Let there be light

An short introduction to the history and future* of lighting - Part II

*But only if we have time today

Let there be light

Mankind has needed light since the dawn of time. Whether or not you are religious and believe in an all seeing, all knowing and all powerful God, the Bible puts it very succinctly on page 1.

Let there be light

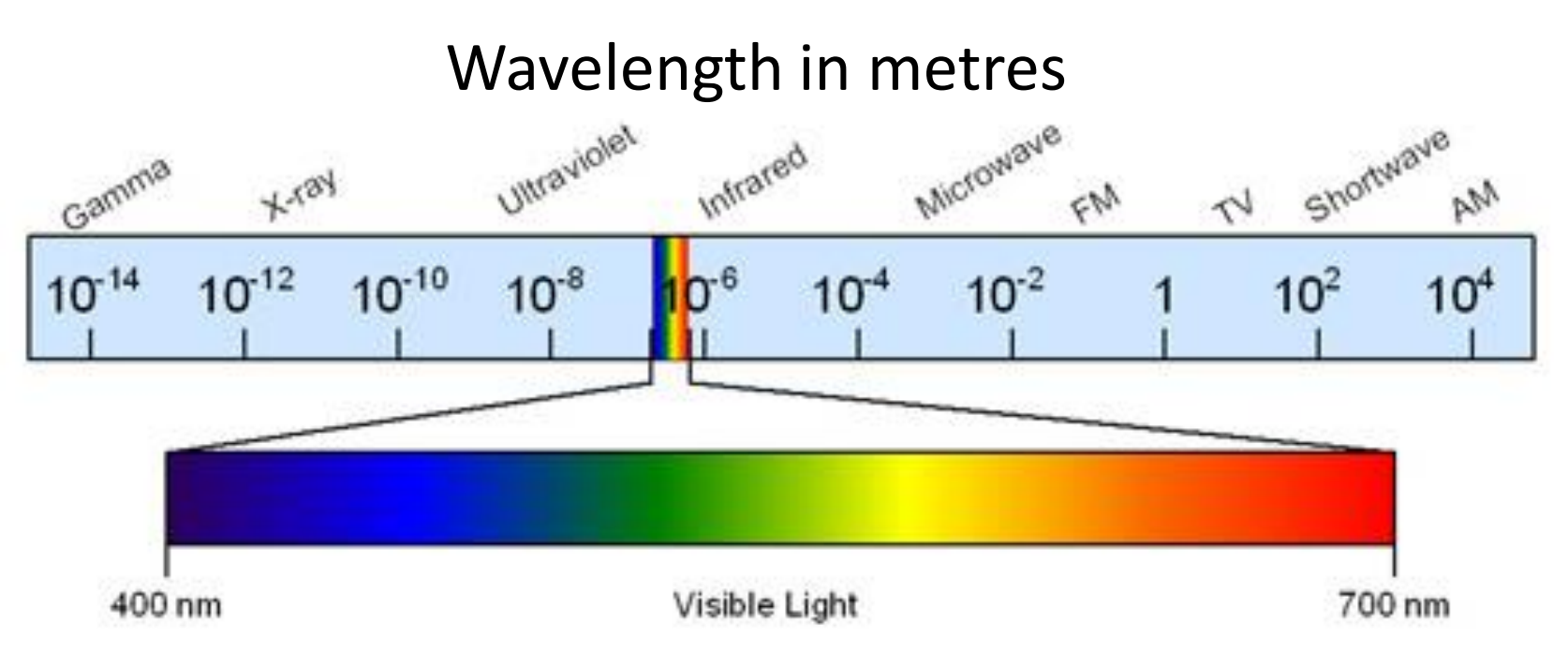
In the beginning God created the heaven and the earth. And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters.

And God said, **Let there be light**: and **there** was **light**

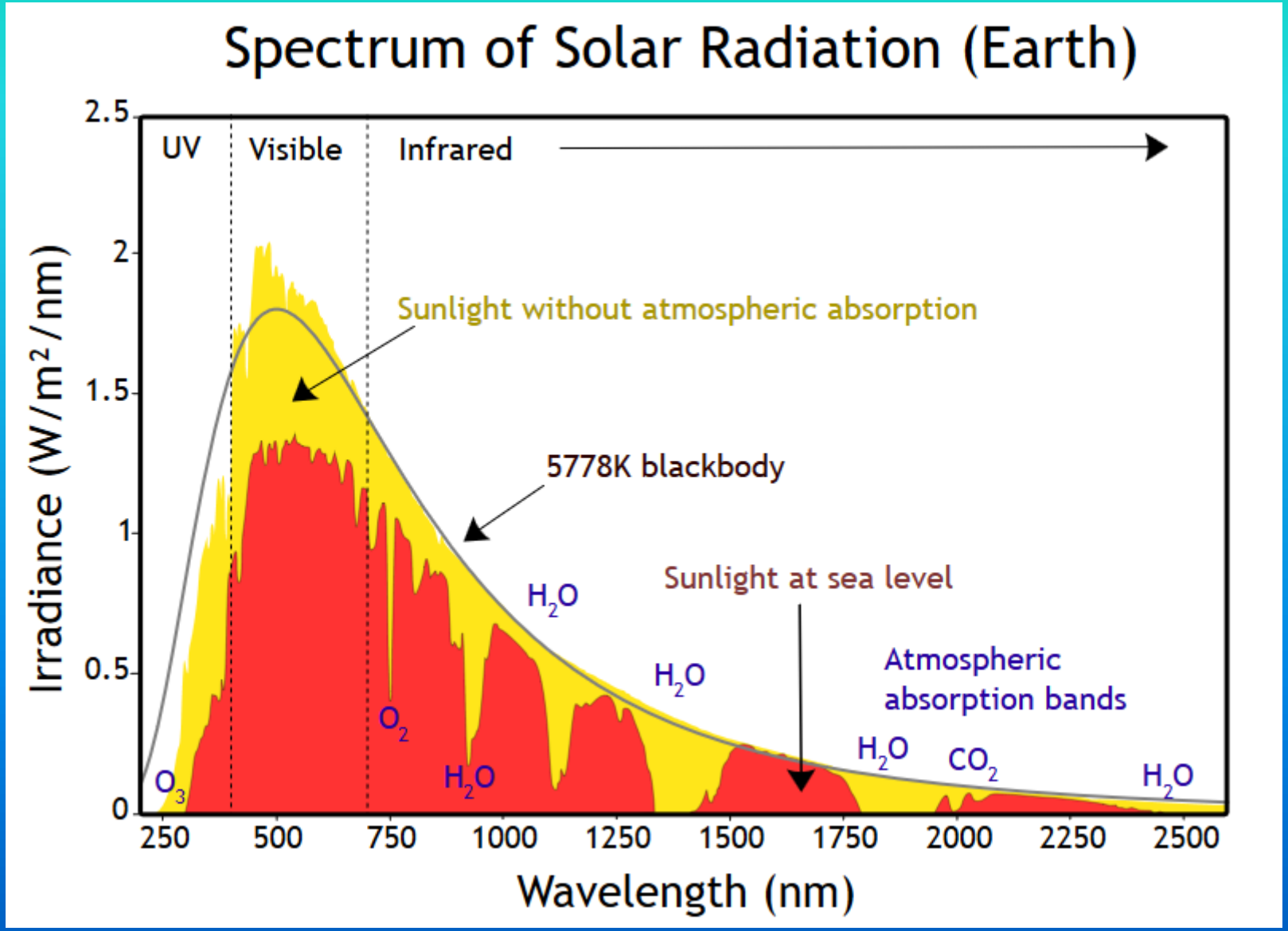
Let there be light

First, we need some revision from June 2016

The Electromagnetic Spectrum



Light from the Sun



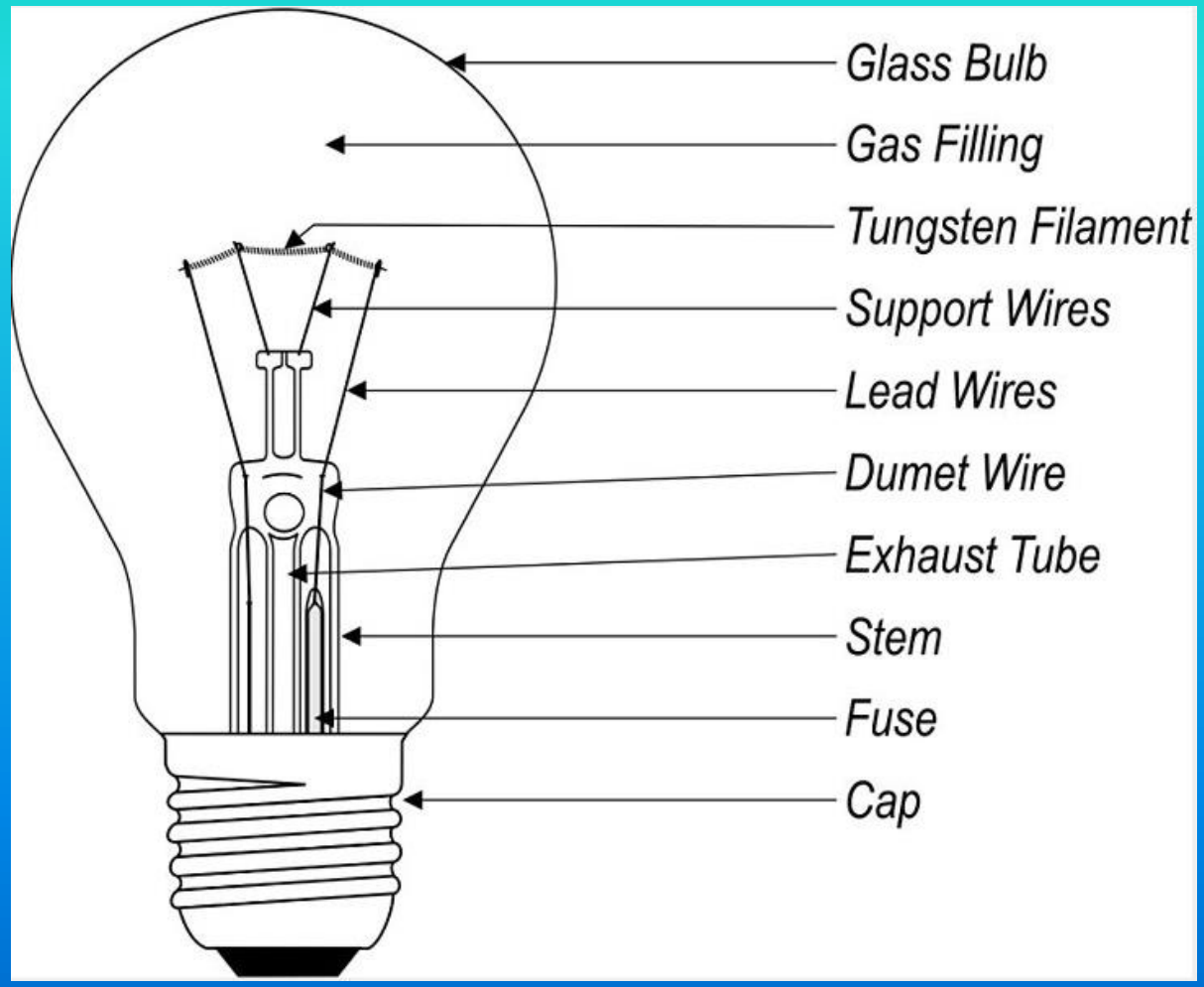
A useful guide to buying

Most domestic lamps will be labelled as Cool white; Neutral white, or Warm white

They are now labelled with LUMENS as well as wattage because it is more important

An old-style 60 watt "GLS" lamp supplied about 800 LUMENS. So it is a good benchmark

Construction of a GLS lamp



History of lighting

4,500 BC Early pottery lamps appear – simple wicks and animal oils

History of lighting

These were some of the first "luminaires"

History of lighting

3,000 BC Invention of candles. Still in use as the prime source of light up to the 17th century

Controlling light distribution
Concept of the luminaire.
Detailed work for lacemakers

History of lighting - gas

History of lighting

The gas lamp before use of the incandescent mantle

History of lighting - gas

1881 First gas mantle (Welsbach) 60% magnesium oxide; 20% lanthanum oxide; 20% yttrium oxide

1891 Successful gas mantle. 99% thorium dioxide; 1% cerium dioxide. Problems with radioactive decay products

History of lighting - gas

A London street scene of the 30's with gas lighting much in evidence – and fog!

History of lighting - gas

A typical Victorian gas lamp, with the two cast iron outriders for the lamplighter to rest his ladder upon

History of lighting - gas

The lamplighter at work. Predates the use of clockwork timers for turning the burner on or off

History of lighting - gas

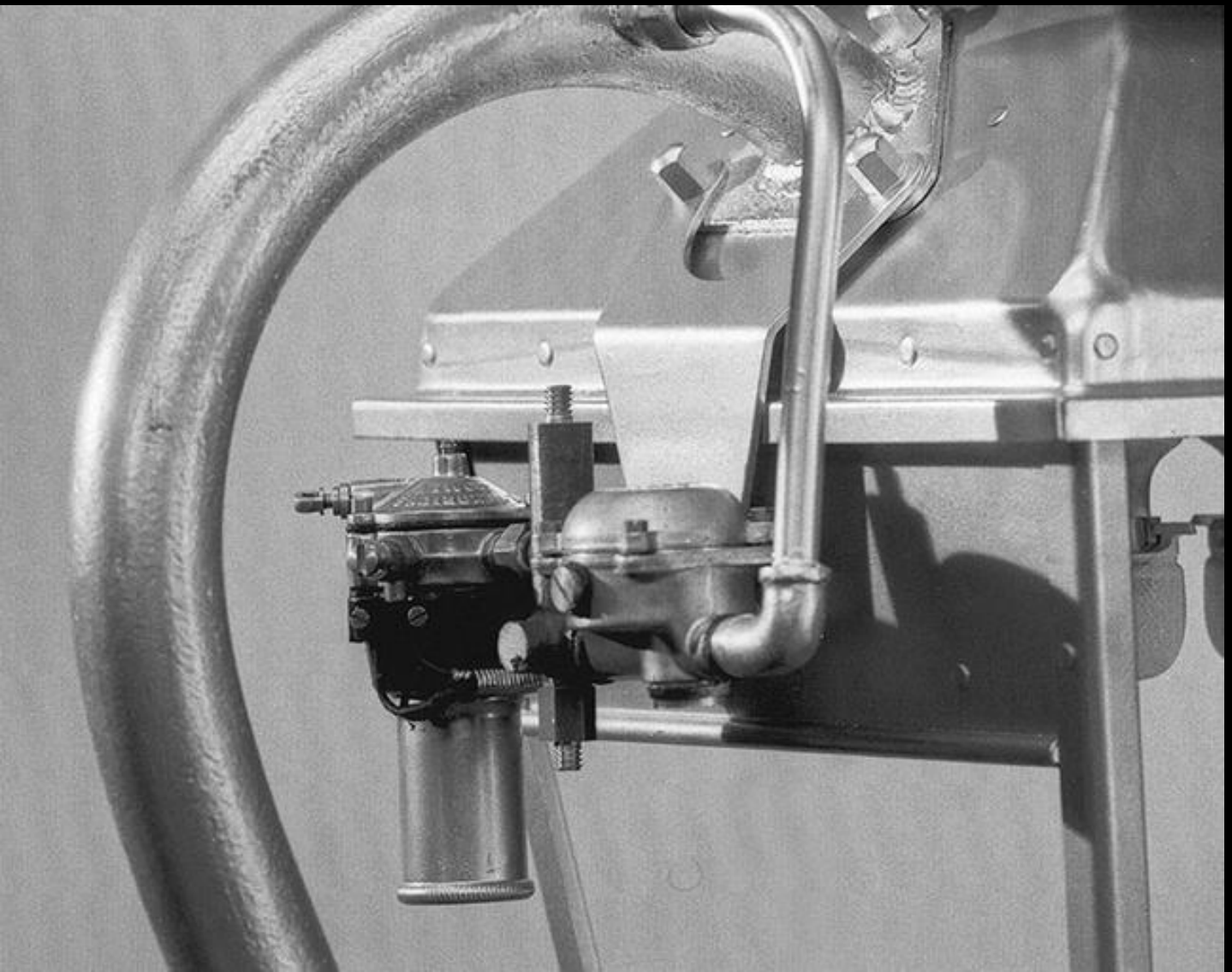
A modern gas lamp. In this case the unit is fully automated, with a pilot light and battery operated times

History of lighting - gas

A clockwork timer designed to cope with the full year's lighting seasonality.

This one – installed in 1966 – was rescued from the roof of The House of Lords!

History of lighting - gas

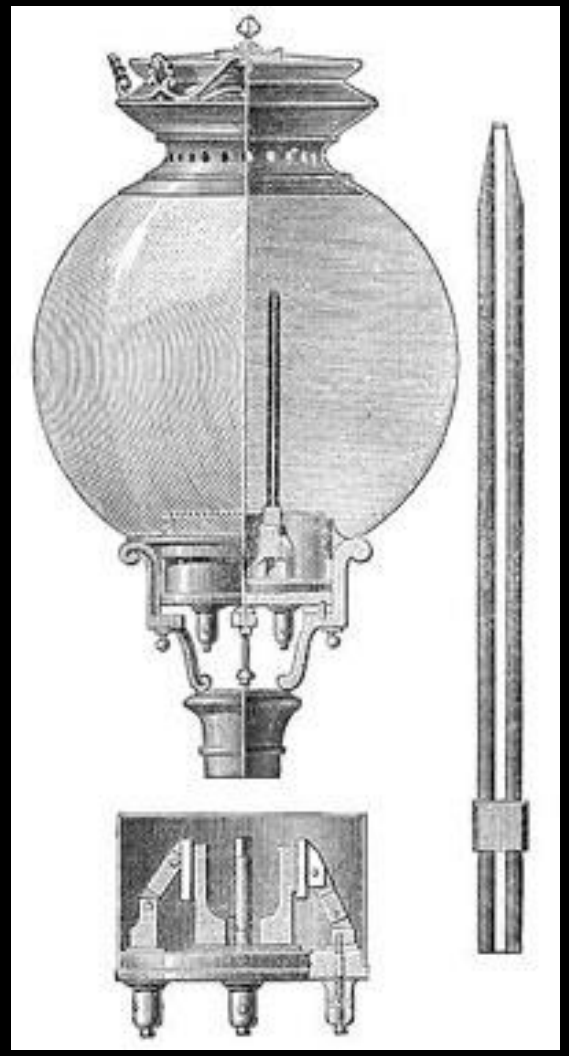


A rather more modern battery operated timer

History of lighting - gas

The ultimate modern "Victorian" gas lamp

History of lighting - Electricity



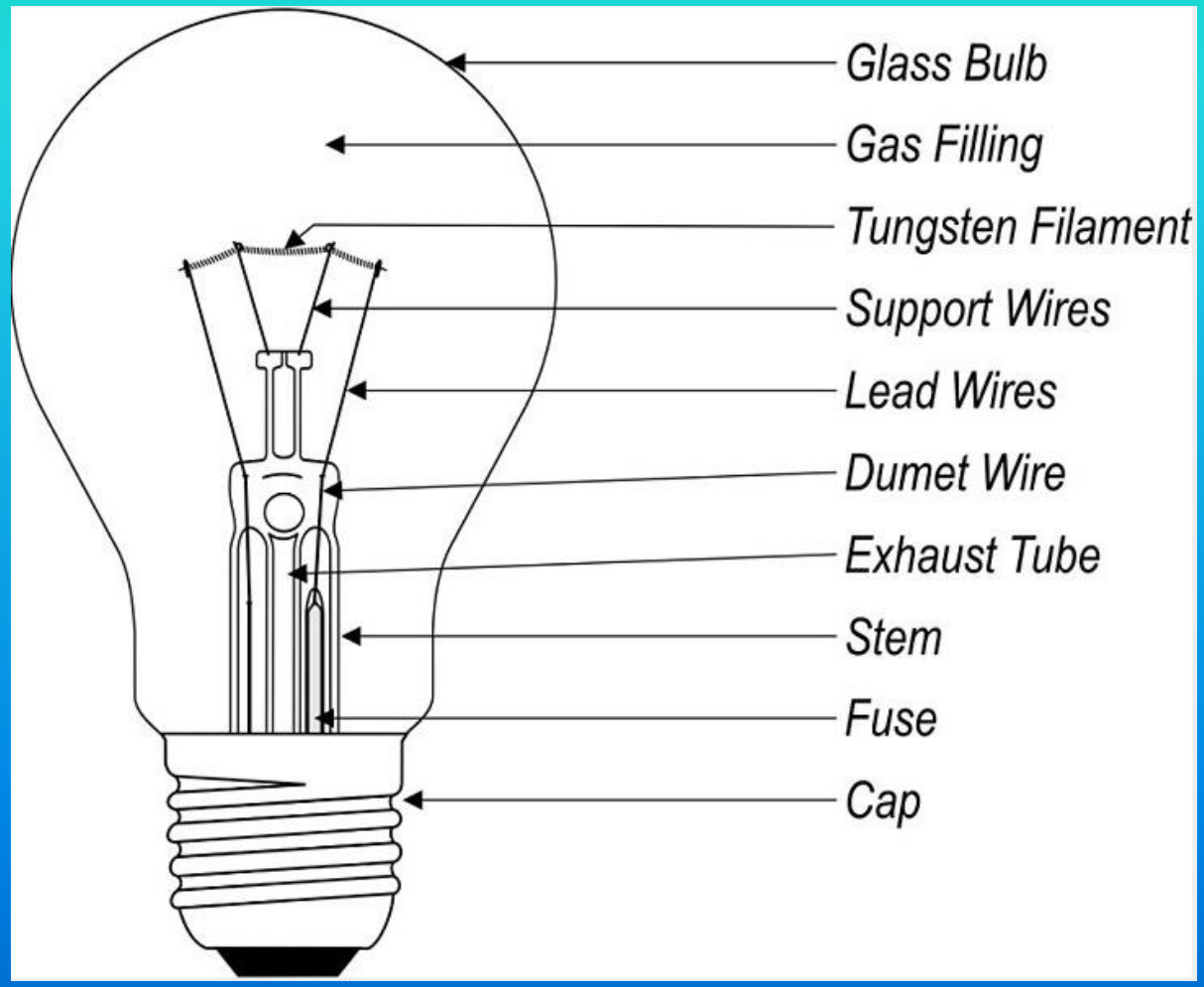
Electric light is born

1876 *Pavel Yablochkov* invented the Yablochkov candle, the first practical carbon arc lamp

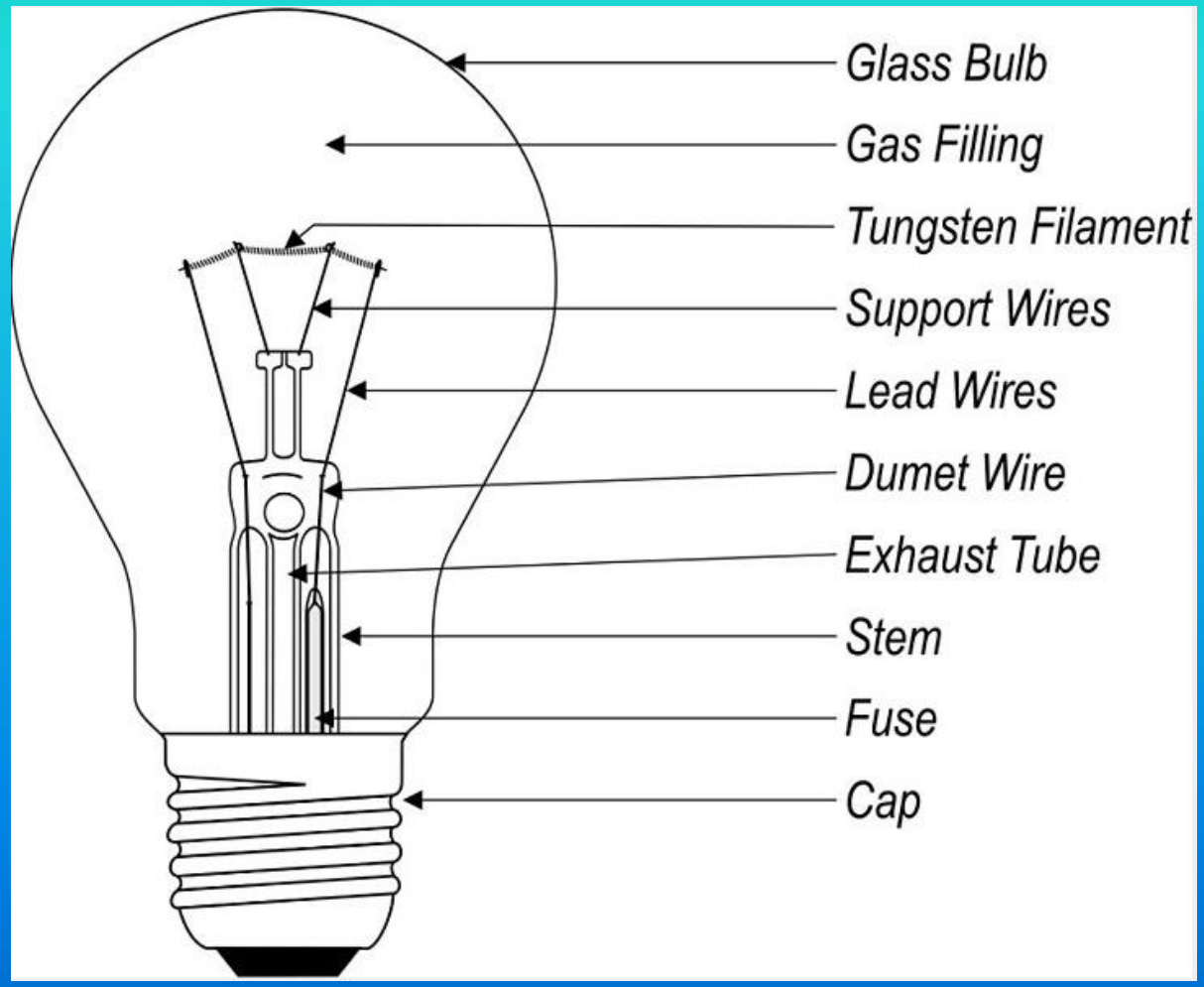
History of lighting - Electricity

The first commercially successful "GLS" filament lamps were introduced in 1882 and were in widespread use throughout the Western world by 1900

Construction of a GLS lamp



Born to fail! A myth exploded



So how long SHOULD a lamp last?

- The optimum life for "old-style" lamps ("bulbs") was agreed at a 50% failure after 1000 hours
- Why? And does it matter anyway?

The ever-lasting lamp

The lighting industry standardised on the 1,000 hour GLS lamp because there is a real trade-off between filament temperature and lamp life

A hotter filament is more efficient but fails sooner. So why does it fail?

Born to fail! A myth exploded

The coiled coil filament

A sublime problem!

- Tungsten melts at 3,422 ° C
- But well before melting it sublimes from the incandescent filament and is deposited on the glass bulb at lower temperatures
- As the lamp ages more and more tungsten is deposited on the bulb, which blackens with time
- Eventually after being switched on and off many times, and suffering the corresponding stresses of expansion and contraction the filament will finally crack and separate at the crystal defect on switch off

We can make lamps that last for 3000 hours

A 3000 hour 100 watt light bulb gives out about 820 lumens.
So the efficiency is only about 8.2 lumens/watt

If the lamp costs, say £1.50p
Electricity costs 15p/kilowatt hour
The lamp will cost you £46.50 during it's life of approximately THREE years
(300 x 0.15 or £45 for the electricity and £1.50p for the lamp!)

Things are very different when lamps are hard to reach!

Luminaires

What is a luminaire?

Definition – (Wikipedia)

A light fixture, light fitting, or luminaire is an electrical device used to create artificial light by use of an electric lamp. All light fixtures have a fixture body and a light socket to hold the lamp and allow for its replacement.

What is a luminaire?

Definition – (John Wells)

A light fixture, light fitting, luminaire or lantern is a device used to create artificial lighting, using a light source to direct and control light. All luminaires comprise a light source; the means to direct light to the right place in the right quantity at the right time and with the right colour rendering

Welcome to the world of the luminaire designer and developer!

- **Luminaire's Disease symptoms:** Luminaire's Disease attacks the central nervous system. It is characterised by the sufferer suddenly stopping in mid stride, or worse applying car brakes unexpectedly. This is followed by a severe craning of the neck; narrowed eyes, and either a sage nod or a long period of reflection. After the initial attack repeated attacks will follow on a completely random basis

- **Curing the disease:** There is no known cure

- **Risk of infecting others:** High – particularly if employed by a major electrical equipment supplier or as a council Roadlighting engineer

A sad case of terminal Luminaire's Disease!

Welcome to the world of the luminaire designer and developer!

- **Lamp failure:** The interval between switch-on and (say) 10% failure needs to be many thousands of hours, so special light sources are needed

- **Environmental problems:** The environment in which the luminaire has to operate may be extremely aggressive, so materials have to be chosen very carefully

- **Light distribution:** The distribution of light from the luminaire has to be very carefully tailored to put light in the right place

Welcome to the world of the luminaire designer and developer!

- **Operational control:** How and when to switch a remote luminaire off or on?
- **Control gear:** All lamps apart from GLS filament lamps require some form of control gear
- **Light distribution:** The distribution of light from the luminaire has to be very carefully tailored to put light in the right place

Welcome to the world of the luminaire designer and developer!

- **Aesthetics:** The luminaire has to be designed to fit in with the environment in which it will be sited.
- **Ease of installation:** The design must allow speedy and simple installation and alignment.
- **Serviceability:** Inevitably, all luminaires eventually require servicing – so make it easy
- **Choice of materials:** Enormous in principle

Welcome to the world of the luminaire designer and developer!

- **Energy conservation:** The design is required to ensure the lowest possible energy consumption through the whole life, from manufacture to recycling.

- **Safety:** Whether designed for domestic, industrial or commercial use, designing for safety is a paramount concern.

Road safety issues – concrete lamp standards of the 50s and 60s

Road safety issues – concrete lamp standards of the 50s and 60s

Unforgiving nature of concrete:

This column has been struck by a vehicle. The impact has shattered the reinforced concrete, with predictable results

Road safety issues – concrete lamp standards of the 50s and 60s

Unforgiving nature of concrete:

This one may not have been the reason for this particular collision

Road safety issues – steel lamp standards are also rather solid

Road safety issues – steel lamp standards are also rather solid

Road safety issues – steel lamp standards are also rather solid

Even the police have problems:

Note that this column has simply bent, absorbing a lot of energy – as also has the front of the police car.

Road safety issues – Frangible or progressively crumpling structures

Now appearing alongside major roads:

This design is being used extensively where new street furniture is being installed alongside motorways and busy trunk routes.

The structure is adequately stiff, but crumples and compresses gradually, so that impact forces are spread throughout he collision period and the maximum amount of energy is absorbed in the process

And above all – compliance with standards!

- Fragmented situation before Europe came together on standards with important standards houses

- UK: British Standards Institution – the Kitemark
- Germany: VDE (Verband der Elektrotechnik Elektronik Informationstechnik)
- Denmark: D mark
- Sweden: S mark
- Norway: N mark
- Finland: Finmark
- US: UL (Underwriters Laboratories)
- Canada: CSA (Canadian Standards Association)

And above all – compliance with standards!

- **BS4533** – The standard I had to work to
- Luminaires. Particular requirements. Specification for fixed general purpose luminaires, plus many more sections
- In detail: BS4533-102-102.1:1981
- Harmonised with the IEC standard IEC 60598-2-1:1979
- and ultimately by the European standard
- BS 4533-102.1:1990, EN 60598-2-1:1989
- BS EN 13201: 2015. Roadlighting

BS4533 and successor standards cover everything to do with a luminaire

- **Construction:** Choice of materials and dimensions of attachment to lighting columns, etc
- **IP classification:** Ingress of particulate matter or water.
- **Optical performance:** Photometrics. Light output and light in the right place.
- **Safety:** Avoidance of electric shock – use of the standard finger!

Primary requirements for light sources

- **Long life needed where access is difficult:** Typified by motorway or "A" road dual carriageways or tunnels
- **Highest efficiency:** Particularly important in terms of energy conservation
- **Size, weight and shape of light source:** May severely constrain mechanical design
- **Colour rendering:** Significant in all areas except highway lighting.

What has European togetherness achieved?

(Enough of this talk about straight cucumbers!)

You may or may not have voted for BREXIT. But were you aware of just how much vitally important work has been going on behind the scenes by dedicated experts looking after European wide standardisation?

Well before the existence of the EU, even before the EEC and EFTA existed, work has been continually in progress to achieve a single set of European wide standards.

A product marked with the CE mark represents that it complies with all the relevant harmonised standards. This is particularly applicable to all electrical products.

The referendum of June 2016 never really touched upon the significance of standardisation. Would so many people have voted for BREXIT if they knew how much important work our standardisation engineers had achieved, working together on a European-wide basis?

The CE mark – the ultimate European standard

- **What is the CE mark?:** A safety mark. It shows that the manufacturer has checked that these products meet EEA safety, health or environmental requirements

- **What does CE stand for?:** Conformité Européene

- **Where is it needed?:** For products to be sold ***anywhere in the European Economic Area.*** This means the 28 Euro countries plus Iceland; Norway; Liechtenstein; Switzerland and Turkey

- **How long has it been in force?:** Since 1985

Thoughts on lighting efficacy

TYPE OF LIGHT SOURCE	LUMENS/WATT	LIFE HOURS
Normal gas-filled incandescent lamp (GLS)	8 - 14	1,000
Fluorescent tube (TL)	80-100	4000
Compact fluorescent lamps (CFL)	65-70	8000
High pressure sodium discharge lamps (SON)	150	30000
High pressure metal halide lamps (HPI)	130	
Low pressure sodium lamps (SOX)	208	
Light emitting diode (LED)	100 - 120	50000
Organic light emitting diode (OLED)	100	40,000??
Latest high efficiency TLED tube	200	?

Discharge lighting types

All gas discharge lamps have two things in common:

- A discharge tube, filled with a cocktail of gases and elements.
- Control gear to ensure that the current through the discharge tube does not run away and destroy the lamp

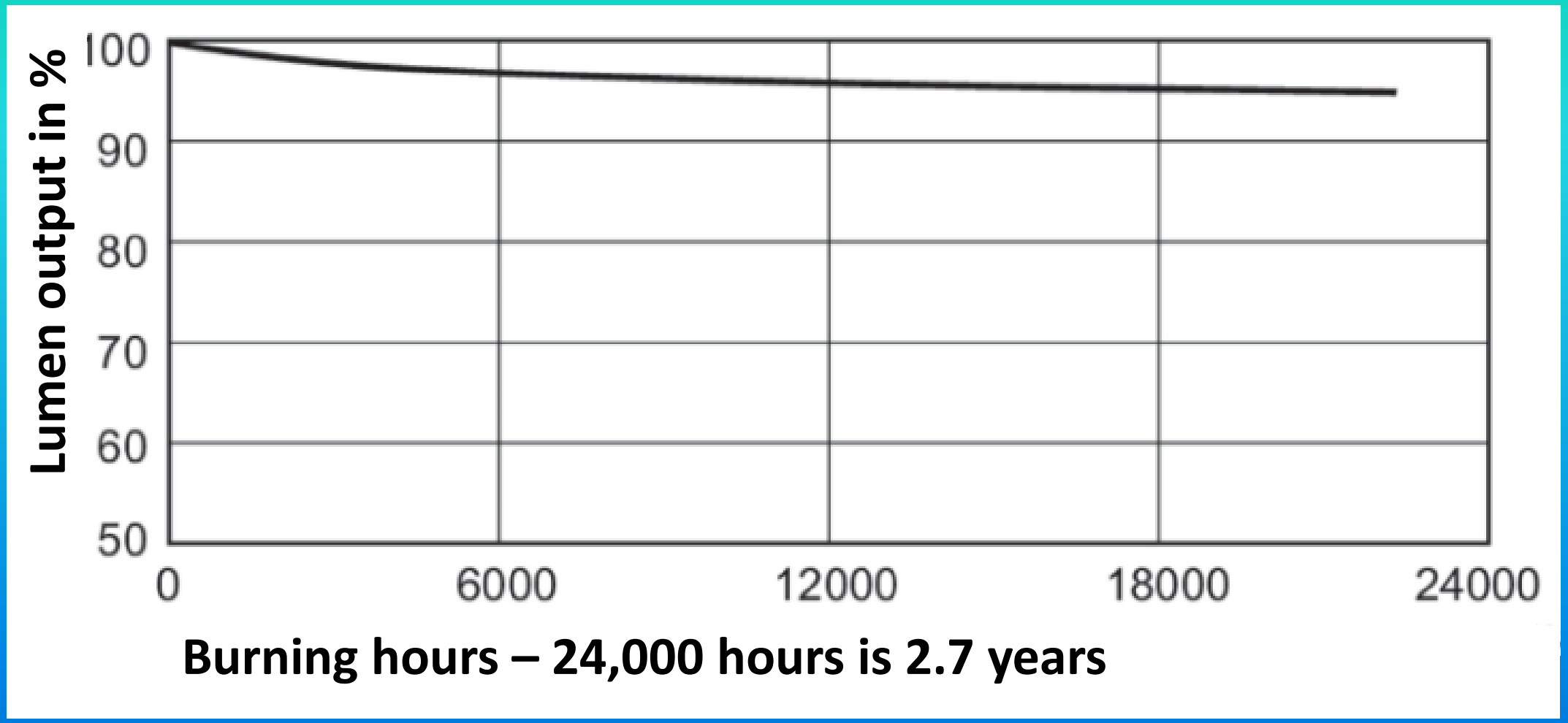
Low pressure sodium lighting – use of the SOX and SOX-E lamp

- The SOX lamp produces 208 lumens/watt - the highest lumen output of any light source, but the poorest colour rendering, because it is essentially monochromatic light.

- Use of SOX lamps was restricted to roadlighting and security lighting

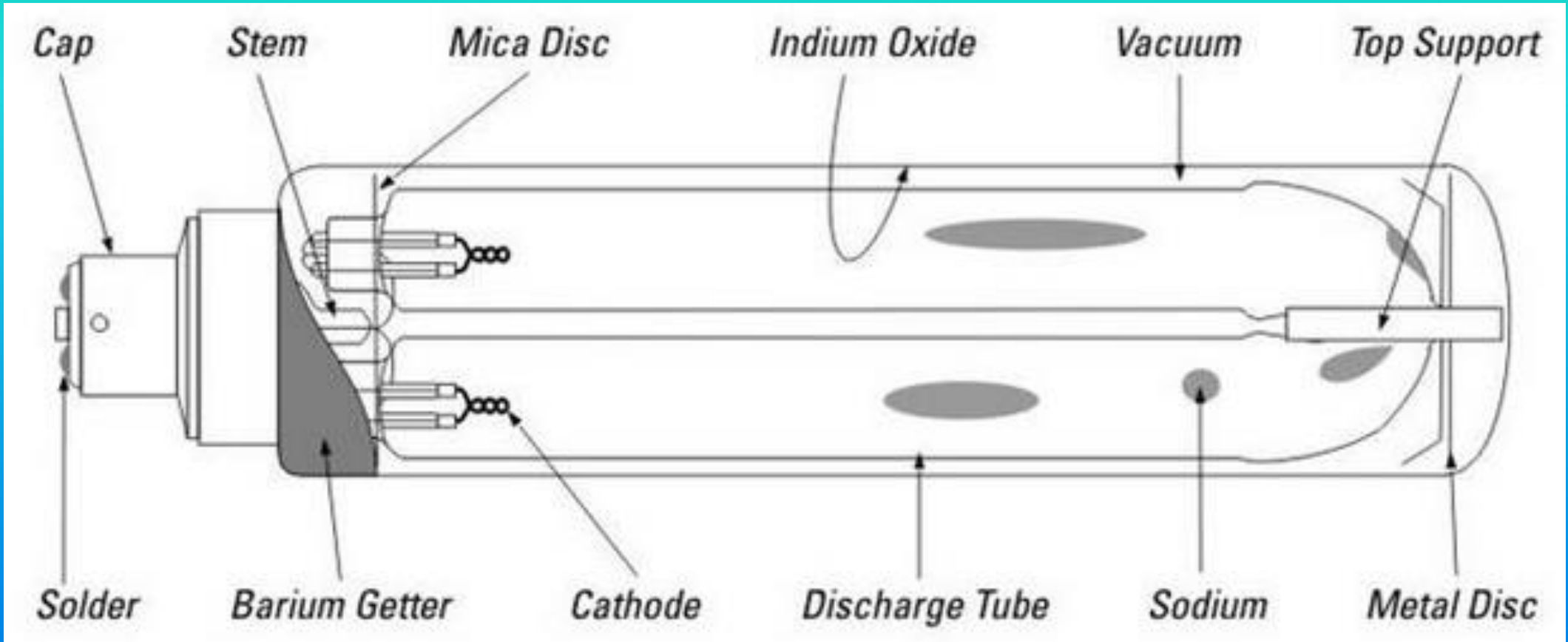
- Nevertheless a significant of the UK's roads were lit by SOX – now superseded by high pressure sodium, high pressure metal halide lamps and ultimately by LED.

SOX and SOX-E lamp lumen maintenance



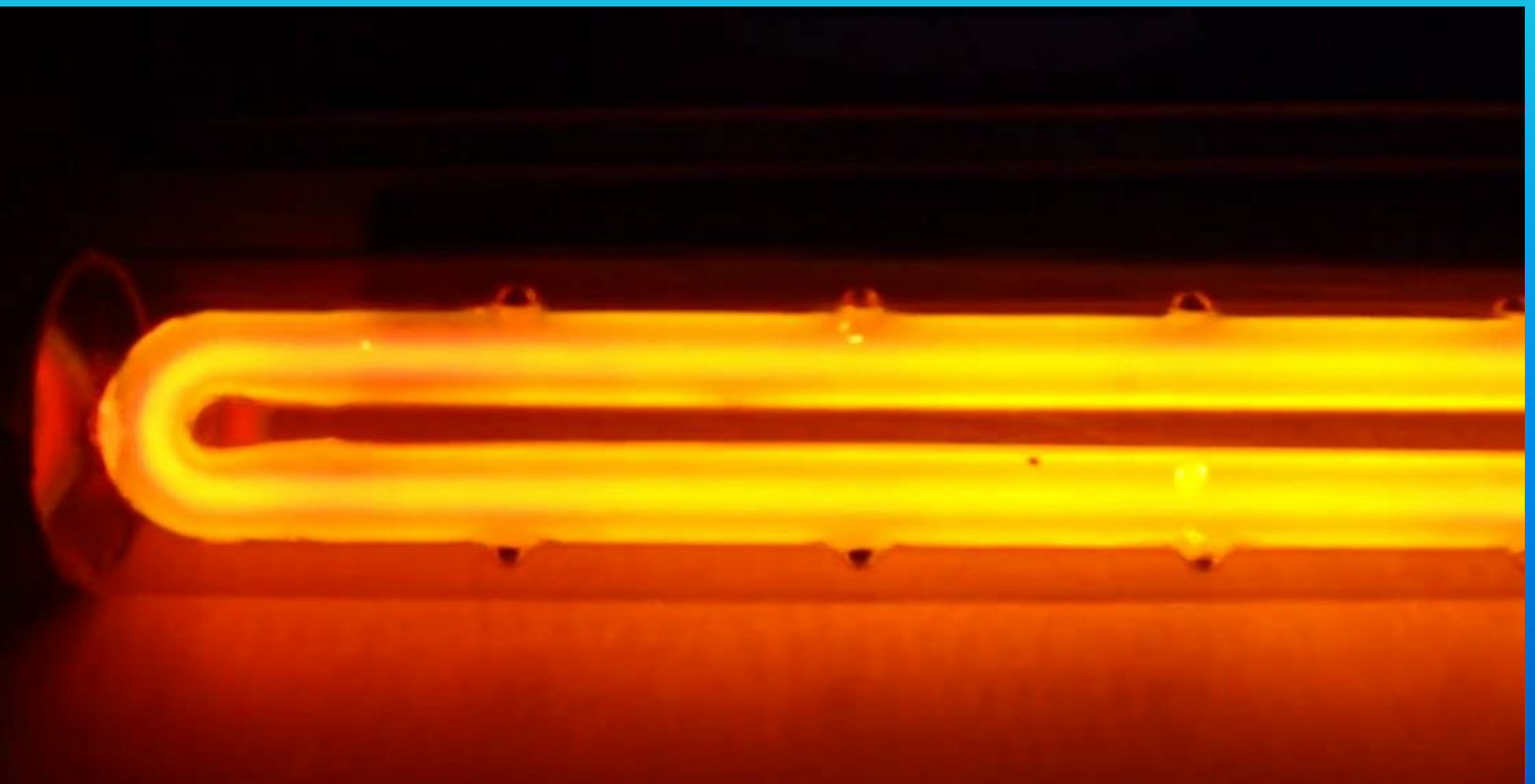
95% output after 2.7 years and still working! End of life even later….

Construction of a typical SOX lamp



Dimples in a higher power SOX lamp

The dimples in the borosilicate U-tube contain sodium metal. One reason for the SOX lamp's Achilles' heel. It cannot be mounted more than 20 degrees from the horizontal

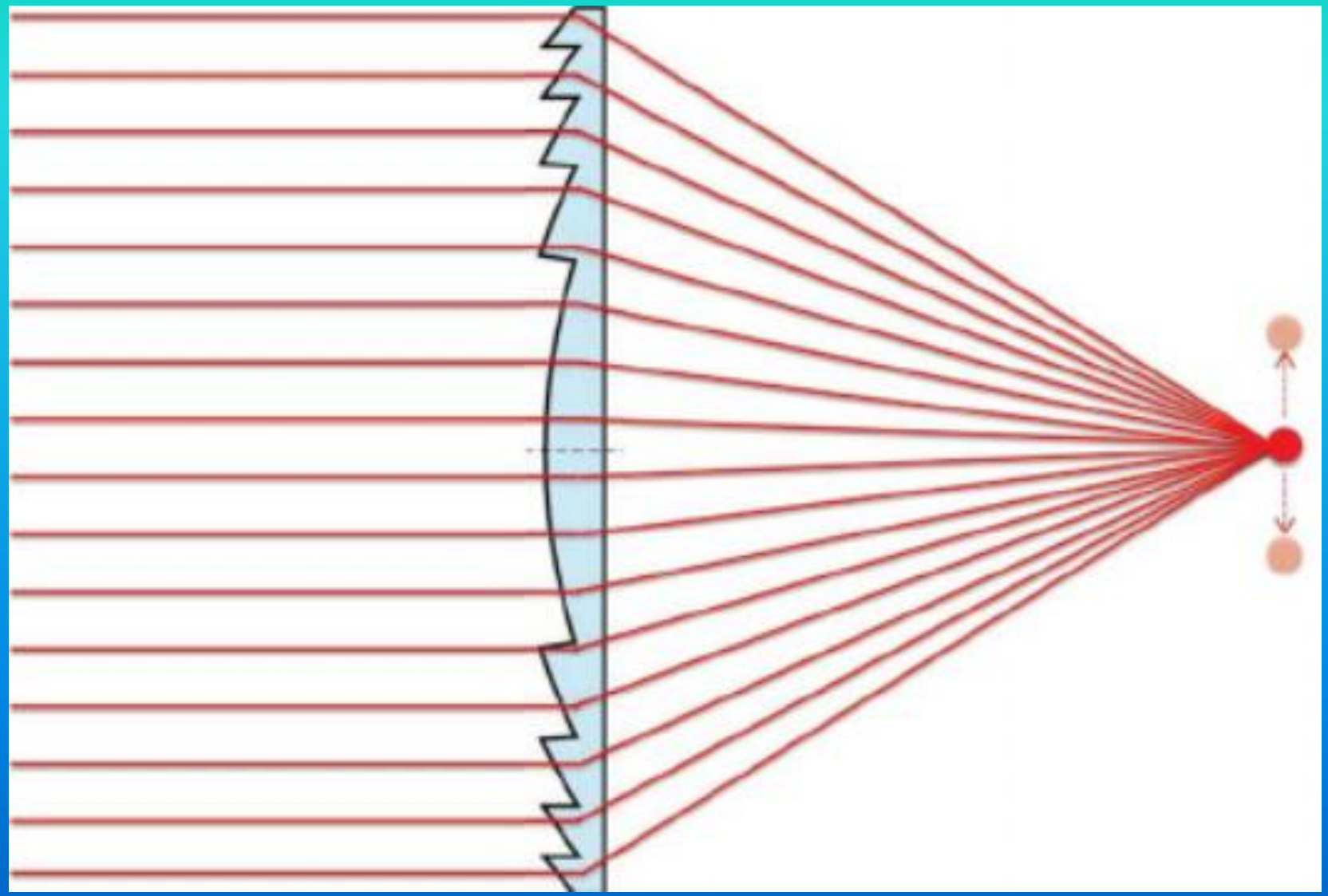


Optical control of a SOX lamp luminaire

The simplest lamp for designing an optical control

- A linear light source which can be considered as a simple line of light
- Use of a series of prismatic ribs in the transparent underneath "bowl"
- Effectively a Fresnel lens

The Fresnel lens



The Fresnel lens –Advantages and disadvantages

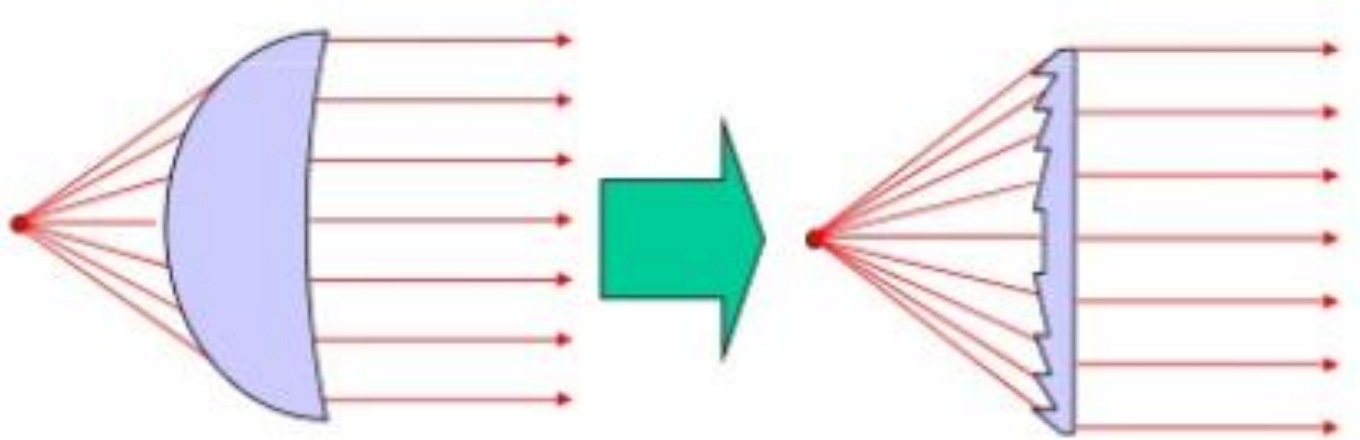
A Fresnel lens focuses the light in exactly the same way as a conventional "thick" lens

Advantages:

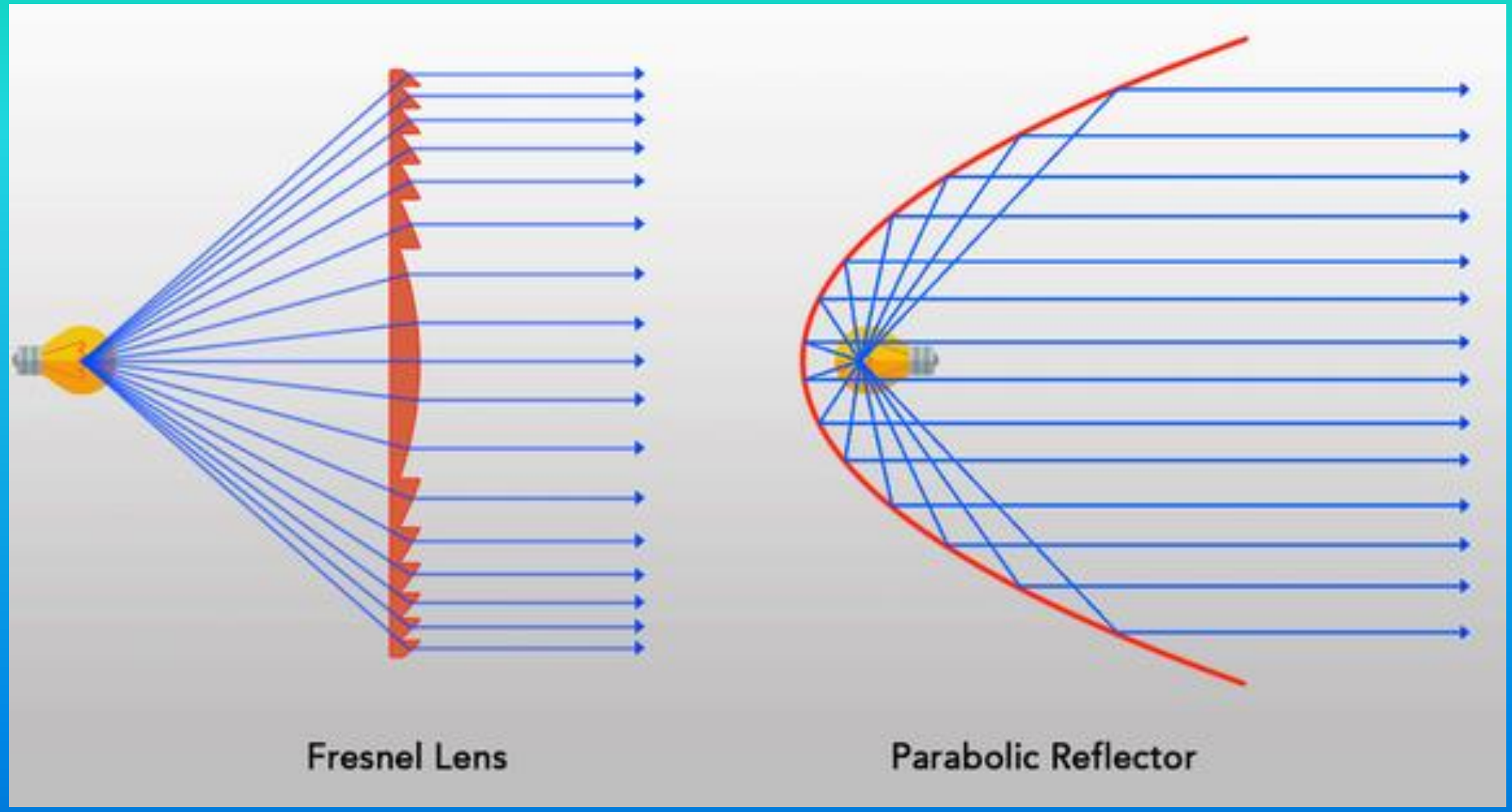
- Weight reduction
- Thickness reduction

Disadvantages:

- Sharp edges can produce multiple reflections
- Sharp "valleys" can act as stress concentrators



The Fresnel lens versus a parabolic reflector



Here's one I did earlier!

55 Watt SOX lamp used as a security lighting installation. Note the pointed photocell on top

Here's another one I did earlier!

40,000 units for Humberside:

This is a 35 watt SOX luminaire which we designed in Croydon and which I assembled and shipped from our factory in Kingston upon Hull

Here's another one I did earlier!

Originally designed for a Mercury lamp in Denmark: We had to redesign this unit completely to replace just about all components with UK sourced materials. What was intended to be a simple adaptation became a nightmare

Originally designed for a Mercury lamp in Denmark: The ONLY component that we imported from Demark was the grey canopy. Everything else tooled and produced in the UK

Wide variety of knowledge required

A luminaire designer needs to know a great many diverse things

- A working knowledge of the appropriate standards
- Comprehensive knowledge about:
  - Plastics – both as structural items and optical controls
  - Elastomers – use in gaskets
  - Metals – many different applications
  - Types of light source
  - Control gear
  - Illumination engineering
  - Structural testing, including vibration tests and impact tests
  - Electrical safety
  - Electrical and thermal testing
  - Optical measurements
  - Design for manufacturability

A luminaire designer needs to know…

Plastics and plastics technology - I

- ✓ Thermoplastics
  - Polymethyl methacrylate (Acrylic)
  - Polythene
  - Nylon
  - Polysulphone
  - PTFE
  - Polycarbonate - Vandal resistance and UV degradation
  - Acrylic butyl styrene (ABS)

A luminaire designer needs to know…

Plastics and plastics technology – II

- ✓ **Thermosetting plastics**
  - Crosslinked polyester
  - Phenol formaldehyde
  - Phenol urea

- ✓ **Plastics moulding and forming techniques**
  - Vacuum forming
  - Injection moulding
  - Extrusion
  - Dough moulding
  - Thermoplastic creep

A luminaire designer needs to know…

Metal casting techniques

- ✓ Sand casting
  - Appropriate alloys to use
  - Prototype model making
  - Small batch manufacture
- ✓ Die casting
  - Gravity vs pressure die casting
  - Appropriate alloys to use
  - Tool manufacture and ownership

A luminaire designer needs to know…

Manufacturing techniques for steel items

- Shearing, drilling and bending
- Manufacturing tolerances
- Press techniques
- Burst/pierce operations
- Electroplated zinc

Protection of mild steel

- Pre-coated steel sheets and post forming
- Passivation
- Electroplated zinc
- Hot-dipped zinc

Testing techniques

A luminaire designer needs to know…

Protection against corrosion

- ✓ Aluminium - copper
  - ➢ Worst electrochemical potential difference
- ✓ Aluminium – Stainless steel
  - ➢ Bad electrochemical potential difference
- ✓ Alloys suitable for marine environments
- ✓ Testing techniques – enhanced salt corrosion test

A luminaire designer needs to know…

Suitability and types of paint systems

- Passivation of substrates
- Prevention of UV degradation
- Scratch resistance
- Chalking
- Powder coating
- Dip coating
- Spray coating
- Polyester
- Two pack resins
- Testing techniques – enhanced salt and UV corrosion tests

A luminaire designer needs to know…

How to keep water at bay and how to prevent ingress of particulate matter

The Ingress Protection (IP) classification

Two characters:

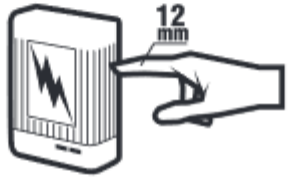
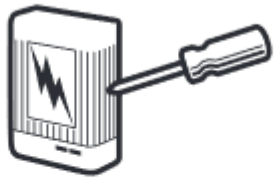
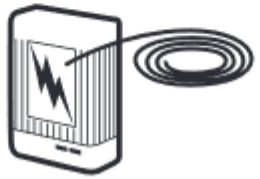
I=Ingress of a solid item (levels 1-6)

P=Protection against water (levels 1-8)

Protection against solids and liquids

IP (Ingress Protection) Ratings Guide

SOLIDS

1		Protected against a solid object greater than 50 mm such as a hand.
2		Protected against a solid object greater than 12.5 mm such as a finger.
3		Protected against a solid object greater than 2.5 mm such as a screwdriver.
4		Protected against a solid object greater than 1 mm such as a wire.

WATER

1		Protected against vertically falling drops of water. Limited ingress permitted.
2		Protected against vertically falling drops of water with enclosure tilted up to 15 degrees from the vertical. Limited ingress permitted.
3		Protected against sprays of water up to 60 degrees from the vertical. Limited ingress permitted for three minutes.
4		Protected against water splashed from all directions. Limited ingress permitted.

Protection against solids and liquids

IP (Ingress Protection) Ratings Guide

5

Dust Protected.
Limited ingress of dust permitted. Will not interfere with operation of the equipment.
Two to eight hours.

6

Dust tight.
No Ingress of dust.
Two to eight hours.

Rating Example:

IP65

INGRESS PROTECTION

5

Protected against jets of water.
Limited ingress permitted.

6

Water from heavy seas or water projected in powerful jets shall not enter the enclosure in harmful quantities.

7

Protection against the effects of immersion in water between 15 cm and 1 m for 30 minutes.

8

Protection against the effects of immersion in water under pressure for long periods.

Typical IP specifications for highways

IP23

IP2X – Protection against a solid object >12/5 mm in diameter
IPX3 – Protection against water sprayed at up to 60 degrees from the vertical through a spray hoop at 12.5 litres/minutefor three minutes

IP45

IP4X – Protection against a solid object >1 mm in diameter
IPX5 – Protection against jets of water (12.5 litres/minute for three minutes)

Typical IP specifications for marine use

IP67

IP6X – Dust tight. Tested in a talcum dust chamber for up to eight hours
IPX7 – Protection for immersion to one metre

IP68

IP6X – Dust tight. Tested in a talcum dust chamber for up to eight hours
IPX8 – Protection for complete immersion during lifetime

Standard test finger

Standard test hoop – IPX3

- The hoop sprays water directed from jets towards the table
- The hoop is swivelled +/- 60 degrees from the vertical
- The table is rotated
- The procedure lasts three minutes

Here's one I did (VERY MUCH) earlier!

180W SOX lighting in central reservation of M67

Optics designed by Brian Rogers and Mechanical design by Tom Doy

Catenary Lighting on M1

These lanterns are CU PHOSCO P415 lanterns fitted with180W SOX lamps, integral gear, Nema socket 1 part photocell.

Probably designed by Brian Rogers who used to work for me at Croydon

Catenary Lighting on M1

Just south of Junction 6A on the M1 Motorway

Note massive size of central carriageway column but protected by crash barrier

Blue sky thinking – wait for PART III !

We have run right out of time. What have we missed?

- More on optical design. Light control with lenses and mirrors. Light pollution
- Particular problems of highway lighting
- Ovoid lamp light sources (High pressure mercury; High pressure SON; White SON; Metal halide lamps)
- Enormous impact of LED light sources. Energy reduction; weight reduction
- Impact of vastly improved computer power
- Computer aided design
- Computer aided manufacture and 3D printing
- Control of luminaires remotely over the Internet
- Self powered lighting