Electric Lamps: Fundamentals of light and its production

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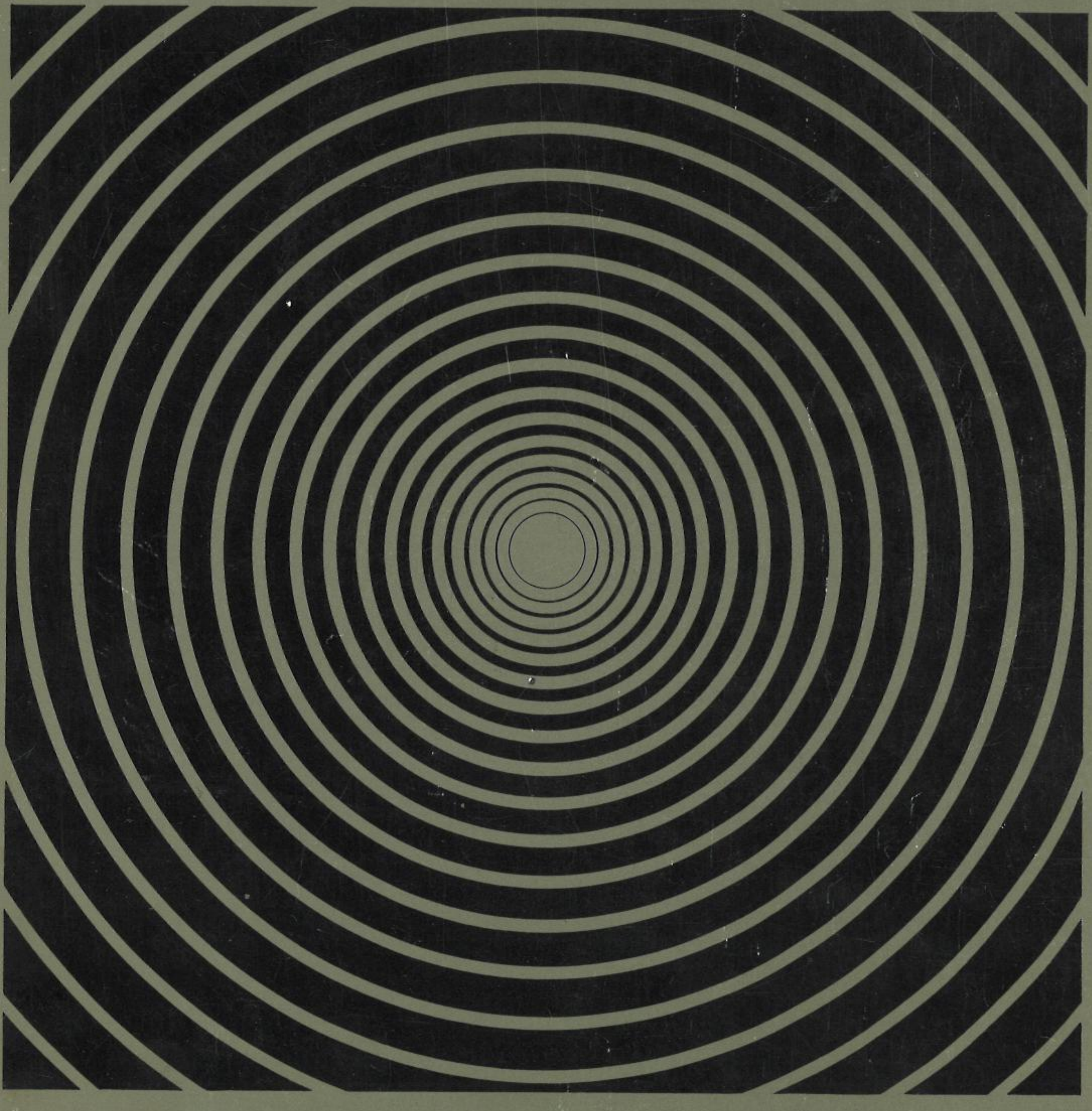

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Electric Lamps Section A

Fundamentals of light and its production

Published by the British Lighting Council
16–18 Lancaster Place, Strand, London, W.C.2.
Telephone: 01-836 7337

Foreword

It was originally intended to produce a new book on Electric Lamps in three parts each complete in itself. It has become apparent, however, that if this were done it would involve a great deal of repetition of fundamental matters in each part. For this reason it has been decided to include all the necessary fundamentals in this Section A and to follow with —

Section B — Fluorescent Lamps
Section C — Filament Lamps
Section D — Discharge Lamps
as soon as they can be prepared.

This series is intended primarily for the lamp user to help answer the kinds of questions that he constantly raises. It is by no means intended for the lamp physicist. Therefore in some cases we have over-simplified physics in order to present the important facts in a manner understandable to the non-specialist reader, and to avoid reference to matters with which he is unlikely to be concerned.

All four Sections will be in the same format so that they can be kept in a single binder.

All references are to paragraph numbers.

1. Nature of light

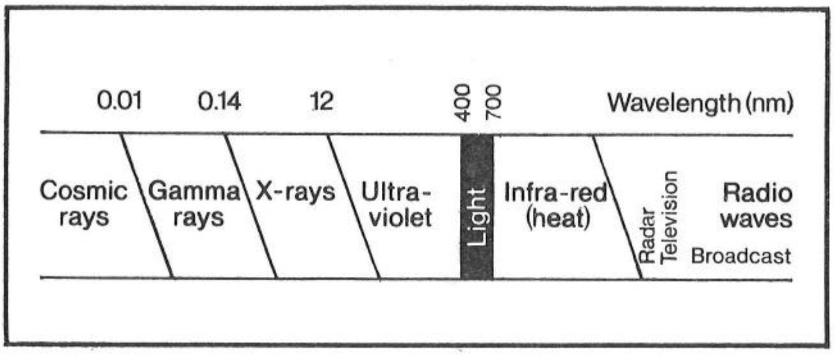

Figure 1
The electro-magnetic spectrum

1.1 Light is one of the family of electro-magnetic radiations which includes cosmic, gamma and X-rays, ultra-violet, infra-red and radio radiations. All these travel through space at a speed of 3 x 10^{10} cms (186,000 miles) per second.

1.2 It is convenient to consider that the radiations move outwards from their origin in the same way as ripples move from the point of disturbance in a pool. The ripples move outwards though the only actual movement of the water itself is vertically up and down. Similarly, light may be considered a wave motion.

1.3 Since all electro-magnetic radiations travel at the same speed, it is apparent that if the crests of the waves are close together (i.e. if the wavelength is short) a large number of them will pass a given point in a given time, or in other words the *frequency* is high; but if the wavelength is long, the frequency will be low.

1.4 In general, ultra-violet and light radiations are described in terms of their wavelength, a common unit being the Nanometre (nm), a wavelength of one ten-millionth (10^{-7}) of a centimetre.
Short radio waves, however, are generally described in terms of frequency, in millions of cycles (megacycles) per second.

1.5 The physical and physiological effects of the radiations depend upon their wavelength or frequency. The names given to the various wavelength bands are shown, though the boundaries between the bands are indefinite; it is not possible, for example, to say precisely where very long-wave X-rays end and very short-wave ultra-violet begins.

1.6 It will be seen that light is the name given to a very small portion of the whole electro-magnetic spectrum. It is only radiations with wavelengths between about 400 nm and 700 nm which stimulate the average human eye; wavelengths a little over 700 nm give us the sensation of heat, and those a little under 400 nm offer the possibility of making use of fluorescent effects (2.23).

1.7 A generator of light would be most efficient — it would produce most light per unit of power input — if it could be made to produce light only and no other radiations, but at present there are no known light sources, either natural or artificial, which do not generate heat also. As lamp development continues, the constant trend is to turn more of the input watts into light and less into heat, so increasing luminous efficiency.

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* nm=Nanometre or $\frac{1}{10,000,000}$ cm. This unit has now been adopted for the measurement of wavelength in place of the Ångstrom unit. 1 nm = 10 Å.

Colour

1.8 The colour sensation received by the eye depends on the wavelength(s) of light entering it. Here again, the boundary between one colour and the next is indefinite, for it is impossible to say, for example, where orange light ends and where red begins; but for convenience a series of divisions is generally accepted as shown.

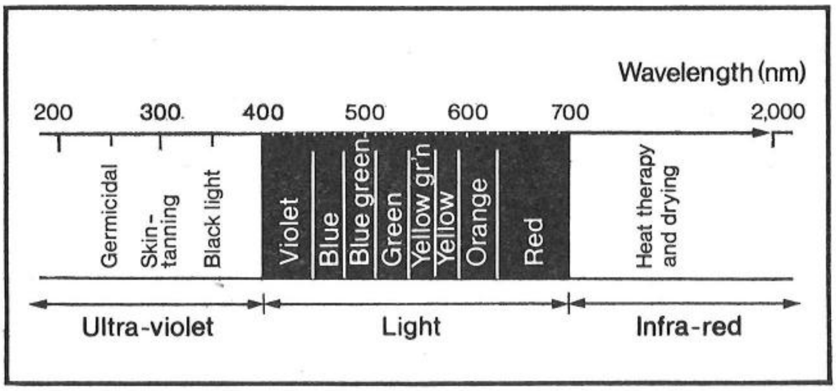


Figure 2
The visible and near-visible radiations of the electro-magnetic spectrum

1.9 The human eye is not equally sensitive to all the wavelengths in the visible spectrum. Under normal illumination levels it responds most strongly to yellow-green radiations (555 nm) but weakly to violet and blue at one end of the spectrum and red at the other. The relative response of the average human eye to equal energies of various wavelengths of light is shown.

This largely accounts for the fact that lamps which give predominantly yellow or green light tend to be more efficient in their own class than lamps giving other colours of light — this is because units of light are based on physiological response, not on physical entities such as watts, feet, pounds, etc.

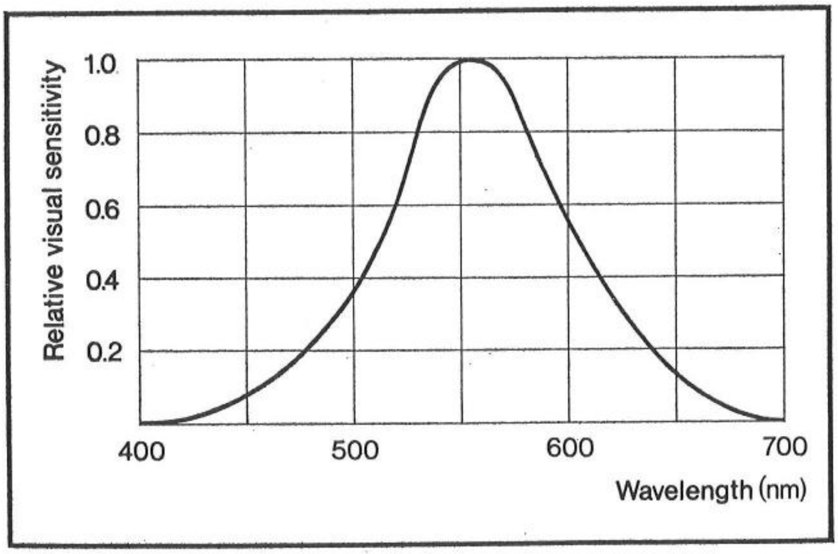


Figure 3
The curve indicates the eye's response to equal energy of light at various wavelengths. It is most sensitive to yellow-green light (555 nm) than to other colours

1.10 The eye recognises as "white" any light which does not appear to be coloured. No single wavelength of light gives the sensation of whiteness, there must be a mixture of wavelengths. White light can be produced by a mixture of only two different wavelengths in special relationship to each other, or by three or any larger number. Light from the sun or an overcast sky contains all possible wavelengths in roughly equal strength, it looks white and gives us a feeling of naturalness. Light from a white-hot material such as a lamp filament also contains all possible wavelengths, though not all at the same strength — they get progressively stronger towards the red end of the spectrum — and this also we accept for most purposes as being reasonably "natural".

ELECTRIC LAMPS SECTION A.

Correction.

Please note that the diagrams on pages 5 and 10 have been transposed. The captions, however, are on the correct pages.

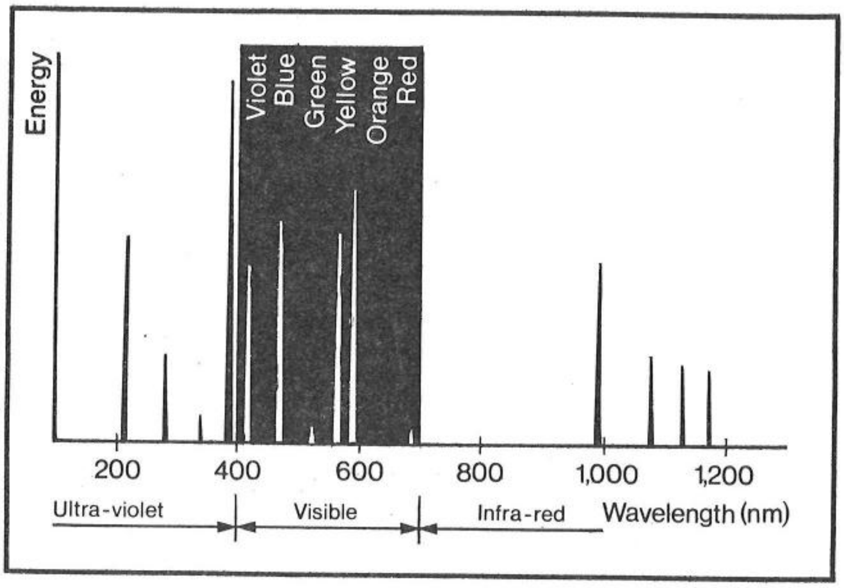


Figure 4
Continuous spectrum of a filament lamp. There is a large proportion of heat (infra-red) radiation compared to light

1.11 A material coloured, say red, appears to us that colour because it is capable of reflecting red light much more strongly than the other colours of light which it partially or completely absorbs. But it can do this only if there is some red light present for it to reflect. It follows that if we are to appreciate the redness of a piece of material there must be red rays in the light we are using to see by. Similarly, if we are concerned with seeing a blue material, there must be blue rays present, and so on.

1.12 Thus if we are to appreciate properly an ordinary scene in which many colours are present, the light we are using should contain all wavelengths in the visible spectrum. And if some of the scenic colours are not to be over-emphasised and others are not to appear too weak, all the wavelengths in the light should ideally be at equal strength.

This is one of the fundamental facts which determine the luminous efficiency of lamps and their colour-rendering properties.

Colour rendering

1.13 A distinction must be made between the colour appearance of a light source, and its colour rendering property. Its colour appearance is an intrinsic property of the source, e.g. low-pressure sodium lamp light looks yellow, mercury lamp light looks blue-green, and so on. Colour rendering refers to the appearance of coloured surfaces seen by the light, and as inferred in 1.12 this depends on the relative strengths of the radiation at each wavelength.

A musical analogy may help to explain a difficulty here. If say, a six-note chord is struck on a piano, the resultant sound consists of six different sound frequencies (disregarding overtones) which the ear adds up and can recognise as, say, C sharp. The *trained* ear can go further, and can distinguish each separate note of the chord. The eye, however, is not so perceptive. It can add up the various frequencies (wavelengths) present in a light, and can recognise the total result as being, say, yellow. But it cannot distinguish the individual components of that apparently yellow light — which might be comprised of any one of various combinations of other colours of light. Each of these combinations would have a different colour-rendering property.

Thus it is quite possible for two different lights — e.g. low pressure sodium light and tungsten lamp light coming through a yellow filter — to have the same colour appearance but completely different colour rendering properties. Conversely it is also possible, though not very likely, for a surface to look the same colour when seen by the light of either of two sources which differ substantially from each other in colour appearance.

1.14 When a material is heated it first glows red, then yellow, then white, according to the temperature it attains. The colour of light given out at different temperatures by a "full radiator" or "black body" — a hypothetical material which radiates all the energy it receives — is well established, and it may thus be convenient to describe the colour of a light by quoting its "colour temperature" e.g. a colour temperature of 2000° K is the colour of light given out by a black body at 2000° K. The filament of an ordinary incandescent lamp behaves nearly like a black body, it emits nearly the same colour of light and its energy is given out — like that of a black body — in smooth progression throughout the visible spectrum. One can therefore refer to the colour temperature of filament lamps without causing any confusion.

With most discharge and fluorescent lamps, however, the distribution of light energy throughout the spectrum is quite different, and, therefore, the colour-rendering property of the lamp is quite different from that of a filament lamp giving light of the same apparent colour. Therefore, although it might be technically correct to ascribe a colour temperature to a particular fluorescent lamp in order to describe the colour of light it produces, it is usually not done in this country since it might be misunderstood to imply a particular colour-rendering property. Many photographers have met trouble in this respect while trying to take coloured pictures by fluorescent light.

2. Production of Light

2.1 Light can be produced in a number of ways, among others by incandescence (2.2 – 2.7), by the electrical excitation of gases or vapours (2.8 – 2.11), by fluorescence (2.23 – 2.28) and by electroluminescence (2.29 – 2.32).

Incandescence

2.2 When a solid body is heated to incandescence the electrons are violently agitated and constantly collide with their neighbours. Some of the energy resulting from these collisions is radiated from the hot material, and due to the relatively close packing of the individual atoms the result is a confused radiation smoothly distributed over a wide band of wavelengths. Some of the radiations may be in the visible band but the greater part will, in practice, always be in the infra-red (heat) band. The amount of energy radiated at any particular wavelength is determined by the nature of the material and its temperature.

2.3 Figure 5 shows the radiation characteristics of a black body (1.14) at different temperatures. The area under each curve represents the total energy radiated. It will be seen that —

(a) the radiated energy increases rapidly as temperature is raised. Stefan has shown that the amount of energy radiated is proportional to the fourth power of the absolute temperature (°K = °C + 273).

(b) the wavelength of maximum radiation decreases as temperature rises. Wien has shown that the wavelength of maximum radiation multiplied by the absolute temperature is constant.

(c) the proportion of the total radiation which is emitted within the visible range increases as the temperature is raised.

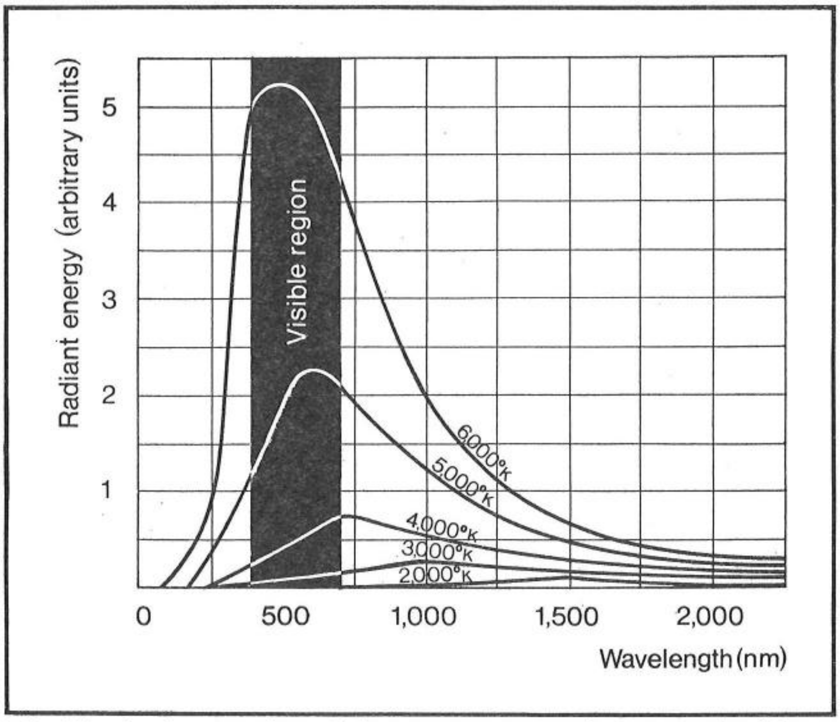


Figure 5
The relative energy radiated at various wavelengths by a "black body" at five different temperatures

2.4 The luminous value of the curves cannot be assessed without taking into account the response of the eye (figure 3) and each ordinate of figure 5 should be multiplied by the corresponding ordinate of figure 3, which will have the effect of modifying the luminous advantage obtained from higher temperatures. At 2000 °K a temperature rise of 20 °C will increase the total radiation by 4%, but will increase light output by 15%.

2.5 No actual substance has the radiation characteristics of a black body, though they are closely approximated by an incandescent carbon filament. Figure 6 shows the energy distribution of some of the "selective radiators" which are being or have been used for making lamp filaments. The materials are operating at the same temperature and the total visible radiation is the same in each case, but it will be seen that the total energy radiated is least in the case of osmium, a little more with tungsten and most with untreated carbon. At first sight, therefore, it appears that osmium would be the best material to use since it dissipates (and requires) least energy to provide a given quantity of light.

Osmium, however, has a melting point of about 2700°C whereas that of tungsten is in the region of 3330°C, and the luminous efficiency gained by using tungsten at higher working temperatures far out-weighs the loss due to its being an inferior radiator.

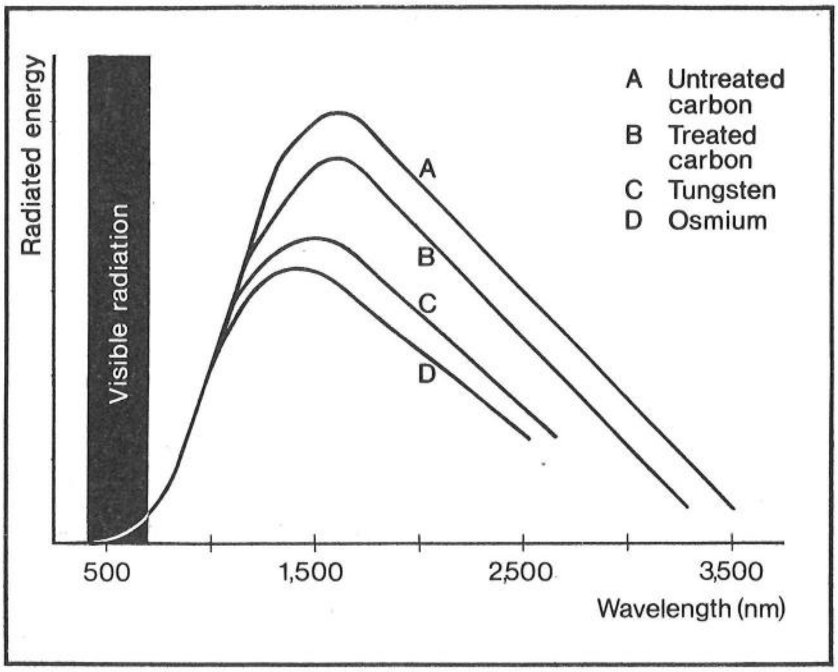


Figure 6
Wavelength distribution of radiant energy from various materials at the same temperature

2.6 If these were the only considerations governing the choice of filament material, carbon might be supremely suitable as its melting point is very high, but it cannot be operated satisfactorily at temperatures beyond 1850 °C on account of rapid evaporation which would soon destroy the filament.

2.7 Manufacturers thus have to choose a conducting material having a high melting point and a low rate of evaporation, with the necessary mechanical properties to enable filaments to be shaped into suitable forms of sufficient strength to withstand ordinary (or sometimes particularly arduous) conditions of service. Tungsten is almost universally used, sometimes in a vacuum, sometimes in an atmosphere of argon/nitrogen or krypton, and in some recent special types with the addition of a halogen such as iodine, bromine or chlorine. (See Section C — Filament Lamps).

Electrical excitation

2.8 An electric discharge works on an entirely different principle. A gas or vapour may be considered to consist of vast numbers of atoms, each atom comprising a positively charged nucleus with one or more negatively charged electrons circulating round it. The positive and negative charges balance each other so that in its normal state the atom is electrically neutral.

Among the normal atoms, however, there will be a few in which the nuclei and electrons have become temporarily detached from each other. Cosmic radiation from outer space will cause this to happen, and the effect is that among the normal atoms there are some positively charged nuclei (positive ions) separated from negatively charged electrons (negative ions).

2.9 If the gas or vapour is enclosed, say in a glass tube with a metal insert at each end, and if a voltage is applied to the ends, the normal atoms will not at first be affected since they are electrically neutral. But the positive ions will accelerate towards the negative pole of the electric supply and the negative ions towards the positive pole.

The speed which the ions have attained at any instant will depend on two things — the voltage gradient (voltage per unit length of tube) and the distance they have travelled up to that instant.

2.10 If the gas or vapour is at low pressure, the atoms which comprise it are spaced relatively far apart. But since there are countless millions of them in the tube, it is inevitable that collisions will eventually occur between the speeding ions and the normal atoms.

If the voltage is sufficiently high and if an ion has by chance avoided an early collision, the ion will have attained a destructive speed by the time a collision occurs. The struck atom will receive such a blow that the nucleus and electron(s) become completely detached so forming new ions which themselves accelerate to collide with more atoms, and so on with snowball effect. The gas or vapour is then said to be "ionised" and the flow of ions constitutes an electric current.

Thus once an electric current starts to flow, it will increase very rapidly of its own accord, and some exterior device such as an inductor or a resistor becomes necessary to limit it to a desired value.

2.11 Not all the collisions referred to above result in the formation of new ions. Some collisions will occur at an early stage when the colliding ion has not attained a destructive speed, but it may be moving fast enough to knock one of the struck atom's electrons out of its normal orbit round the nucleus, into an unnatural orbit. The atom is then said to be "excited". In the collision, the electron will have acquired some extra energy, and it gives up this surplus in returning to its normal orbit. The energy so released appears as radiation. The wavelength(s) of the radiation(s) emitted in this process are a characteristic of the gas or vapour in question, and have normally been regarded as being unalterable except that the relative strengths of radiation at the relevant wavelengths can be changed by altering the temperature and pressure of the gas or

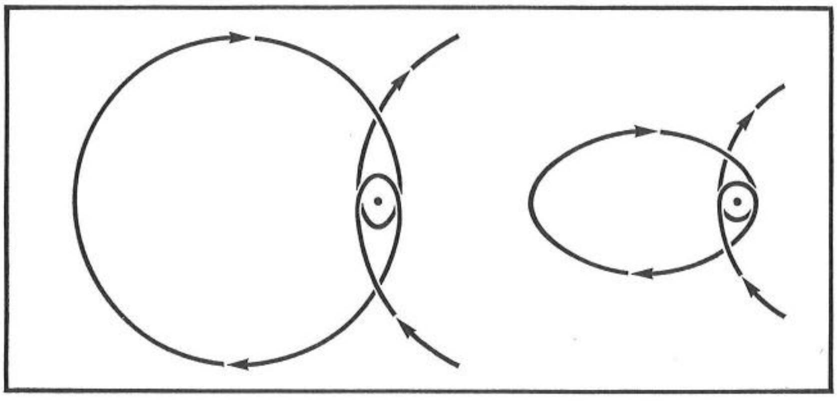
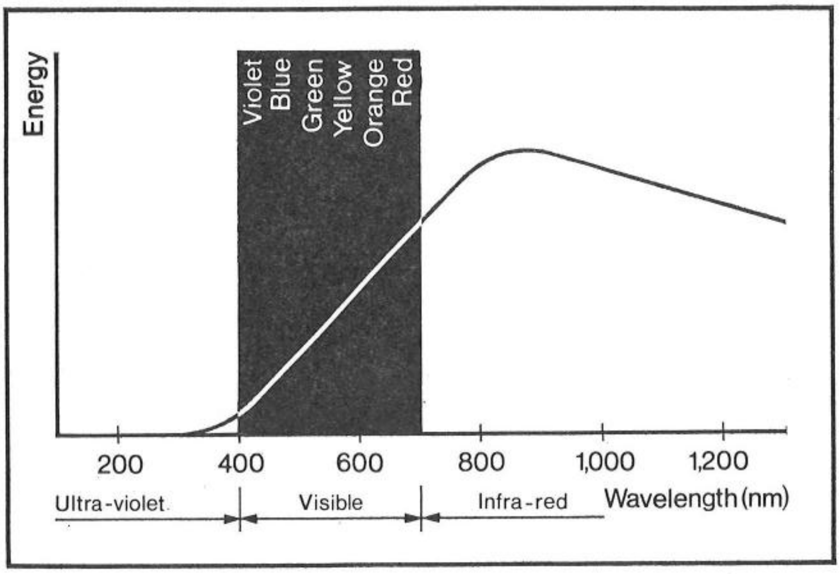


Figure 7
Simplified diagram of a sodium atom showing the orbit of an electron. **Left:** In the normal state. **Right:** In the first excited state

vapour. Recent developments have shown, however, that at high vapour pressures it is possible in certain discharge lamps, notably in the high-pressure sodium lamp, to broaden the "isolated" line radiations until they cover the whole or nearly the whole visible spectrum in a manner to some extent similar to that of an incandescent body.

Early attempts to modify or improve the colour of light from simple mercury discharge lamps by adding other metals to the contents of the discharge tube were not very satisfactory. In the new mercury halide lamps, however, the addition of iodides of such materials as thallium, indium, etc, has enabled both lamp efficiency and colour of light to be improved. (See Section 4 — Discharge Lamps).



See P. 5.

Figure 8
Discontinuous spectrum of a mercury discharge lamp. Note the strong radiations in the ultra-violet region.

Control gear

2.12 It was explained (2.10) that the current in an electric discharge lamp circuit must be controlled by some external device. This could be in the form of a resistor, or for A.C. circuits it might be an inductor or a capacitor or both.

2.13 If a resistor is used, the wattage it consumes is generally comparable with or greater than the wattage of the lamp itself, and since the resistor wattage normally produces nothing but unwanted heat the luminous efficiency of the circuit is reduced substantially below that of the lamp itself. For this reason a resistor is seldom used except for D.C. circuits where there is no alternative, or for A.C. circuits where cheapness in first cost is considered overwhelmingly more important than economy in running cost. It is, of course, possible for the resistor to be in the form of a filament lamp which produces some light as well as heat and this effects some improvement to the luminous efficiency of the circuit.

2.14 On A.C. circuits at normal supply frequency an inductor is used almost universally, in the form of a choke or a leaky field transformer acting as a choke, since this provides the necessary control of current without itself consuming a high wattage. Thus the luminous efficiency of the circuit remains high. But a choke — or any inductor — included in the circuit has the effect of producing a lagging power factor, that is, the A.C. wave of current lags behind the A.C. voltage wave so that the circuit volt-amps are greater than the watts. Generally in a circuit consisting simply of a lamp and choke in series, the power factor $\frac{W}{VA}$ is of the order of 0.5 lagging.

2.15 While this phase displacement between voltage and current has a disadvantage it is nevertheless necessary for an apparently steady output of light from the lamp. In a discharge lamp — and a fluorescent lamp is a form of discharge lamp — on a 50-cycle A.C. supply the electric arc is extinguished 100 times a second as the current wave falls to zero. Consequently the generation of ultra-violet and light also ceases at that moment, and if the lamp is not to have an obvious flicker it must be arranged that the arc strikes up again immediately in the reverse direction.

Consider the curves shown in Figure 9.

2.16 If the choke is correctly designed for its purpose, the current wave lags behind the voltage wave by an angle such that at the instant of zero current (X) there is already a sufficient voltage (V_1) to restart the discharge in the opposite direction.

But if the choke is designed with insufficient inductance — possibly in a misguided effort to save cost or improve the power factor — the angle of lag will be less and at the instant of zero current (Y) the voltage (V_2) is insufficient to restart the discharge. The arc will not strike until point (Z) is reached, so there is a period of time during which the arc is out and there will be no generation of light. The prolonged "out" periods would cause a very noticeable flicker, and the current waveform would be badly distorted with the likely effect that the lamp electrodes would fail early.

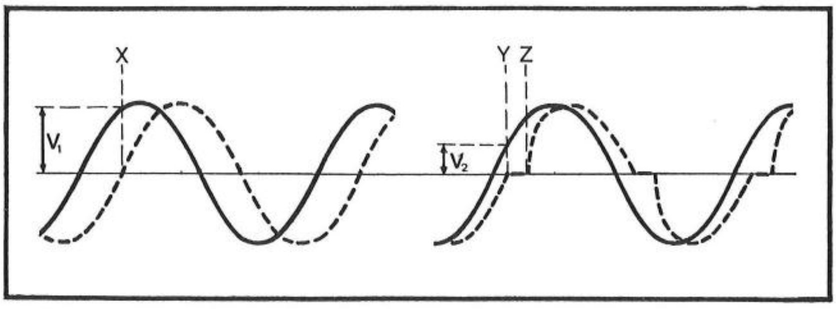


Figure 9

Left: Normal phase relationship of mains voltage (full line) to lamp current (dotted line) in a discharge lamp. **Right:** Too high a power factor of the lamp/choke combination results in a distorted current wave form and increased flicker

2.17 It is essential to use a choke of the correct rating for the lamp and circuit concerned, otherwise the lamp will be either over — or under — run with consequent ill effect on its performance, particularly as regards life. Under ordinary conditions the choke should have a voltage rating corresponding as nearly as possible to the average voltage of the mains measured at the lighting point when the lamp is alight. This is not necessarily quite the same as the nominal mains voltage.

2.18 The cubic shape of choke gives the lowest wattage losses. It meant, however, that for fluorescent lamps the choke had to be housed in an unsightly box on top of the fitting; this might have been acceptable for some industrial style fittings but was inappropriate for commercial styles. For fluorescent lamps the cubic shape was therefore abandoned in favour of an elongated type with higher wattage losses, but which could be accommodated in a fairly unobtrusive channel incorporated in the design of the fitting. There are also circular chokes for use with mercury discharge lamp fittings.

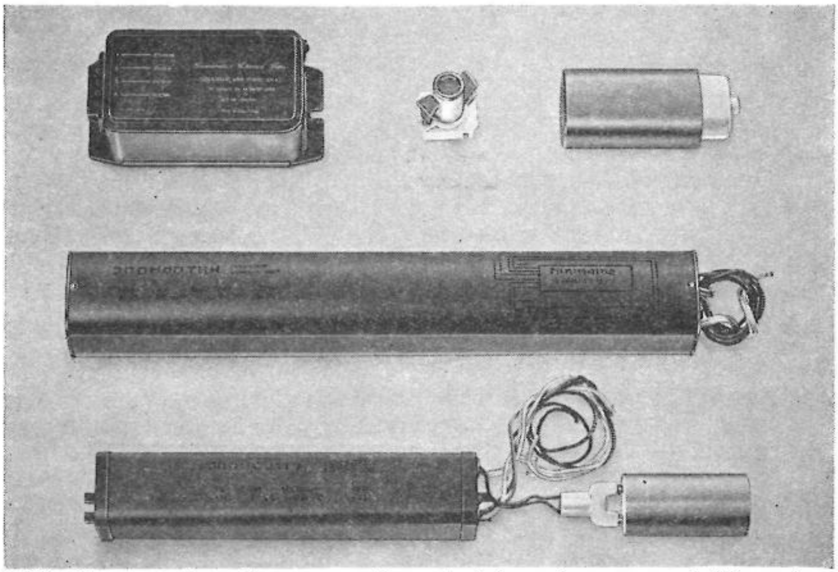


Figure 10

Top: Cubic choke with starter switch and power-factor correction capacitor.

Centre: Early elongated high power-factor choke.

Bottom: Modern semi-resonant choke with series capacitor.

2.19 The use of modern magnetic materials and compound fillings has enabled present-day chokes to be made very small. It is unlikely that they will become much smaller, for the smaller they are the higher the watts they consume and the less the area of outer case from which the generated heat can leak away; the limiting factor, of course, is the safe temperature of the insulation surrounding the wire in the centre of the winding.

2.20 All chokes become warm in use. Some run distinctly hot, but a high temperature of the case is not necessarily an indication that something is wrong. It may merely mean that the design, including the filling, is such that heat is being well conducted away from the centre of the winding, and this in itself is very desirable.

2.21 It is virtually impossible to make a choke completely silent. Choke noise may arise from two causes (1) the vibration of the laminations of the iron core or of the winding as the magnetising effect of the A.C. current rises and falls 100 times a second; noise from this source can be almost prevented by tight clamping of the laminations and by impregnation of the windings by a filling compound capable of preventing movement (2) magnetostriction, i.e. a minute change of dimensions of the core with change of magnetising A.C. current; noise from this cannot be prevented.

In general, open ballasts and those with a considerable magnetic leakage are more likely to prove noisy than ballasts which are totally enclosed in a substantial steel case and which are solid filled.

2.22 Whether or not a choke appears to be noisy will largely depend on the noise level of its environment. In a factory, for example, quite noisy chokes may be unheard; but there are many other situations where they must be as silent as possible if annoyance is to be avoided.

Provided that the lamp pins make good connections with the lampholder contacts, and that the metal stripe (if any) along the lamp is firmly attached to it, there is nothing in a fluorescent lamp itself which can cause noise.

Fluorescence

2.23 A fluorescent material (phosphor) is one which can absorb energy radiated over a certain band of wavelengths and re-emit some of this energy over another definite band of wavelengths. Since the emitted radiations are of longer wavelengths than the absorbed radiation it follows that the latter must be in or near the ultra-violet range if the end product of the conversion is to be light.

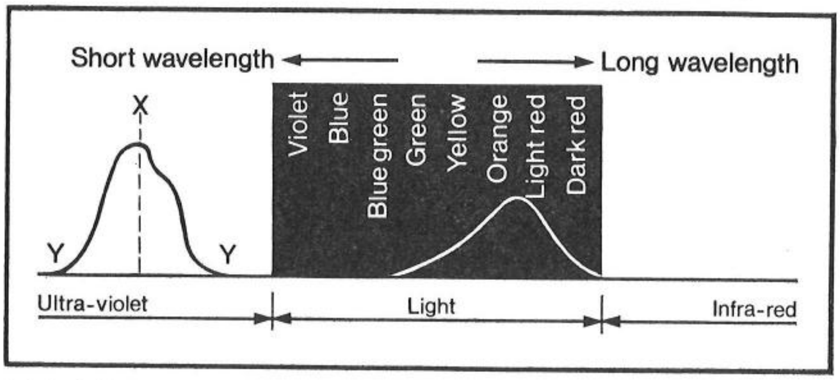


Figure 11

A particular fluorescent material will respond to any radiation in the ultra-violet waveband Y-Y, but most strongly if the stimulus is concentrated at X. Whatever the wavelength of the stimulating radiation, the emitted fluorescent light will remain the same colour

2.24 A fluorescent material has also the following properties:—

1. Each fluorescent substance is stimulated only by exciting radiations lying within definite limits of wavelength, and the emitted light is continuous over another band of wavelengths, whether the exciting rays have a continuous or discontinuous spectrum.
2. If fluorescence occurs, the colour of the emitted light is independent of the nature or wavelength of the exciting rays.
3. Over a wide range, the strength of emitted light is proportional to the strength of the exciting rays.
4. The material may also possess a degree of phosphorescence, in which case the emitted light will die away more or less gradually when the exciting radiation ceases.

2.25 Phosphors used in lighting practice may be conveniently divided into two main groups.

(a) those which fluoresce under long-wave ultra-violet of the order of 300–400 nm. These materials are used outside the discharge tube which generates the U.V., either on the inside of the outer glass of the lamp or incorporated in paints, etc., used for decorating a surface.

Most organic materials fluoresce in this way to a certain extent but deliberate fluorescent effects can be produced most strongly by activated inorganic materials (i.e. containing a trace of metallic "activator" such as manganese). Zinc sulphide, for example, will fluoresce in all colours from blue to red depending on the activator used.

(b) those which fluoresce under short-wave U.V. below 300 nm. Since this short-wave U.V. cannot pass through glass they must either be in contact with the discharge, as in a fluorescent tube, or the discharge tube of the lamp must be made of quartz or other material which transmits this U.V. and the material must be inside the outer glass of the lamp.

2.26 In the special case of tubular fluorescent lamps where fluorescence is responsible for almost the entire light output, it is essential for the mechanism of fluorescence to be efficient, that is, a reasonable amount of light must be produced in relation to the electric power necessary to produce it. Therefore, not only must the ultra-violet be generated efficiently — by passing a discharge through low-pressure mercury vapour — but also the phosphor must be capable of readily absorbing the U.V. as well as performing the wave-change operation without too much loss. These considerations put a limit to the wide variety of phosphors which might otherwise be useful.

2.27 Another most important consideration is that the colour of light emitted by the phosphor — or by a mixture of phosphors — must be acceptable for the purpose envisaged. For ordinary lighting

purposes the light must look more or less white (colourless) and must show up coloured surfaces to reasonably good advantage. For some purposes colours must look very "true to life"; for others it may be wished to emphasize, say, red materials. Strongly coloured light may also be needed on occasions for displays or floodlighting.
The phosphor used in a lamp must be unaffected or little affected by any gas or vapour present, it must retain its properties over a long period of time, it must be able to withstand the heat generated or applied (in the case of curved lamps this may be the heat necessary to soften the glass for bending) and it must neither contain too expensive elements nor be too expensive to process.

2.28 Most phosphors are effective only when they contain very small quantities of a specific activator such as tin, manganese, lead or antimony. The more important phosphors and activators currently used in lamp production are shown below.

Matrix	Activator(s)	Fluorescence	Applications
			Tubular Fluorescent Lamps
Calcium halo-phosphates	Antimony, Manganese	Blue to yellow or orange, including various white colours	Main group of phosphors used in high-efficiency standard colours
Calcium tungstate	— Lead	Deep blue Pale blue	Mainly in blue lamps
Barium disilicate	Lead	U.V. peak at 350 nm	Used to give long U.V. emission
Zinc ortho-silicate	Manganese	Green	Mainly in green lamps
Calcium meta-silicate	Lead, Manganese	Yellow to orange	In lamps of "de luxe" colours
Cadmium borate	Manganese	Orange-red	Mainly in red lamps
Barium pyro-phosphate	Titanium	Blue-white	General
Strontium halo-phosphates	Antimony, Manganese	Blue-green and yellow colours	General
Strontium pyro-phosphate	Tin	Blue	General
Strontium ortho-phosphate (containing Zn or Mg)	Tin	Orange	In lamps of "de luxe" colours
Magnesium arsenate	Manganese	Red	In lamps of "de luxe" colours
Magnesium fluoro-germanate	Manganese	Red	In lamps of "de luxe" colours
Magnesium tungstate	—	Blue-white	Used to limited extent
			Colour-corrected mercury lamps
Strontium ortho-phosphate (containing Zn or Mg)	Tin	Orange	In lamps of high efficiency
Magnesium fluoro-germanate	Manganese	Red	General
Zinc cadmium sulphides	Copper (low content)	Orange	Used to limited extent in lamps with glass inners
			Electroluminescent Panels
Zinc sulphide	Copper (high content)	Blue or green	General
Zinc sulphide	Copper, Manganese	Yellow	General

Electroluminescence

2.29 Electroluminescence is the production of light by phosphors within an electric field (usually alternating). The phosphor employed is commonly a sulphide or sulphoselenide of zinc or cadmium.

2.30 Details of construction of an electroluminescent panel vary but in essence it consists of an electrically conducting plate connected to one pole of the supply, with a thin layer of the phosphor embedded in resin or ceramic on top of it. Above this again is a glass face, on the underside of which has been deposited a transparent conducting layer such as tin oxide; this layer is connected to the other pole of the supply. The phosphor thus acts as the dielectric of a capacitor; with too thin a layer it might break down under the voltage applied, with a thick layer much of the light would be absorbed within the layer itself.

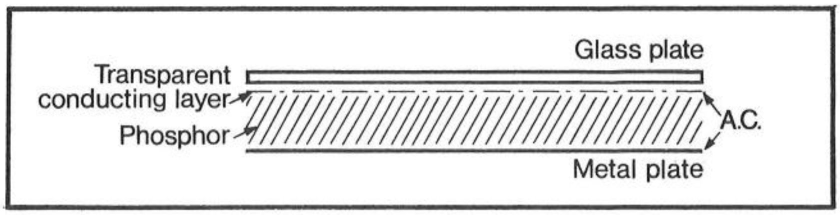


Figure 12
Essential components of an electroluminescent panel

2.31 The luminous efficiency is low (of the order of 8-10 lumens per watt for green light and less for white light) and the current taken by a medium sized or small panel is very low, up to perhaps 0.2 milliamps per sq. cm. Thus the light output is at present very limited and unless it can be greatly improved it is difficult to foresee electroluminescence taking the place of other methods of light generation for normal lighting purposes, using normal A.C. mains voltages. The light output can be increased by increasing the frequency of the supply voltage, but the complication and expense of using a frequency multiplier for this purpose only are seldom justified by the gain in performance.

2.32 Its present domestic use is mainly to provide a luminous surround to bell pushes and for clock faces, nightlights and the like. A form of electroluminescent tape has recently been developed which is expected to have applications in the decorative and advertising fields, and aircraft commonly use electroluminescent signs for messages such as "fasten seat belts" not only for their extremely light weight but also because at aircraft voltage and frequency (350V, 400 c.p.s) the luminous efficiency is increased.

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Published by the British Lighting Council
16–18 Lancaster Place, Strand, London, W.C.2.
Telephone: 01-836 7337

3m April 1967

Layout and illustration: Brian Edwards Design Group, Sheffield
Printed by the Castle Press, Dronfield, Sheffield

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