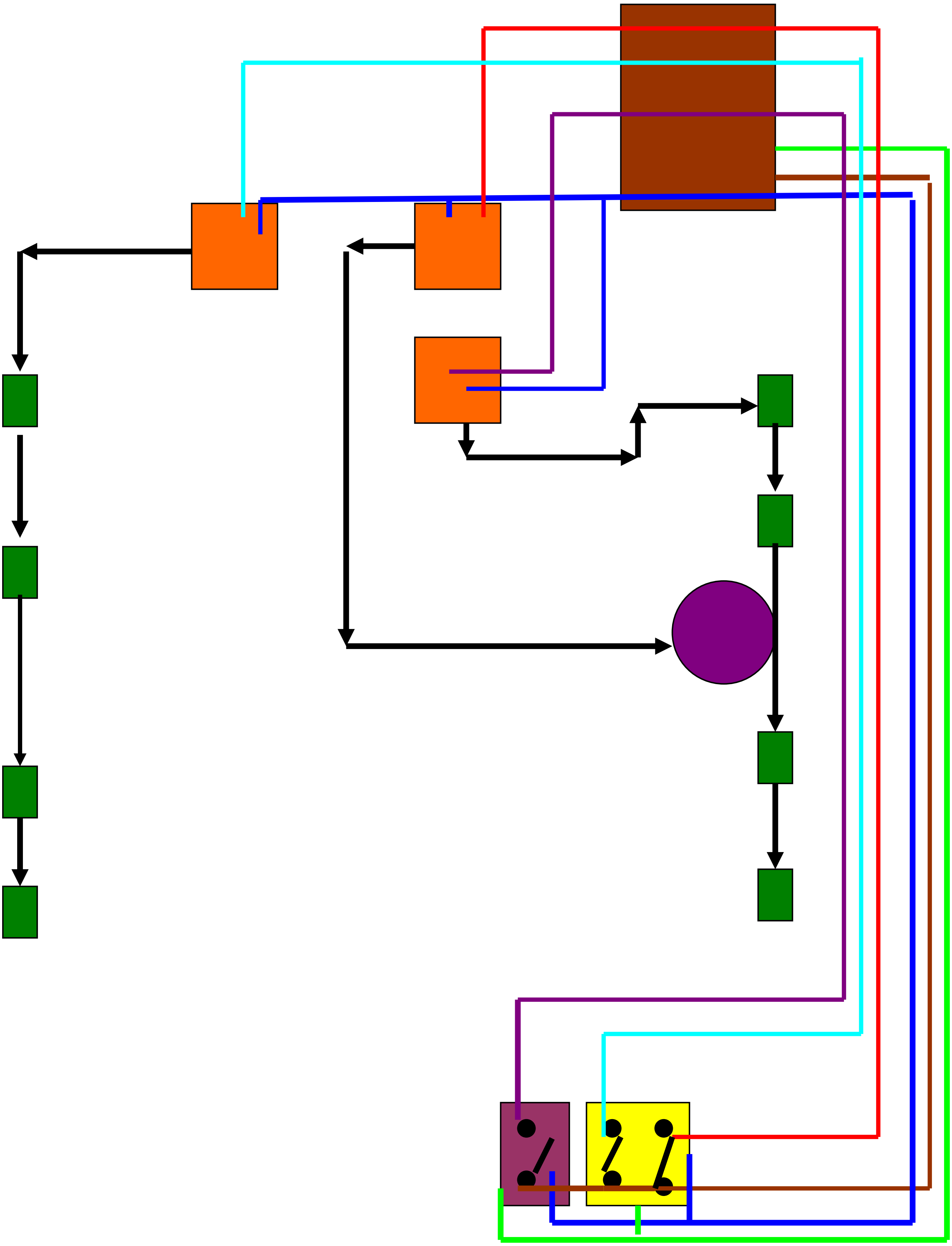
Key -

SWA	fluorescent light
pvc conduit	230V/12V transformer
RCD four way CCU	twin socket
12V LED fitting	light switch
Water feature	external socket
Adaptable box	two gang switch Lights left/right
Switch / water feature	back wall
Earth electrode	

Method of installation

Work out the demand of the installation, add 10 A as an addition for future installation.
Install a 4mm² twin cable from house consumer unit to plastic adaptable box fixed to outside wall, run SWA cable to garden shed, join conductors inside adaptable box using 32A fixed connectors, connect CPC from SWA gland to twin and earth 4mm² CPC, fix RCD – CCU to garden shed, use cleats to fix SWA and install to shed CCU, *do not connect* SWA to main earth terminal in CCU, connect supply to main switch.
Fix adaptable box to outside of shed and install plastic conduit from switches located near rear door to adaptable box on shed, remember to install boxes for light positions and water feature along the route, fix to garden fence using saddles.
Run plastic conduit from shed CCU to adaptable box, run conduit to socket boxes, external socket and fluorescent light position, fix transformers in position, making sure they are ventilated to release heat.
Using single core cable supply switches and lights in flower beds, see wiring diagram.

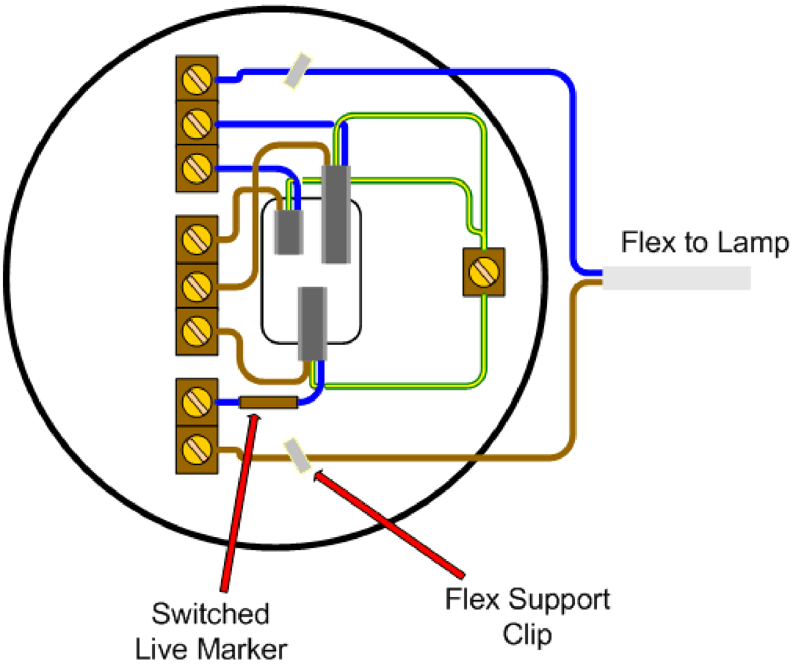
<u>Wiring diagram garden lighting</u>



Connect single core cables, line, neutral and earth to terminals in switches, line connects to common terminal of first switch and is then linked across the common of all switches, neutral is required for neon indicator in switch front, take switch lines from each switch and connect in shed as supply to each transformer, transformer neutral is taken from the same circuit neutral in CCU, the circuit must have a CPC installed.
The client can switch lights and water feature on from the back door, as the lights and water feature are 12V they are double insulated and do not require an earth connection, convenient to turn on and off, easily maintained and very safe.

Replacing single light fittings

Probably the most common type of lighting task is to replace a central ceiling rose and replace it with a decorative fitting.

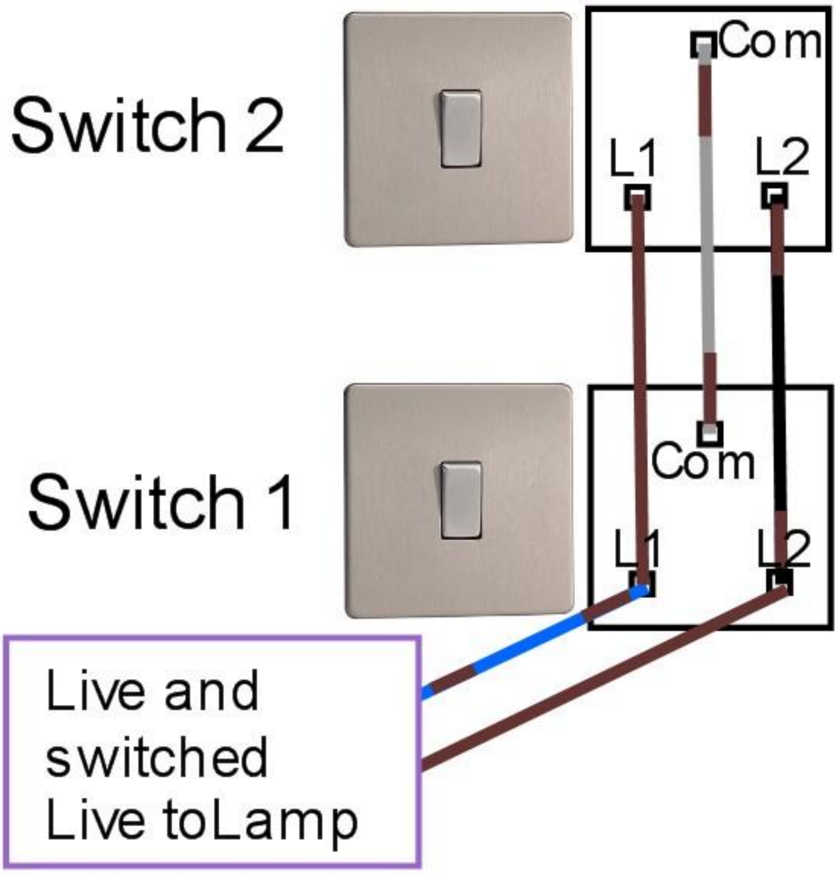


Remove all cables from ceiling rose and connect the three brown conductors into a connector block and cover with insulating tape, connect the new light fitting live to blue conductor with brown tape or sleeving connect light fitting blue conductor to two blue conductors using connector block, cover this connection with insulation tape, finally connect conductors with green/yellow sleeving to earth connection on new fitting push brown coloured connector block into ceiling making sure that no nails or screws will come into contact with connection, finally screw fitting into joist or noggin using suitable Screws, ensure a good fixing,

Switching

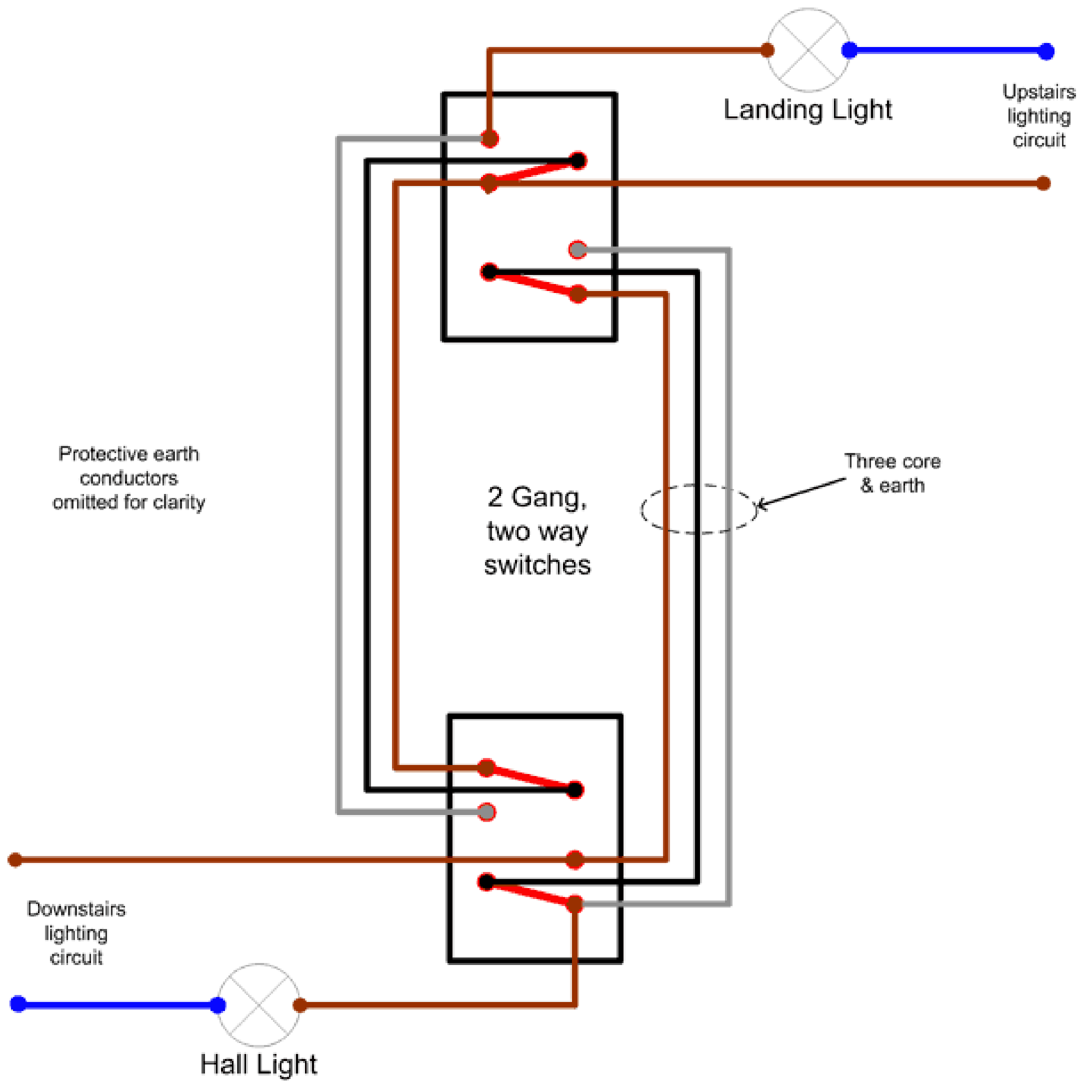
There are several types of switches used for three plate lighting systems, the most common are two way switching and intermediate switching, these are used to switch lights on or off from two or more positions, the most common being staircase lighting.

Two way switch



Connect the switch line twin cable to terminals marked L1 and L2
Connect blue with brown tape to L1 and brown to L2 terminal, the three core cable should be connected as follows, brown to L1 , black to L2 and grey to common terminals, note that all the conductors should have brown sleeving to identify them as line conductors.

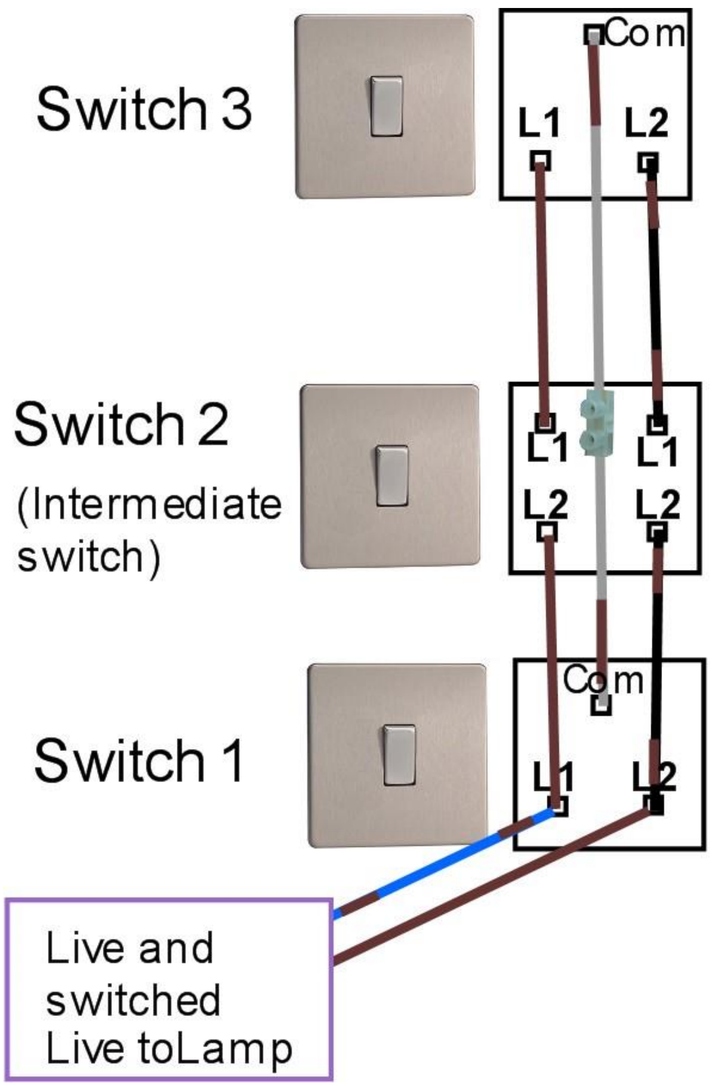
Two way two gang switching



In this wiring it allows for both upstairs stair lighting and downstairs passage lighting to be controlled from either switch, it is common for a third passage switch to be installed this is used to control a front entrance lamp.

Two way and intermediate switching

This is used where there are several staircases in a building, lamps can be switched on or off from each switch.

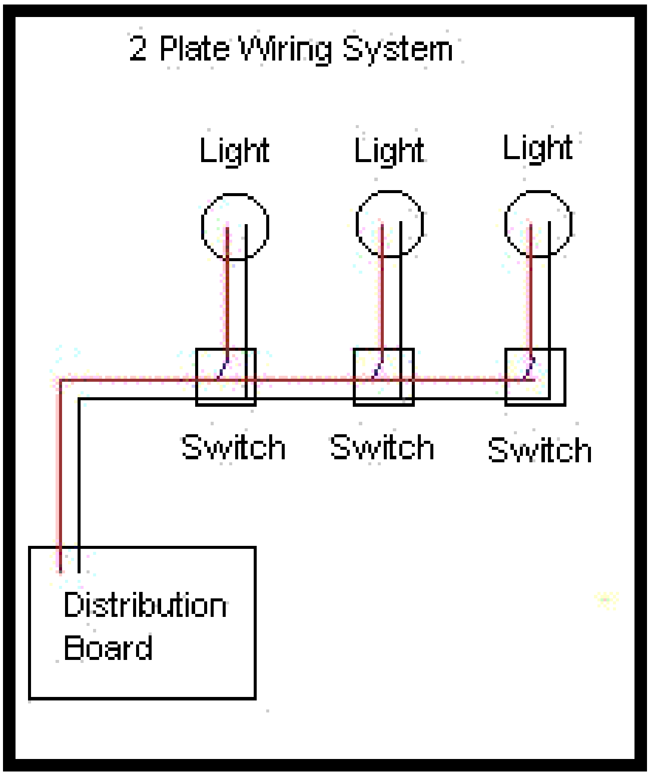


Commercial lighting installations

The type of lighting system generally used in shops, offices and showrooms. The type of wiring system is known as two plate, the supply is installed to the switch instead of the light in a three plate system. cables are usually installed through trunking and conduit , and are single core which is either flame retardant or smoke resistant , the catalogue number is 6491X , circuits are supplied from a three phase distribution board with larger stores using separate supplies for lighting and power.

The on site guide will give diversity values for these type of premises, control for these lighting systems is often by a computer attached dimmer rack or similar control which gives both aesthetic quality and allows for the enhancement of individual pieces within the store.

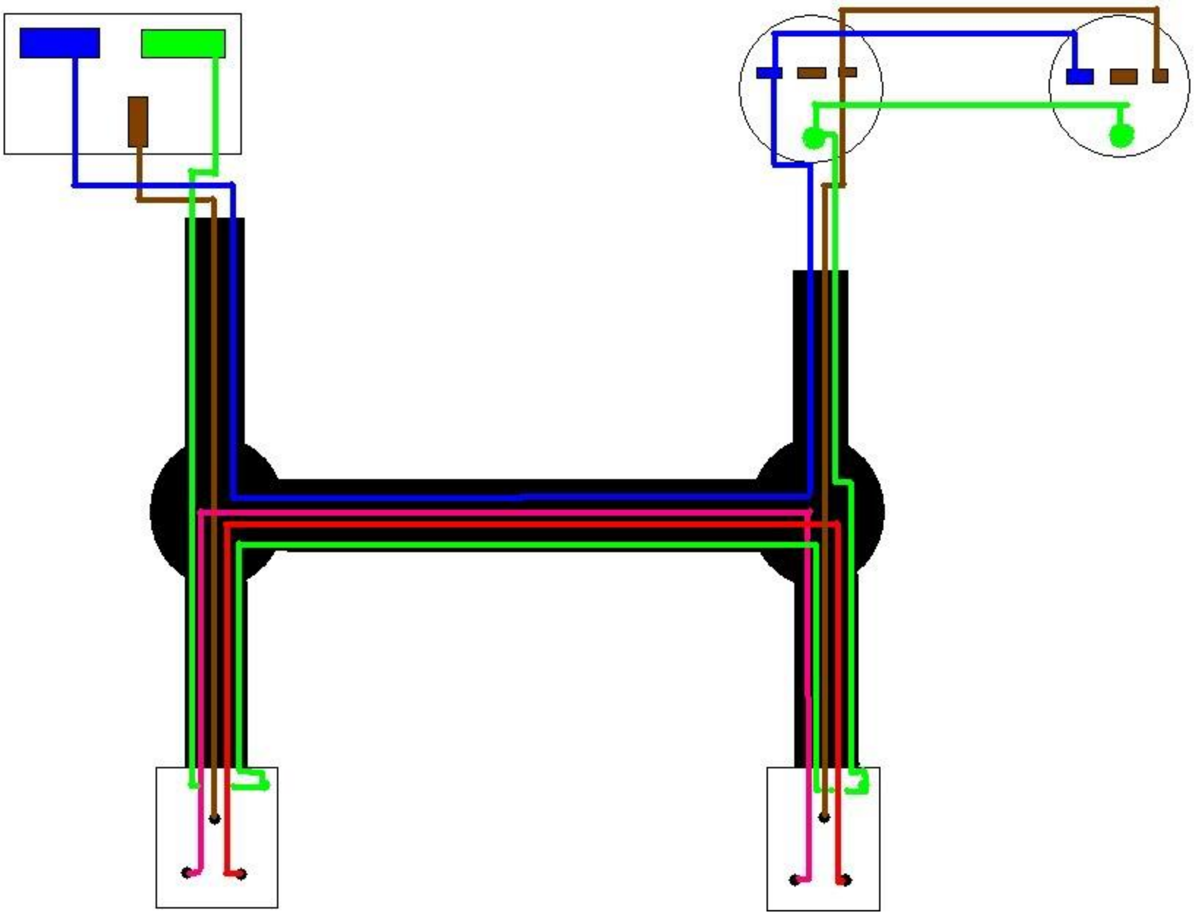
Two plate wiring system



Types of switching

Two way and intermediate switching in a two plate system slightly differs from the three plate system used in domestic premises.

The line is taken to the common terminal of the switch and then supplies the next room, in commercial premises it is common to install a grid switch system, the shop lights are switched on from a central position and are switched off by either a contactor or timer control, for modern energy efficient systems LED lighting is used and switching by PIR or other source is used as a switch on when building is occupied system.



Two way switching two plate

Two way and intermediate two plate staircase lighting

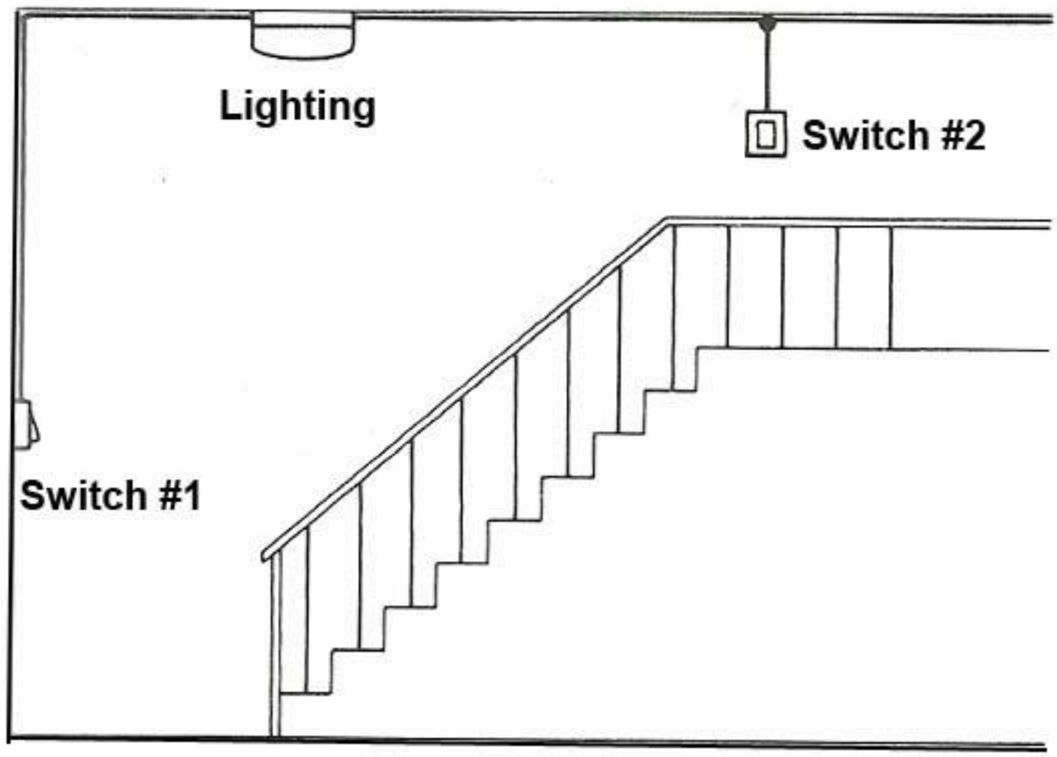
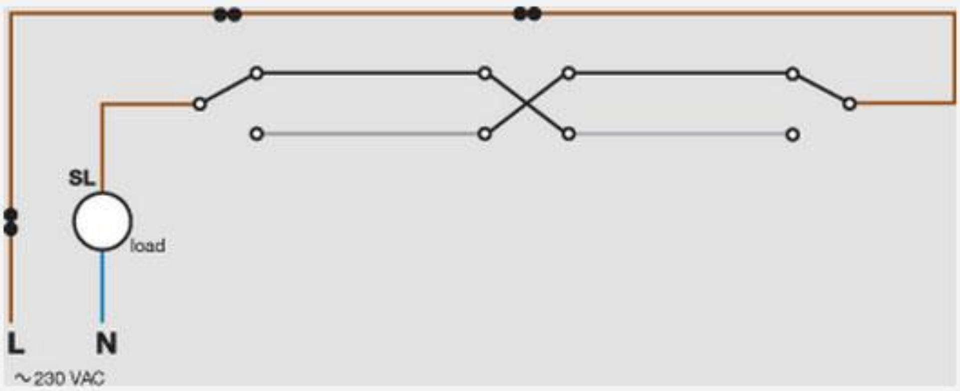


Fig.1: 2 Way Switch At Staircase

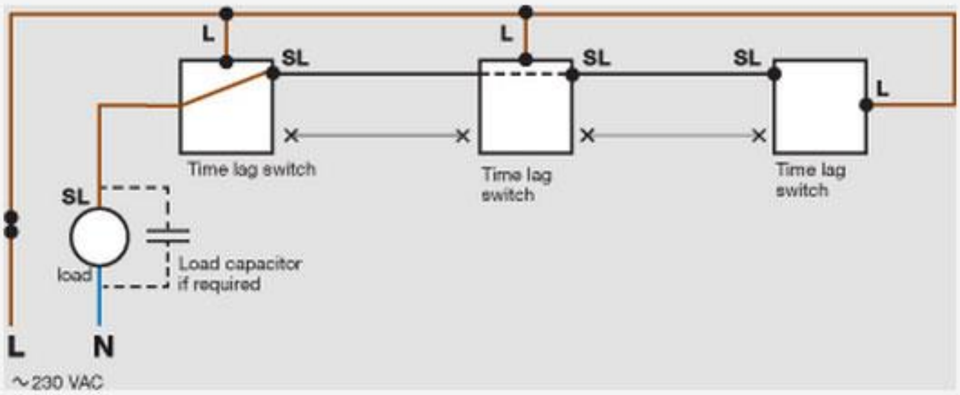
Switch 1 will be a two way switch, switch 2 will be an intermediate switch, for further floors install intermediate switches until the last floor which will be a two way switch

Connect bottom light to first switch and then loop from light to light, Switches are usually timed so that they go off when no light is needed, most modern systems are switched via movement detection.

Two way and intermediate switching two plate



The circuit diagrams here illustrate a 2-way wiring configuration typical of those found on location. They also demonstrate how DANLERS Grid time lag switches (2-wire versions) and DANLERS Slave switches can be incorporated.



These circuit diagrams use the BS 7671:2001 harmonised colour coding with the triple-and-earth colours of brown, black and grey for the lines. For clarity all earth wires are omitted. They show the physical connections with • or •• as appropriate. They use brown and blue for the line and neutral feeds to the circuit. They use twin-brown and earth for the feed to the first 2-way switch. Any unused wires are terminated with the x symbol.

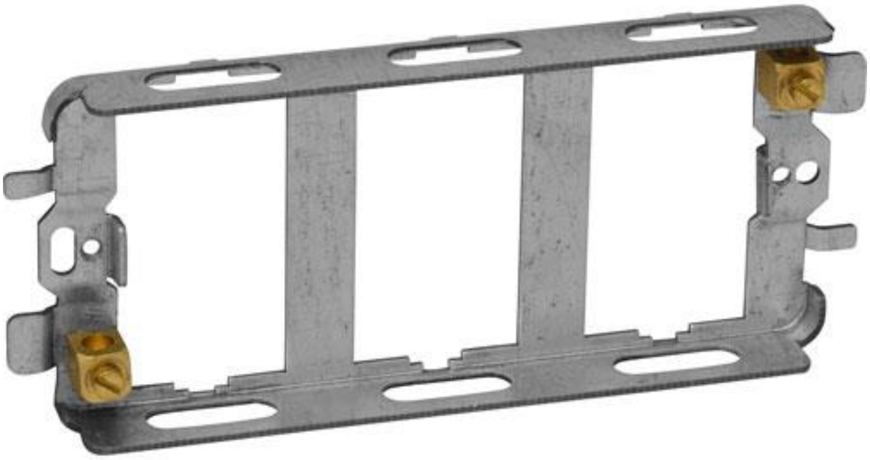
note: These circuits are only recommendations and the contractor remains responsible for their own work.

Grid switches

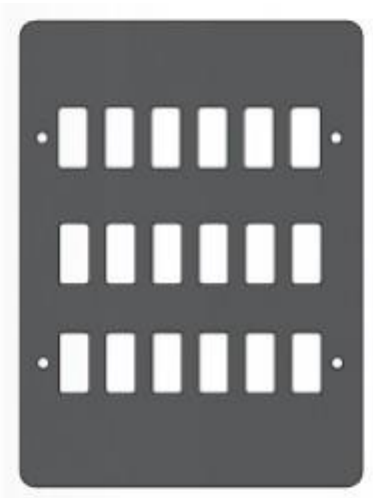
These type of switches are used to control both shop and office lighting, a surface switch box is installed to the conduit and fixed, the wiring is completed and then the grid switches are installed usually in rows which represent the light fitting rows, the switches are then connected and finally the front cover plate is screwed back to the grid box, it is often that emergency key switches are incorporated in this type of system allowing for maintenance of emergency lights to be carried out.

Grid switch box

Grid switch plate



Any combination of switches can be installed into the grid plate, a range of switches can be used to perform any type of switching, it is common for modern lighting systems to be controlled by a contactor where only one switch is used to switch rows of fittings on.



18 way front grid cover

Grid switches

a selection of common switches with fish key for emergency lighting applications.

Display lighting

Where shop items are displayed it is common for a type of display lighting to be used to highlight one particular item and make it stand out.
Angled down light LED fittings are easily installed and provide colour change via wireless signal adapter which can be operated from any blue tooth source or wireless control system.

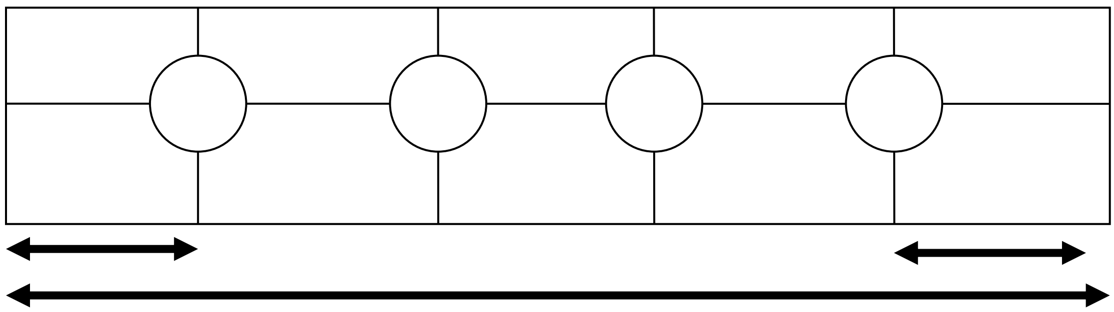
LED angle downlighter

Side LED display lighting

Installation method

To install down lights, using a template cut out holes in pelmet at regular intervals See diagram 1.

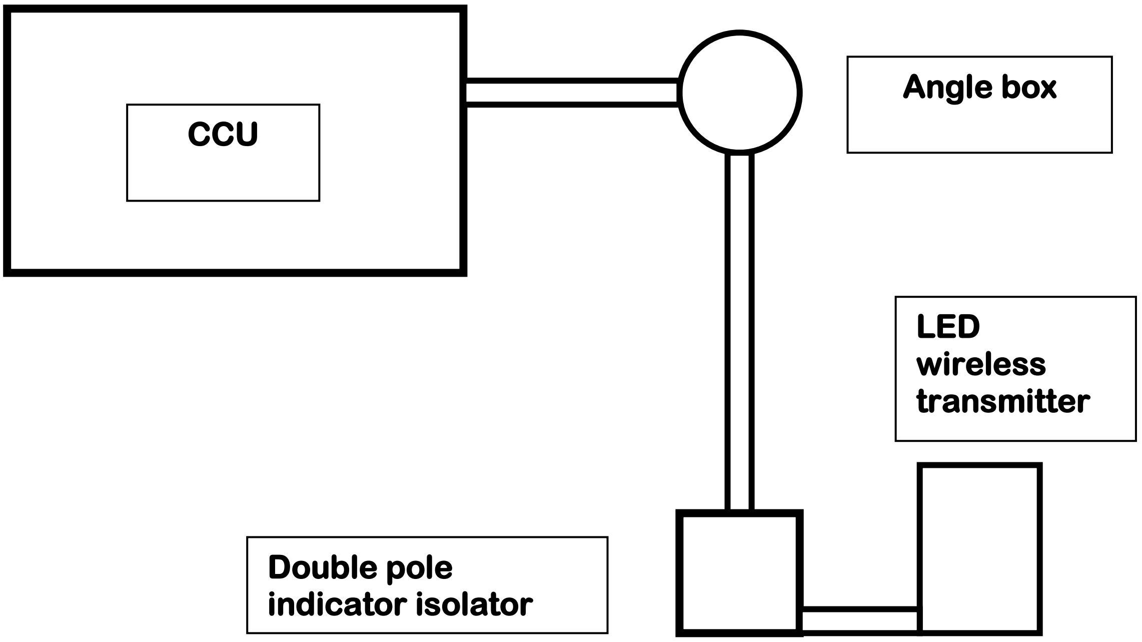
Diagram 1



Divide pelmet into five sections, end sections should be equal distances, two central fittings divided into centre space, mark and cut down light holes

From a 6A circuit breaker supply a one gang double pole isolator switch, this is used to connect the transmitter which sends the wireless signal to the display lights. See diagram 2.

<u>Diagram 2.</u>



Both line and neutral are connected to the double pole switch as it will require a connection to a neon indicator, this is so that location of the switch at night or in low light is available, the switch can be used for maintenance of the system as all live conductors can be isolated from this local point.

Control of the display lighting can be achieved by connection to an I pad or telephone, applications can be used or downloaded for colour change and effects.

Where several shop front displays are installed, a dimmer rack installation may be used which can be controlled via connection to a computer, this can be programmed for dimming, timer function and colour.

Office lighting

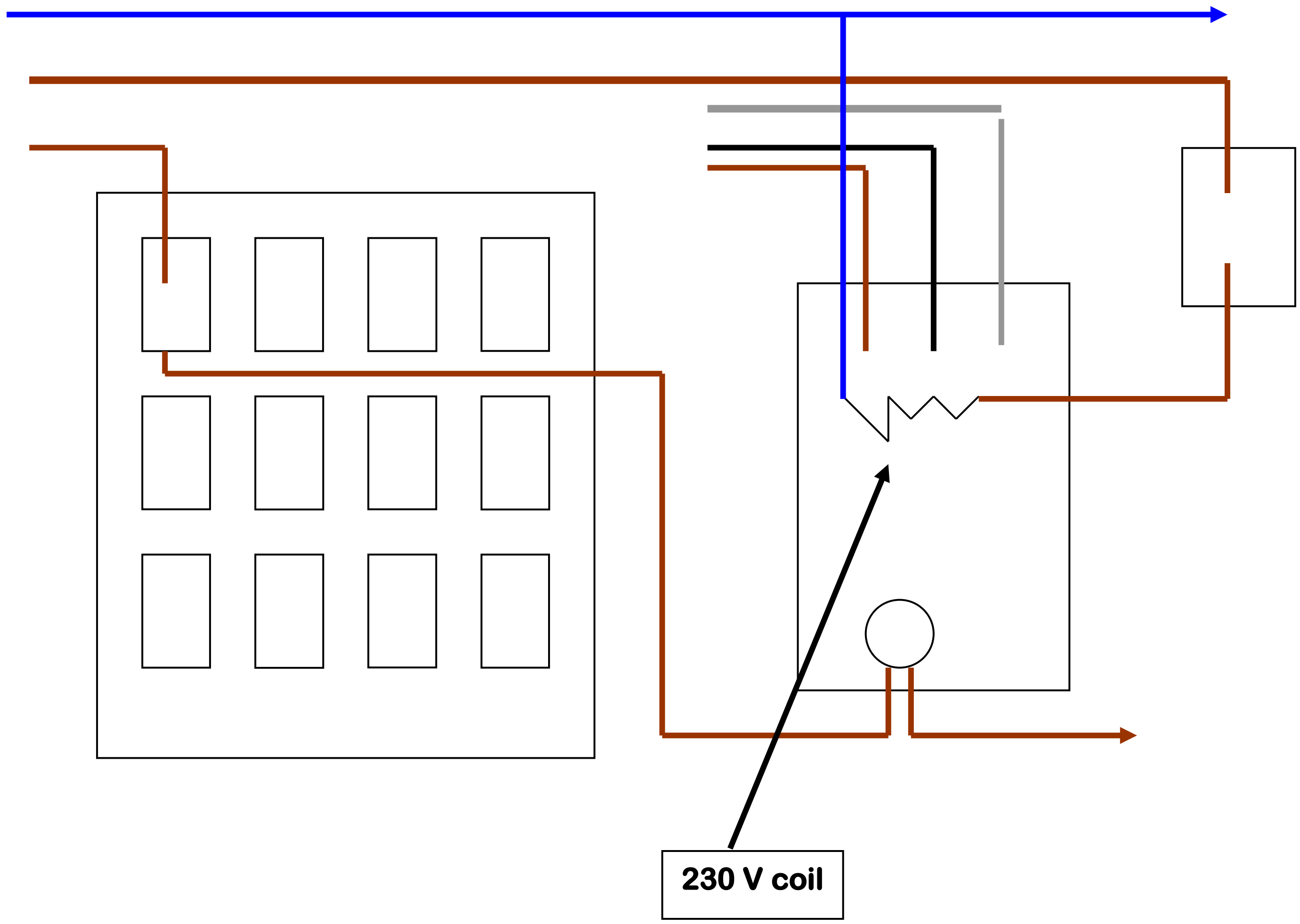
Open plan office lighting will be wired using a two plate system, it is common for Lighting to be switched using a contactor system, this allows for all office lights to be switched from one position or individually from several locally positioned grid switch banks.

Use the address below for contactor types

http://www.eaton.com/ecm/groups/public/@pub/@electrical/documents/content/vol05_tab06.pdf

for typical installation layout and wiring, see drawing on following page, there are several ways to control office lighting, this system is only one typical solution.

Wiring diagram contactor control for lighting



Circuits can be switched individually from the grid bank, when all lighting is required to be operated, the contactor facility is used, the same phase must be used to connect each lighting bank, the contactor is operated from one switch controlled from a circuit on a 6A breaker, each circuit is supplied in two ways, via contactor or individually switched, other forms of control can be used to supply auxiliary contacts.

For isolation of circuits it will be necessary to isolate both switched and contactor circuits, neutral cables will be wired from distribution board directly to light fittings.

Industrial lighting

There are many types of premises classed as industrial lighting applications, warehouses, highway lighting and sports grounds to list but a few.

Exterior lighting has recently changed with the onset of LED cluster lamps, these are now the choice but electricians will need to install older type discharge lighting circuits, these can include neon display, for lighting design options may include fibre optic multicore stranded looms as these can be installed to a design, this allows the electrician to choose from effect to colour rendering which is paramount where security cameras are used for recognition in high crime spots.

Types of lamp

The very high luminous efficiency of discharge lamps has led to their almost universal application for industrial and commercial premises; the introduction of low rated types as direct replacements for filament lamps is beginning to see their wider use in domestic situations.

Discharge lamps are those which produce light as a result of a discharge in a gas. Included are:

Fluorescent
Really low pressure mercury vapour lamps, very widely used for general lighting in homes, shops, offices, etc.

High pressure mercury
Provide a very intense lighting level for outside use in situations where the (sometimes) poor colour rendering is not important.

Low pressure sodium
The most efficient lamp of all, but its poor colour (orange) light output limits its use to street and road lighting

High pressure sodium
The acceptable golden light colour enables the lamp to he used for road and outside lighting in areas where better colour rendering is needed, as well as for large indoor industrial applications.

Discharge lamps, unlike their incandescent counterparts, require control gear in the form of chokes, ballasts, autotransformers and transformers. These devices result usually in a lagging power factor, which is corrected, at least partially, by connecting capacitance across the supply. This control gear should be positioned as close as possible to the lamps. Because of low power factor and the inductive/capacitive nature of the load, switches should be capable of breaking twice the rated current of a discharge lamp system, and maximum demand is calculated by using a multiplying factor of 1.8.

Electronic devices are becoming increasingly common to provide high voltage pulses to assist discharge lamps to strike (start). These pulses can cause problems with insulation breakdown in some types of cable, particularly low voltage mineral insulated types

Tungsten Halogen

Some high intensity / long life globes are called tungsten halogen or quartz halogen. These lamps are filled with a halogen gas, usually bromide or iodine. The nature of this gas means that any tungsten atoms that evaporate from the surface of the filament combine chemically with surrounding iodine atoms. In this state, they cannot form a black coating on the inside of the bulb, moving around until they impact with the hot filament. When this happens, they split back into tungsten and iodine, depositing the tungsten atom back onto the filament and releasing the iodine atom to continue the cycle. This allows much higher operating temperatures which require special bulbs, usually made from quartz or fused silica.
These are used for security garden lighting and can be controlled by a passive infra red detector and timer mechanism.

Tungsten-halogen lamps are dimmable. However, dimming will reduce the bulb temperature causing the tungsten-iodine cycle to stop, resulting in bulb wall blackening. Manufacturers claim that turning up the lamp to "full on" will clean the lamp. Extended dimming will increase lumen depreciation and reduce lamp life slightly.
Tungsten-halogen is an expensive incandescent lamp that has a very compact envelope which makes it an excellent lamp where optical control is important. It still has all of the negative aspects of the standard incandescent which are a

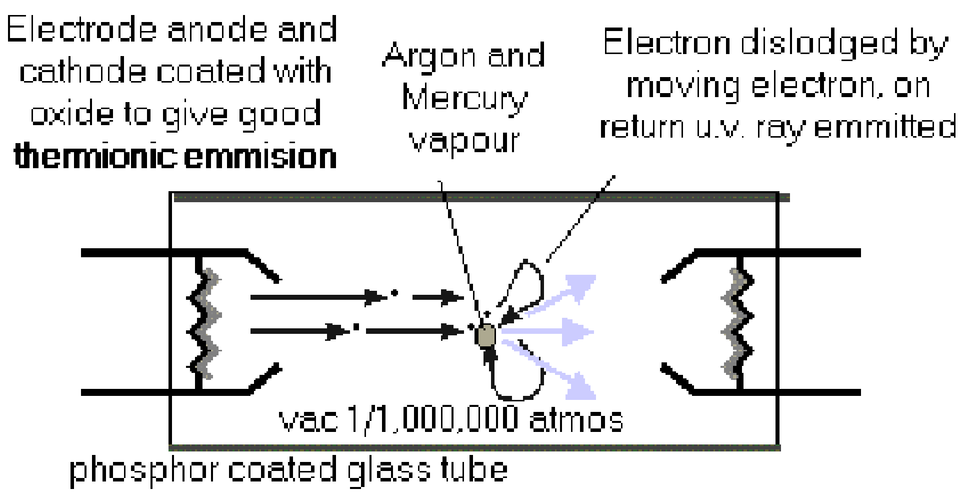
relatively short life and a low efficacy which makes the tungsten-halogen expensive to operate and maintain. Colour rendition, however, is excellent.
The normal voltage (120/240 V) lamp requires no auxiliary equipment (no ballast) which results in a slightly lower initial cost. The low voltage tungsten-halogen lamps require a step down transformer to reduce the line voltage from 120/240 V to 12 V. The transformer adds to the initial cost of the system and introduces a device that may require additional maintenance and has to be put somewhere.
The output spectrum of a tungsten halogen lamp is very similar to other incandescent lamps

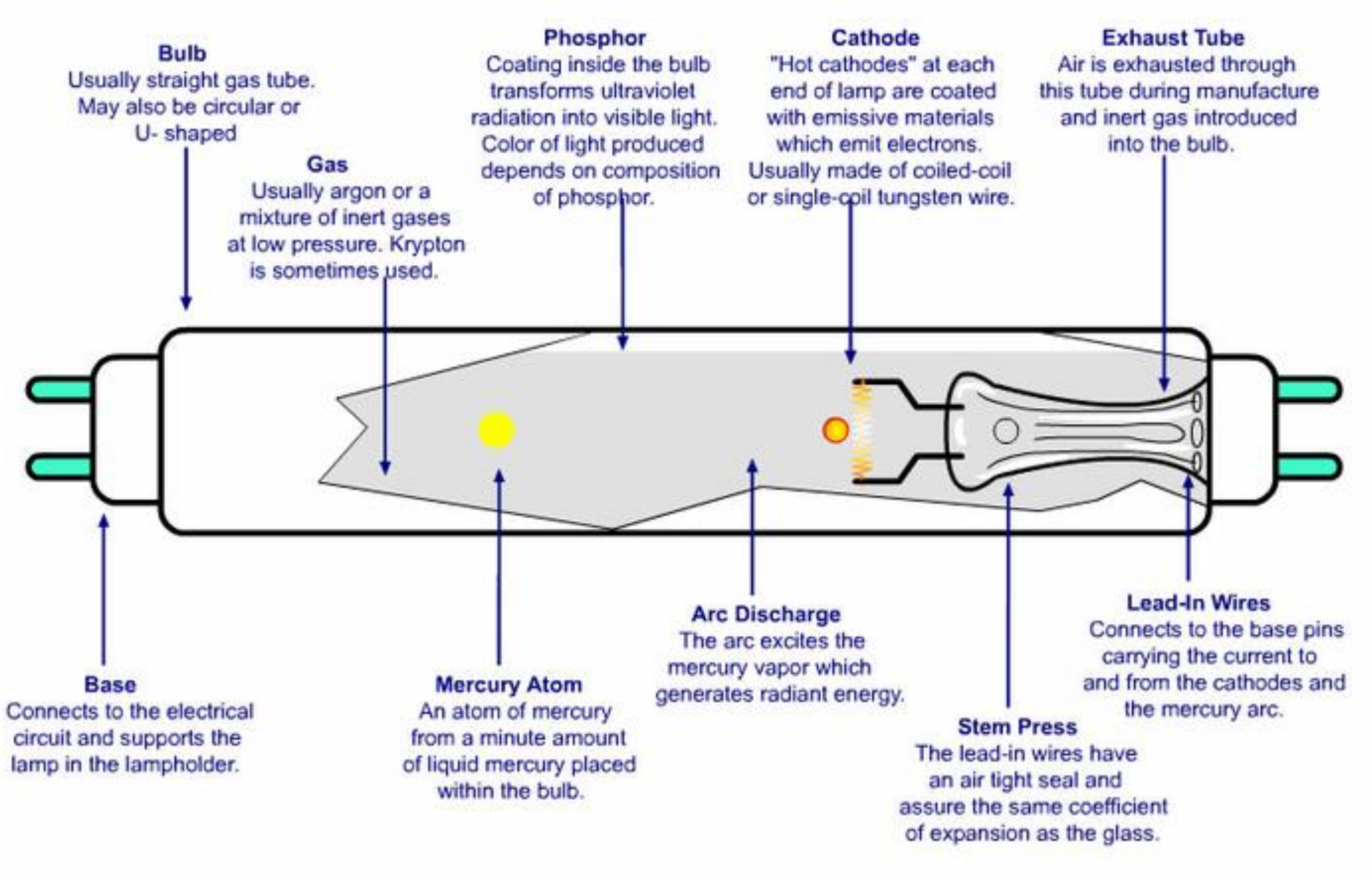
Electrical Discharge Lamps

When electric current is passed through a low pressure gas, the electrons flowing between the two electrodes collide with gas atoms, temporarily increasing their energy. These atoms quickly decay to their stable state, releasing photons of ultraviolet radiation. Phosphor coatings on the inside of the bulb absorb most of this energy and re-radiate it as visible light.

Fluorescent Lamps

The most common application of this technology is in tubular fluorescent lamps. A range of different phosphor coatings are used to modify the output spectrum. The standard fluorescent tube has a diameter of 38mm and a length of 0.6, .9, 1.2, 1.5, 1.8 or 2.4 metres. More recently, such lamps are available in both circular form as well as compact fluorescents utilising folded tubes of much smaller diameter





The fluorescent lamp requires three elements or components to produce visible light:

Cathodes

Electrodes are the electron-emitting devices. Two types of cathodes are in current use. The hot cathode is a coiled coil or a triple-coiled tungsten filament coated with an alkaline earth oxide that emits electrons when heated. The electrons are boiled off the cathode at about 900°C. The cathode of a cold cathode lamp is a pure iron tube that also has an electron-emitting material applied inside the tube. The cold cathodes are subjected to higher voltage, releasing electrons at about 150°C. Cold Cathode lamps are used in special application such as neon signs and can be bent into different shapes. The hot cathode lamp is the most common type of electrode used in fluorescent lamps for most applications. Therefore, we shall not describe cold-cathode lamps.

Gases

A small quantity of mercury droplets are placed in the fluorescent tube. During the operation of the lamp, the mercury vaporizes at a very low pressure. At this low pressure, the current flowing through the vapour causes the vapour to radiate energy principally at a single wavelength in the ultraviolet region of the spectrum (253.7nm). The pressure of the mercury is regulated during operation by the temperature of the tube wall.

The lamp also contains a small amount of a highly purified rare gas. Argon and argon-neon are the most common, but krypton is sometimes used. The gas ionises readily when a sufficient voltage is applied to the lamp. The ionized gas decreases in resistance quickly, allowing current to flow and the mercury to vaporise.

Phosphor

This is the chemical coating on the inside wall of the tube or enclosure. When the phosphor is excited by ultraviolet radiation at 253.7nm, the phosphor produces visible light by fluorescence. That is, visible light from a fluorescent lamp is produced by the action of ultraviolet energy on the phosphor coating on the inside surface of the tube or enclosure. The phosphor mixture can be altered to change the colour of the lamp or the lamp's spectral power distribution.

Effect of Temperature

The most efficient lamp operation is achieved when the ambient temperature is between 20 and 30°C for a fluorescent lamp. Lower temperatures cause a reduction in mercury pressure, which means that less ultraviolet energy is produced; therefore, less UV energy is available to act on the phosphor and less light is the result. High temperatures cause a shift in the wavelength of UV produced so that it is nearer to the visual spectrum. The longer wavelengths of UV have less effect on the phosphor, and therefore light output is also reduced. The overall effect is that light output falls off both above and below the optimum ambient temperature range.
Fluorescent lamps can be operated down to a temperature of 10°C on a standard ballast. However the light output (in lumens) will be greatly diminished. Special low-temperature ballasts are available for starting and operating fluorescent lamps at very low temperatures. These ballasts provide a higher starting voltage, and usually contain a thermal starting switch. Though they will start the lamp in low ambient temperature, these special ballasts will not overcome the dramatic loss in light output.

Effect of Humidity

Starting voltage requirements are affected by the electrostatic charge on the outside surface of a fluorescent lamp. Moist, humid air has unfavorable effects on the surface charge. This factor must be taken into account when the relative humidity exceeds 65%. A silicone coating on the outside surface of the lamp and the proper distance between the lamp and metal housing of the luminaire will usually solve starting problems under any conditions of humidity. However, dirt accumulation on the lamp will nullify the effects of the silicone coating and cause starting difficulties. Cleaning the lamp with an abrasive cleaner may also remove the silicone coating.

Burning Position

Fluorescent lamps should be operated in a horizontal position. Vertical operation causes a non-uniform distribution of gases in the lamp resulting in a reduction in light output and uniformity. In a vertical position, the mercury droplets are concentrated near the lower cathode increasing deterioration of the cathode and resulting in a reduction in lamp life.

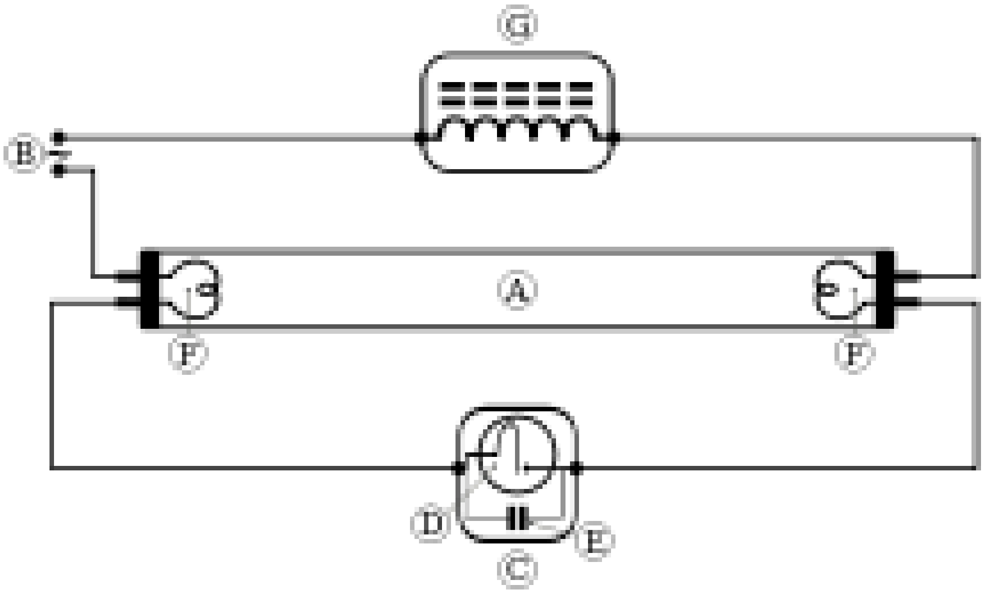
Stroboscopic Effect

Stroboscopic is derived from the Greek meaning "to see motion." The arc stream extinguishes during each reversal of the sine wave (100 times per second for a 50Hz current), however the phosphor coating continues to radiate light during this brief period. Generally this is not noticeable, but it can make high-speed rotating machinery appear to stand still. The use of a series sequence ballast on rapid-start circuits will eliminate this problem. Another solution is to use a lead-lag ballast, which puts one lamp out of phase with the other in a two-lamp unit. This results in one lamp being at maximum light output while the other lamp is at zero output. The net effect is to eliminate the flicker.
Flicker is also most obvious at each end of a fluorescent tube where the concentration of phosphor is less. It is therefore possible to reduce the perception of flicker by capping or obscuring from vision the two ends.

Disposal

Fluorescent tubes are actually categorised as hazardous waste and as such should not be disposed of through the normal waste stream in any real quantity. A single fluorescent tube contains enough mercury to pollute more than 30,000 litres of water. Most companies are unaware of this and subsequently more than 60 million tubes are sent for conventional unregulated landfill each year. Apart from the increasing difficulty in the disposal of fluorescent tubes there are health hazards associated in their handling. For example an employee attempting to dispose of a fluorescent tube in a skip may be exposed to flying glass and small amounts of toxic materials including lead and mercury released as dust or vapour which could be inadvertently inhaled.

Fluorescent switch start



A = FLUORESCENT TUBE

B = SUPPLY

C = STARTER

D = BI METAL STRIP

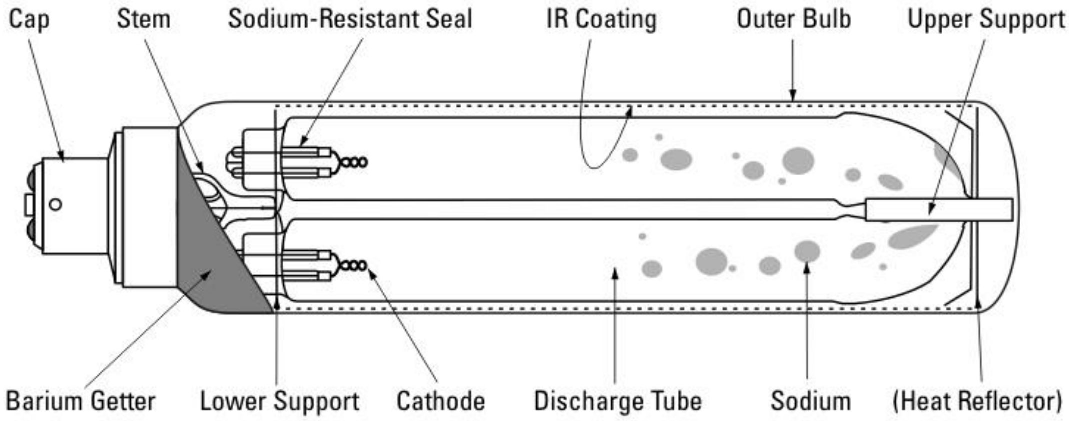
E = CAPACITOR

F = CATHODES

G = BALLAST

Low Pressure Sodium Vapour

Another commonly used discharge lamp is based on Sodium Vapour. When this type of lamp is first switched on, a small current passes through the gas giving off a faint red discharge. After several minutes the sodium inside evaporates. The resulting sodium vapour produces the almost totally monochromatic emission characteristic to this lamp (589-589.6, yellow). This makes colour perception very difficult which means that it is almost solely used for street lighting.

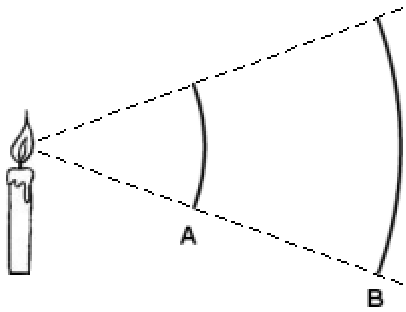


These type of lamps are widely used on motorways, however for recognition purposes these lamps have a low colour rendering which causes problems in urban areas where lighting is used alongside security cameras to help prevent crime, where this is required it is usual for high pressure sodium lamps to be used which give a bright white light.

LIGHTING SCIENCE

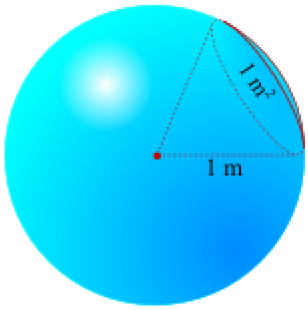
There are many unfamiliar terms used in lighting, here the main terms are explained.

Candela -



The candela (unit cd) has its origin in the brightness of a "standard candle", but it has received a more precise definition in the International System of Units (SI) —and at that time the unit was also renamed from "candle" to "candela".

The candela measures the amount of light emitted in the range of a (three-dimensional) angular span. Since the luminous intensity is described in terms of an angle, the distance at which you measure this intensity is irrelevant. For ease of illustration, in the picture at the right the three dimensions have been flattened to two. In this picture, screen B would catch exactly the same amount of light rays (emitted from the light source) as screen A —provided that screen A were removed to not obscure screen B. This is because screen B covers the same angle as screen A.



The angular span for candela is expressed in steradian, a measure without unit (like radian for angles in a two-dimensional space). One steradian on a sphere with a radius of one metre gives a surface of one m^2. A full sphere measures 4π steradians.

The SI unit of luminous intensity

THE LUMEN

If you look at LEDs, especially high-brightness LEDs, you may notice that the LEDs with a high luminous intensity (in candela or milli-candela, mcd) typically have a narrow apex angle. Similarly, LEDs with a wide apex angle typically have a relatively low luminous intensity. The same is true for halogen spots with reflector: those with a narrow-beam reflector have a higher rating in candela than the "floodlight" spots of the same power.

The cause for this relation is the total energy produced by the LED. LEDs of a specific class (for example, "high flux") all produce roughly the same amount of luminous energy. However, when a LED emits its total energy in a beam with a narrow angle, the intensity will be greater (in the direction of that angle) than when *the same* energy had been emitted over a wide angle.

The lumen (unit lm) gives the total luminous flux of a light source by multiplying the intensity (in candela) by the angular span over which the light is emitted. With the symbol Φ_v for lumen, I_v for candela and Ω for the angular span in steradian, the relation is:

$$\Phi_v = I_v \cdot \Omega$$

If a light source is isotropic (meaning: uniform in all directions), $\Phi_v = 4\pi I_v$.

This is because a sphere measures 4π steradians.

As a frame of reference, a standard 120V/60W light bulb is rated at 850 lm, and the equivalent 230V/60W light bulb is rated at 700 lm. A low voltage (12V) tungsten halogen lamp of 20W gives approximately 310 lm.

Lux

Lux (unit lx) is a measure of illumination of a surface. Light meters often measure lux values (or footcandles, but these are directly related: one footcandle is 10.764 lx). Formally, lux is a derived unit from lumen, which is a derived unit from candela. Yet, the concept of lux is more easily compared to candela than to lumen.

The difference between lux and candela is that lux measures the illumination of a surface, instead of that of an angle. The net result is that the distance of that surface from the light source becomes an important factor: the more distant that the surface is from the light source, the less it will be illuminated by it.

One steradian on a sphere with a diameter of one metre gives a surface of one m^2 From this, it follows that at a measuring distance of 1 metre, the values for candela (lumen per steradian) and lux (lumen per m^2) are the same. In general, measurements in lux can be converted to and from candelas if the measurement distance is known. Note that when measuring LEDs, the virtual origin of the light source lies a few millimetres behind the physical point source because of the lens of the LED —this becomes relevant when measuring LEDs at a short distance.

Luminance

Luminance is a measure for the amount of light emitted from a surface (in a particular direction). The measure of luminance is most appropriate for flat diffuse surfaces that emit light evenly over the entire surface, such as a (computer) display. Luminance is a derived measure, expressed in Candela per square metre (cd/m^2). An alias for the unit cd/m^2 (unofficial, but still commonly used) is "Nit".

Luminance and illumination ("Lux") are related, in the sense that luminance is typically used for light-emitting surfaces and illumination for surfaces that are *being lit*. Assuming a perfect diffuse reflecting surface, you can multiply the measure in "Nits" by π to get the equivalent value in Lux. That is, with L_v for Luminance and E_v for Lux:

$$E_v = L_v \cdot \pi$$

As with Lux, there are several older units for luminance, of which the foot-lambert is probably the most common (because of its 1-to-1 relation with the footcandle on a Lambertian-reflecting surface). These older units are easily converted to candela per square metre by multiplying them with a scale factor. For foot-lambert, the scale factor is 3.425.

Apex Angle

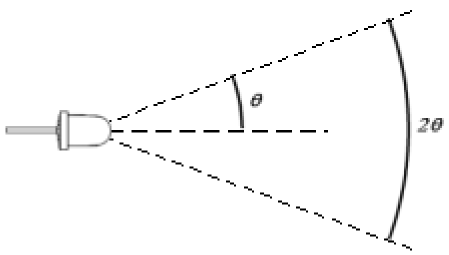
Since the lumen and the candela measures are related through the viewing angle (or *apex angle*), it is useful to know how this angle is defined.

One measures the angle between the axis where the light source gives its highest luminous intensity and the axis where that intensity is reduced to 50%. In the picture at the bottom, this angle is denoted with θ . The apex angle is twice that angle (meaning 2θ).

Observe that the reduction of intensity to 50% is based on a linear scale, but that our perception of brightness is *not* linear. The CIE has standardized the relation between luminous intensity and perceived brightness as a cubic root; other sources claim that a square root better approximates this relation.

The three-dimensional angular span for an apex angle, using Ω for the angular span (in steradian) and 2θ for the apex angle, is:

$$\Omega=2\pi(1-\cos 2\theta 2)$$



Efficacy

There are ample ways to illuminate a surface or a room: incandescent lamps, fluorescent tubes, LEDs, tungsten-halogen bulbs, electroluminescent sheets, and others. These are often compared in their efficiency of turning electrical energy to luminous energy.

The official name for lighting efficiency is "luminous efficacy of a source". This should not be confused with the "luminous efficacy of radiation", which disregards losses due to heat generation and others (and therefore gives significantly higher values). The lighting efficiency is measured in lm/W (lumen per Watt).

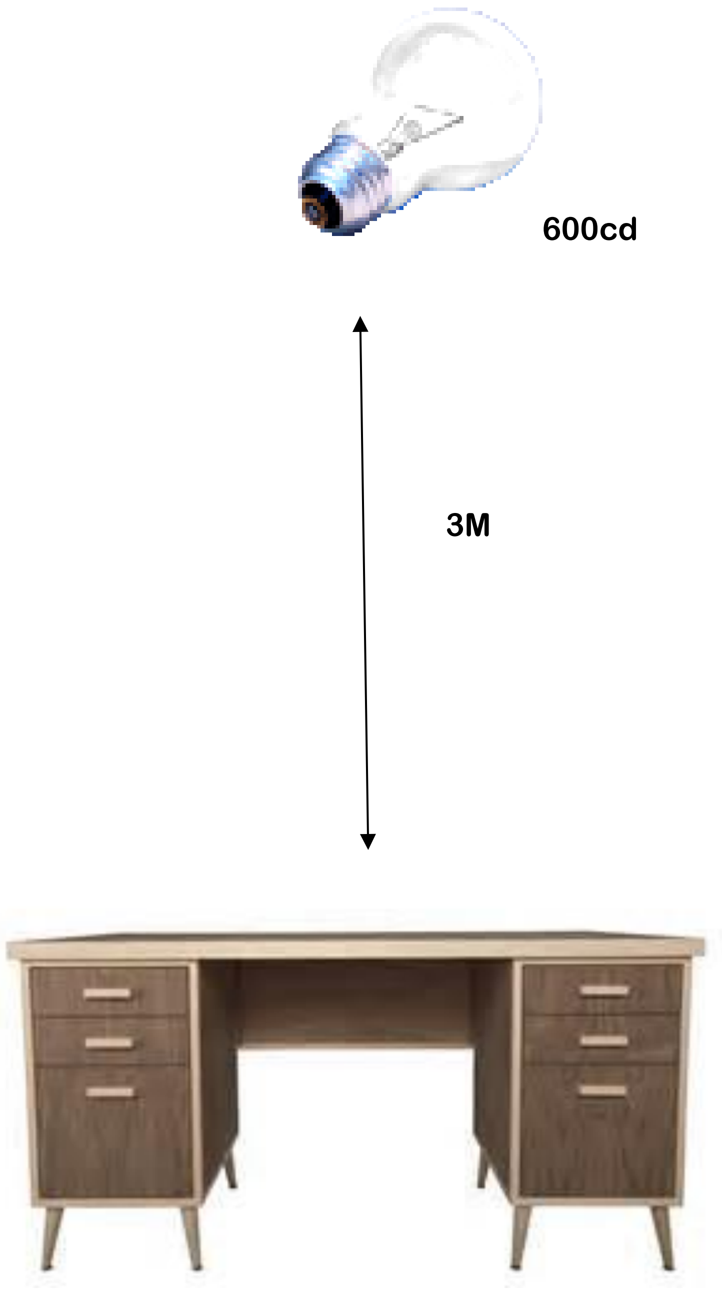
Lighting efficiency is often expressed as a percentage, based on the theoretical maximum value of lighting efficiency of 683.002 lm/W (at a wavelength of 555 nm). For example, at the time of this writing, a white 1 Watt "lumiled" can reach an efficiency of over 100 lm/W, giving an efficiency of 15%. While this may seem low, LEDs are actually quite efficient in comparison with other lighting methods.

As an example, if the data sheet of a high brightness LED mentions that it produces 1500 mcd (1.5 cd) at an apex angle of 70°, that LED gives:

$$\Phi_v = 2\pi \cdot 1.5(1-\cos 70/2) = 3\pi(1-\cos 35^\circ) \approx 1.70\,\text{lm}$$

Point source calculation

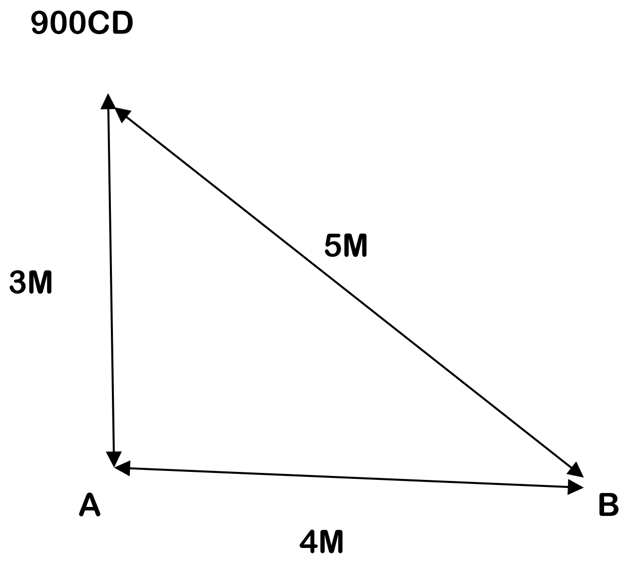
This is used to determine the lux hitting a surface directly below a light fitting. As light is transferred as a square quantity, the distance is also squared.



$E = I/D^2$ LUX $= 600/\ 3^2 =$ 66.66 LUX

Light depreciation

The light between two points will decrease rapidly, lux directly below a fitting will be fine, but light a little further from this point will diminish greatly, this is because light decreases at a square ratio.



Lux at point A = 900 / 3^2 = 100 Lx

Lux at point B = 900 / 5^2 = 36 Lx

Maintenance factor

A number below one which represents how well a fitting is kept free from debris, moths, flies, cleanliness, the lower the number, the worse the condition, this will include the diffuser if fitted.

Co-efficient of utilisation

A number below one which represents the reflection of light on walls, ceilings etc, this will judge if columns will stop light from getting to some parts of a room.

What every electrician really wants to know is how to find the number of light fittings required to light a premises correctly, in terms of required lux.

Calculation of fittings required

1. **Find the required Lux from CIBSE guide**
2. **Find the area to be lit**
3. **Judge the maintenance factor**
4. **Judge the co-efficient of utilisation**
5. **Find the efficacy of lamps used from data sheet**

Number of fittings = $$\frac{E \times a}{M \times u}$$

Consider a room lit by twin 36W fittings, m = 0.8, u = 0.78, required Lx = 300

300 x 20 x 20, the room is 20 M long and 20 M wide

= 120000 this is divided by the result of M X U

0.8 x 0.78 = 0.624

120000 / 0.624 = 192307.692

This large number is then divided by the efficacy of each fitting, in this case it is 80

192307.692 / 80 = 2403.8

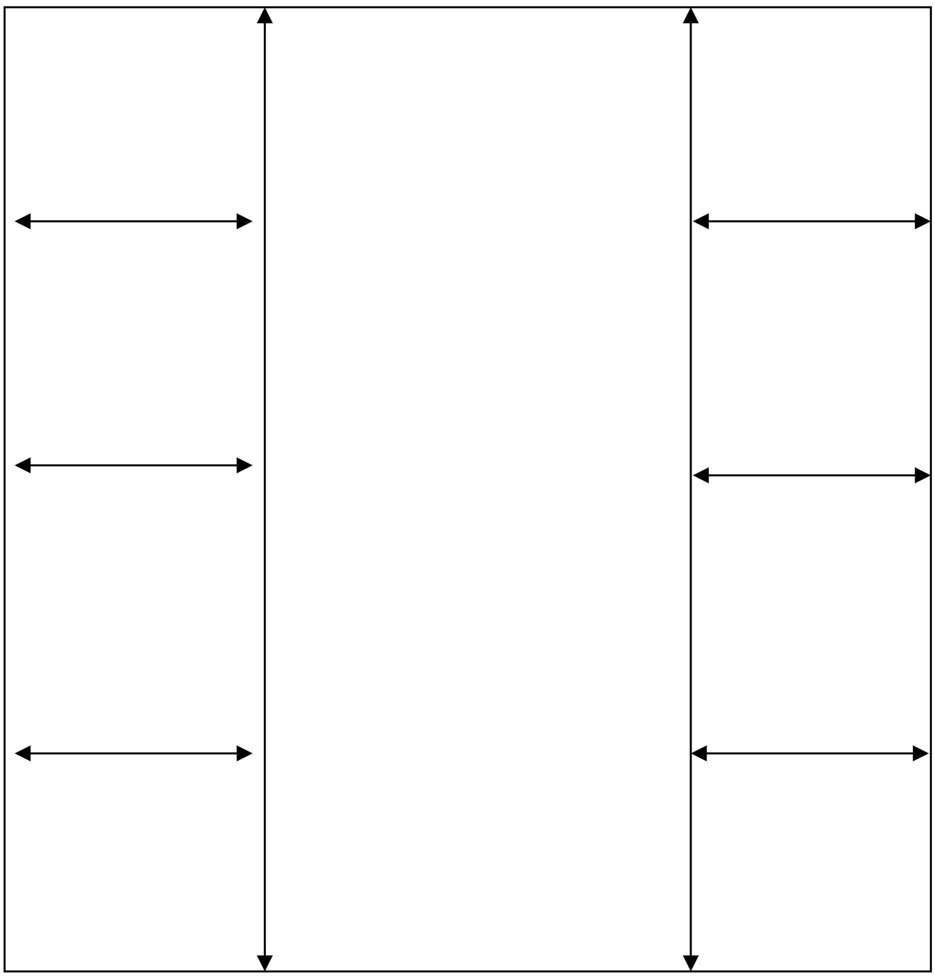
This is then divided by the wattage of each lamp = 26 x 2 = 72W

2403.8 / 72 = 34 fittings required

Note you must go above the target not below, round up not down.

Design

Using a lighting grid, even in a kitchen, will solve where lights will appear well installed, aligned, not out of place.



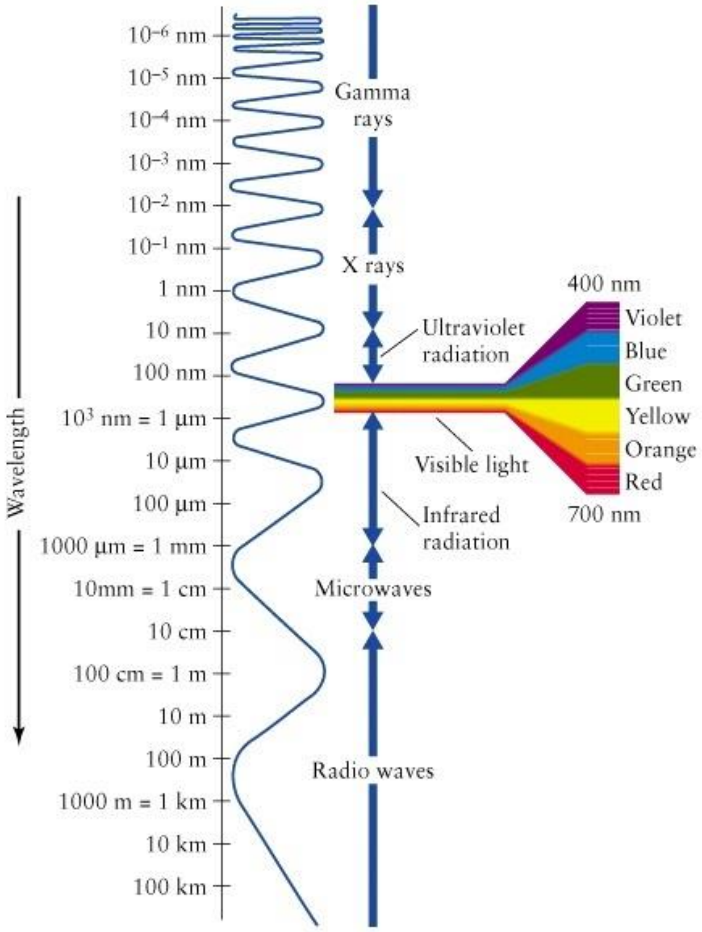
The development of the incandescent lamp

Many believe that it was Edison that invented the incandescent lamp, this is somewhat untrue as an Englishman named Joseph Swann was the first to invent the electric light bulb.

Swann had let Edison copy his lamp as he had little interest in the USA market, the first residence to be lit entirely by electric lighting was Swann`s house in Sunderland, his best demonstration was to use his lamp to light the Savoy theatre in London.

The first street lighting in England, was installed in Mosley street in Newcastle, the first lit shopping areas in London was Electric Avenue in Brixton in 1904.

The lighting spectrum



Visible light makes up just a small percentage of light rays, light or electromagnetic radiation, comes in many forms in different wavelengths, all forms of light are used in the electrotechnical industry, Gamma rays are used in astrology, x-rays are used in health care, ultraviolet light is used in security systems and fish farms, infra red is used in detection systems, microwaves are used in catering and security as well as the defence sector, radio waves are used in telecommunication and are used as switching systems for meters, street lighting and media.

People can only see the visible spectrum, some animals can see infra red and use this to detect prey.

The photocell

A common form of electronic switching system for street lighting, dawn to dusk is the standard operation settings, the photocell comes in many forms, miniature sets are fitted into the light fitting itself, some are operated by installing several street lights onto a contactor which is operated by the switching mechanism of one photocell.

Wiring diagram

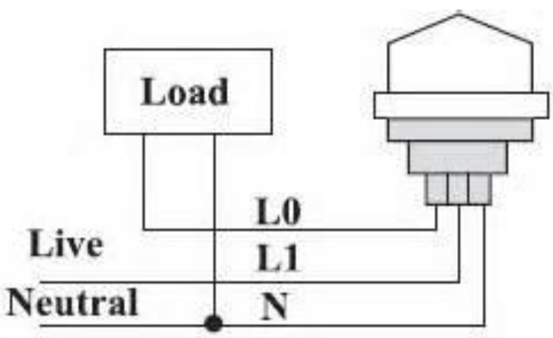


Fig 2

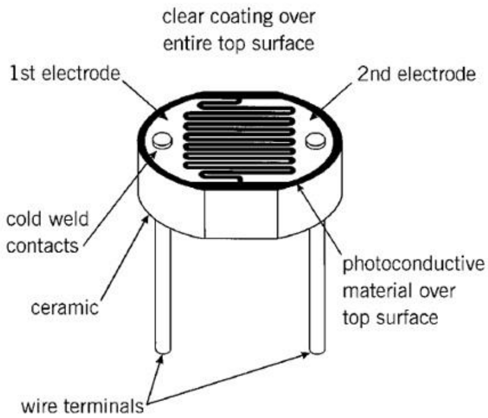


Figure 3
Typical Construction of a Plastic Coated Photocell

Note- neutral connection will continue to light fitting

Neon Lighting

This type of lighting is used as a shop front display, the tube is very similar to fluorescent lamps, the inert gases within the tube require an extremely high voltage across the tube ends to enable the gases inside to produce coloured light, as this voltage is considered high, these signs will have a firemans switch in case of a fault, this enables them to be switched off from outside the premises.

Different types of inert gas are used inside the glass, each will produce a different colour when a high voltage is discharged across the electrodes.

Firemans switch

dimmers

these devices are used to limit the current to a light fitting, this will produce an effect that shows that a lamp light output is minimised and so produces a glow type effect.

Dimmers are devices used to lower the brightness of a lamp. By changing the voltage waveform applied to the lamp, it is possible to lower the intensity of the light output. Although variable-voltage devices are used for various purposes, the term dimmer is generally reserved for those intended to control light output from resistive incandescent, halogen, and (more recently) compact fluorescent lamps(CFLs) and light emitting diodes(LEDs). More specialized equipment is needed to dim fluorescent, mercury vapour, solid state and other arc lighting.

Dimmers range in size from small units the size of a light switch used for domestic lighting to high power units used in large theatre or architectural installations. Small domestic dimmers are generally directly controlled, although remote control systems are available. Modern professional dimmers are generally controlled by a digital control system. In newer systems, these protocols are often used in conjunction with ethernet.

In the professional lighting industry, changes in intensity are called “fades” and can be “fade up” or “fade down”. Dimmers with direct manual control had a limit on the speed they could be varied at but this issue has been largely eliminated with modern digital units (although very fast changes in brightness may still be avoided for other reasons like lamp life).

Modern dimmers are built from semiconductors instead of variable resistors, because they have higher efficiency. A variable resistor would dissipate power as heat and acts as a voltage divider. Since semiconductor or solid-state dimmers switch between a low resistance "on" state and a high resistance "off" state, they dissipate very little power compared with the controlled load.

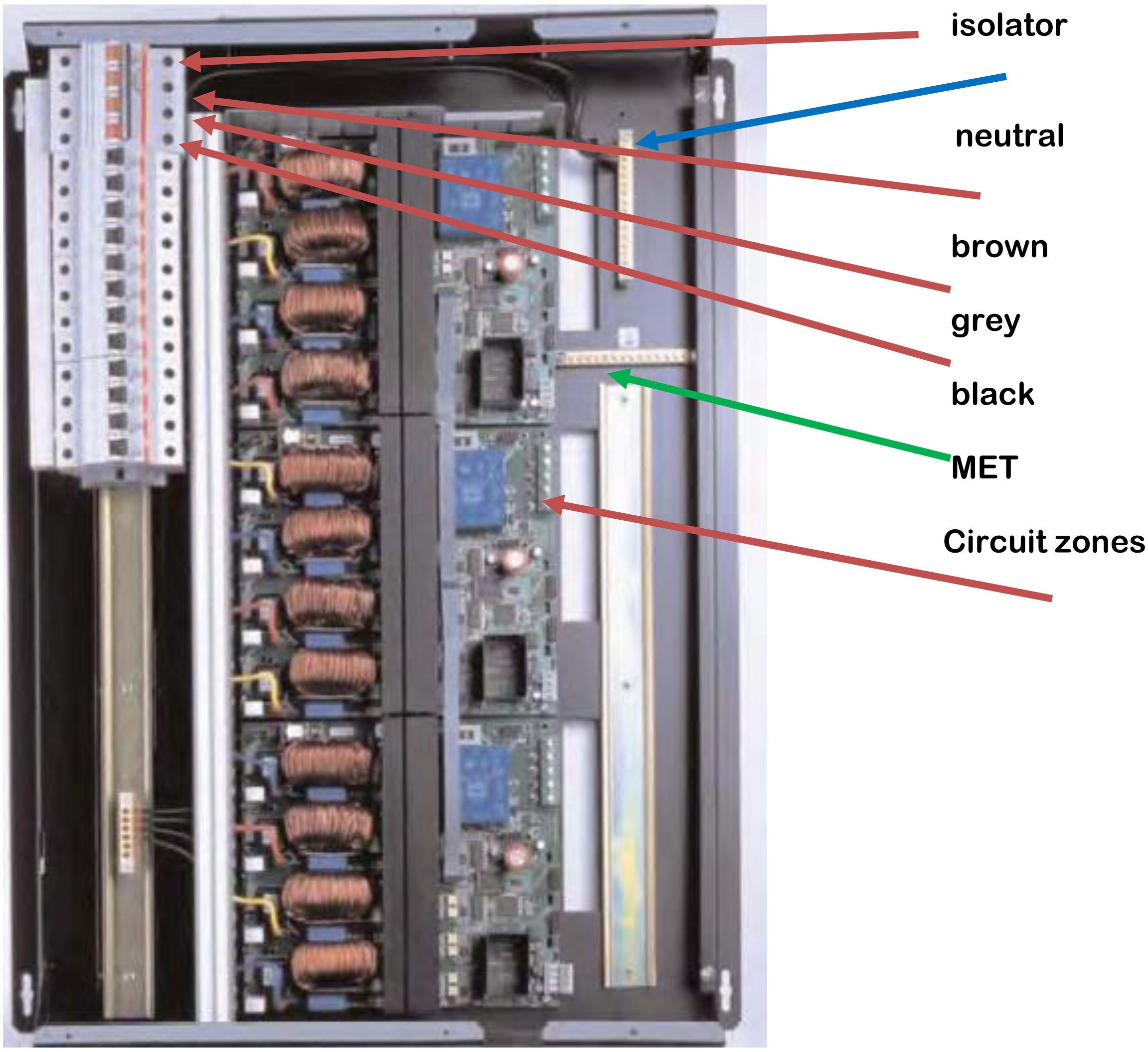
A common mistake by consumers is that they believe a dimmer will dim any type of lamp, they do not install inductive dimmers for the downlighters installed.

Dimmer racks

In theatres and other places of entertainment including museums and art galleries, lighting needs to accommodate the aesthetic qualities of the objects being exhibited or the performance being acted.

Lighting is often controlled by dimmer racks which can give effect to the stage or exhibit.

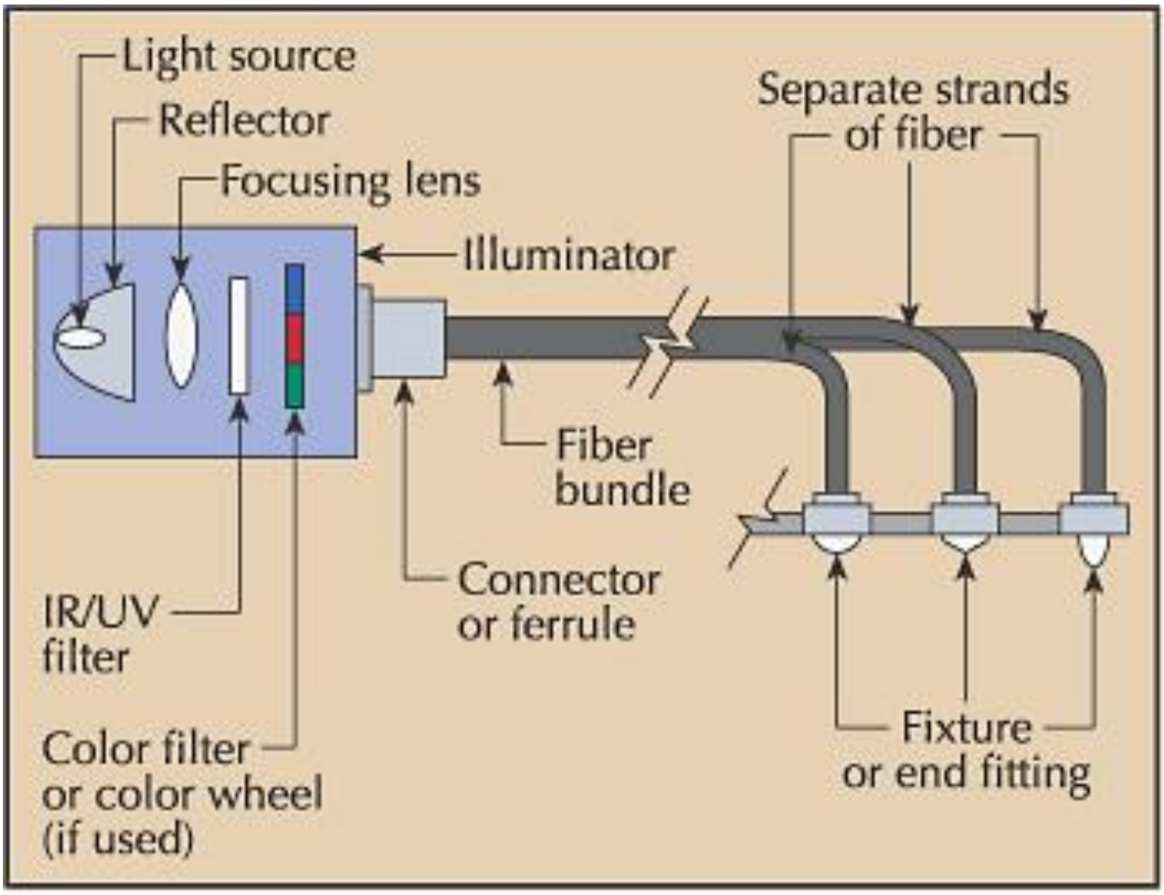
These racks can be controlled from a PC or by remote control system, well established makes include Lutron or Leax, both these systems are expensive to install but are almost maintenance free.



Cat 5 cables are installed between switches and circuit zones.

Fibre optic lighting

A new type of light source for stunning effects, often referred to a star lights. The cable consists of glass tubing which light will travel along producing a glow at the end of the fibre, the light source can be off any type but the most popular is a power LED.

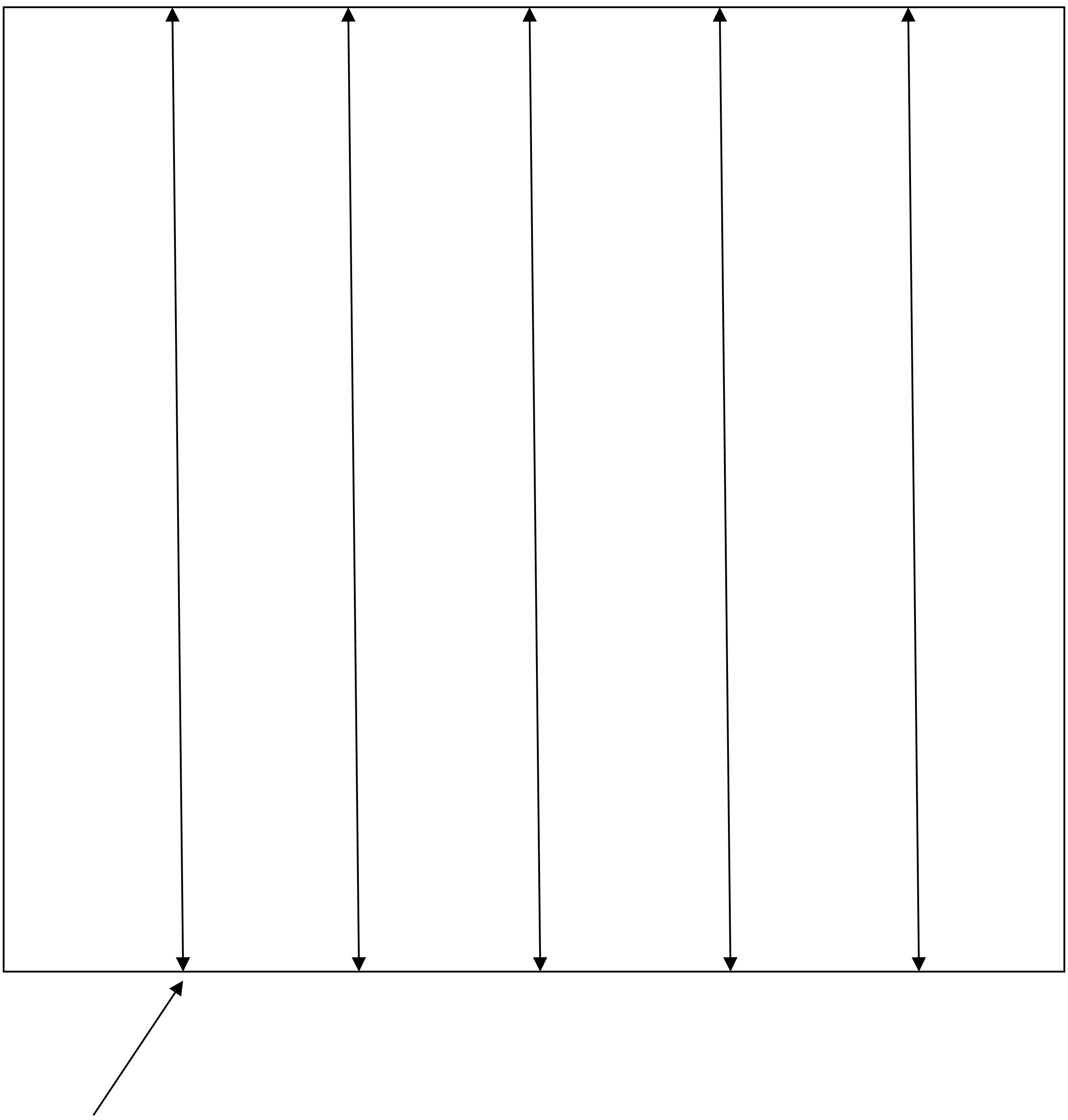


To create a system of star type lighting, the method of installation should be followed.

Step 1. Above the room ceiling, find the joists and drill a small hole close to the joist so that the free area can be seen from below.

See figure 1.

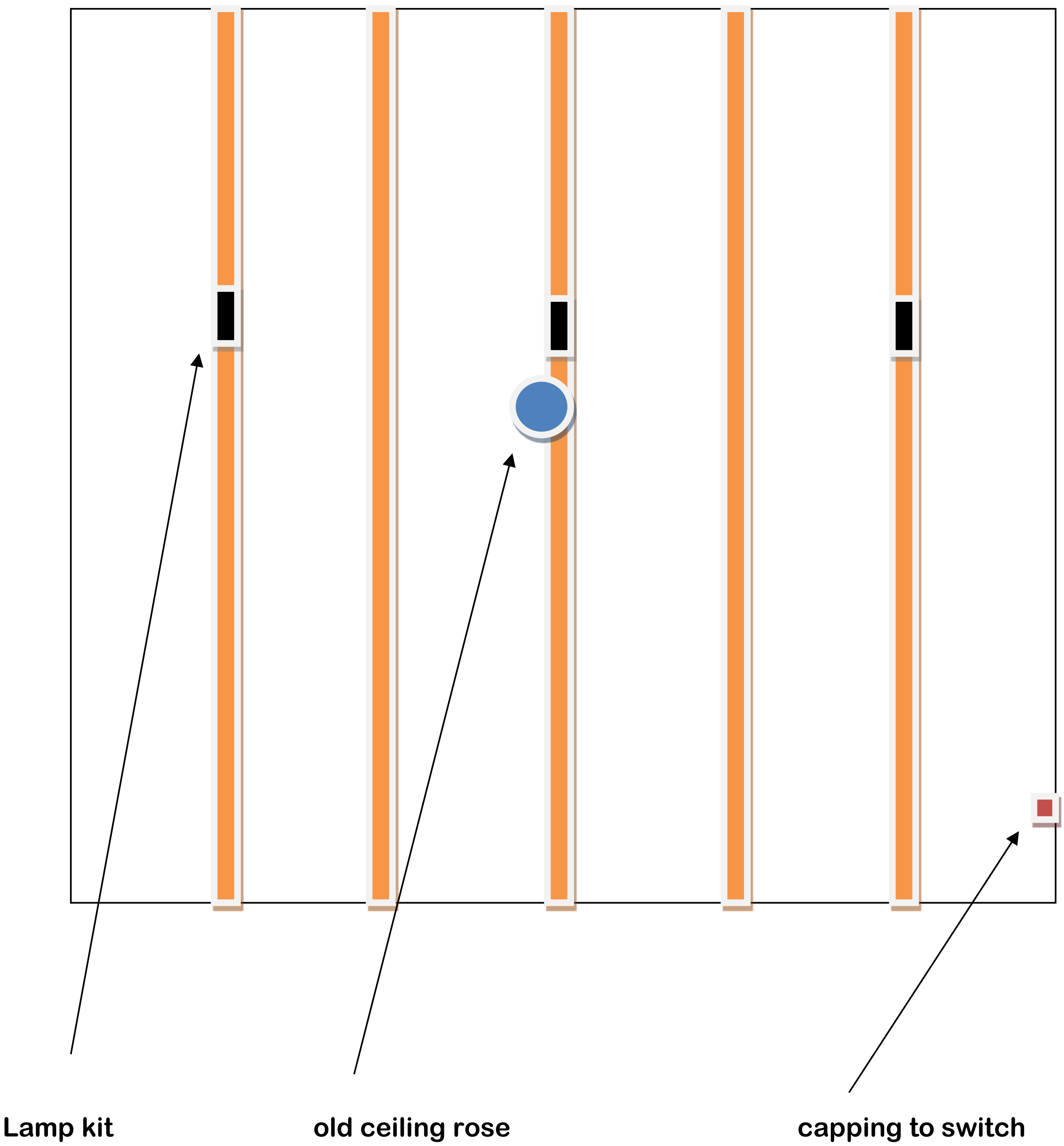
Figure 1.



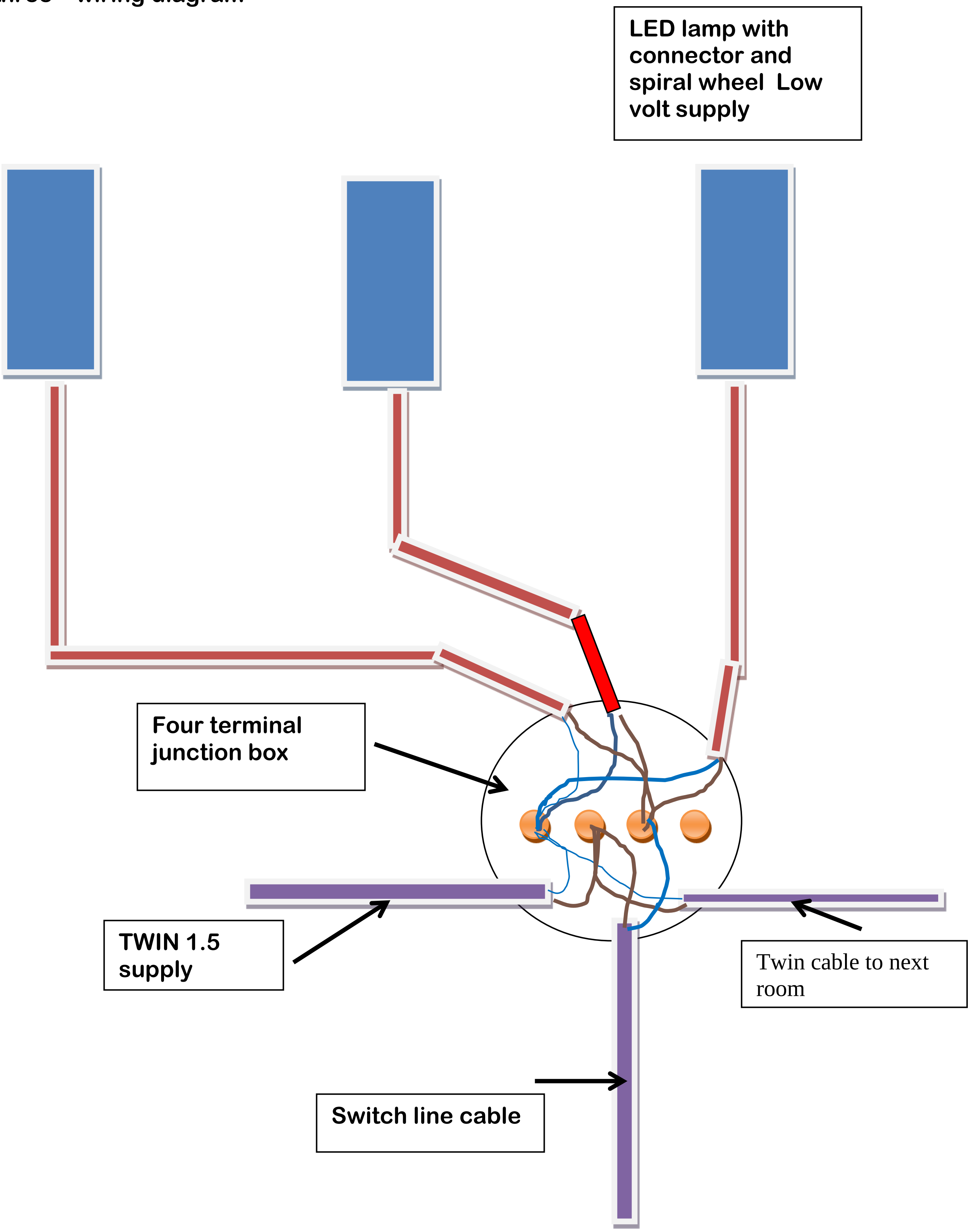
Small hole here seen from below, installation space will be between each joist, light source and fibre optic cables will be fixed to joists above see figure two.

Step two – fix lamps and cable source to joists allowing the fibres to be evenly spread in a fixed area.

Figure two



Step three – wiring diagram



Replace twin and cpc cables from ceiling rose and connect as shown in wiring diagram, note cpc`s have been left out due to clarity but must be connected in spare terminal in junction box.

Step four- drill 0.8 mm holes in ceiling below and feed fibes down holes , note if you require some brighter stars add more fibres, cut fibres below, remember for safety wear goggles and non static gloves, shards of glass can cause blindness.

Change switch for infra red version so that the stars can be remotely operated.

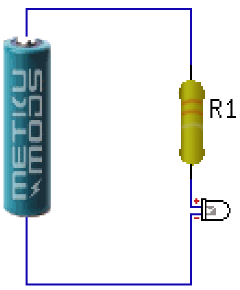
End product

LED resistor calculation

The low voltage and current required to enable light output from a light emitting diode has to be brought down to a low value, this is because too much current will destroy the junction between the P type and N type materials.

It is usually the case that a resistor is placed in series with the terminal of the LED, the calculation is shown here.

$$R\ series = \frac{V\ supply\ -\ V\ lamp}{I\ lamp}$$



For a supply voltage of 5 V and a lamp voltage of 0.2 V , this would be a lamp current of 4.8 Ma , the resistor would be 1000 Ω.

Solar panel displays

The most energy efficient way to light modern signs etc is to charge a battery by means of solar panels, this can then be used to illuminate signs or provide real time accurate information without an electrical supply.

The system is switched via a radio receiver , bus shelters use this system to display the time of the next bus or other information received from a central control.

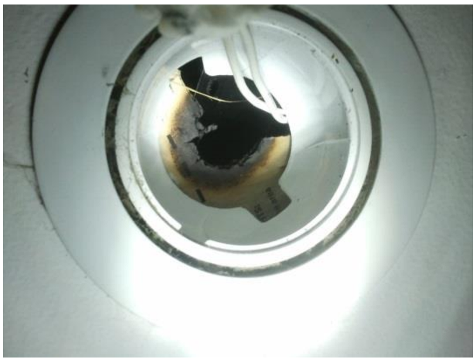
Most display lighting is energy efficient and the need for street furniture to have an electrical supply is becoming a thing of the past.

Lighting safety

Where 230V downlights have been installed, it is often the case that not enough air to cool the temperature around the lamp has been thought about.
This is against IET requirements and also building regulations.

The result of not providing sufficient cooling space is of course fire, floorboards and joists can become charred and eventually set alight.

The solution to this problem is fire retardant top hats, these come as kits and should be used where the lamp manufacture states that the heat produced must be allowed to dissipate within the building structure.
This is also a problem with transformers, they too need air.



top hats

Examples of Decorative lighting