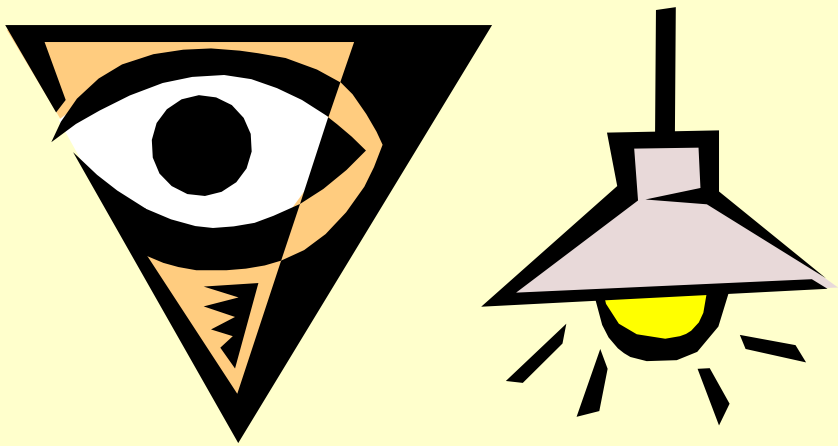
MECH3422 Building Services Engineering I

http://me.hku.hk/bse/MECH3422/



Lighting Systems – Light Sources and Luminaires

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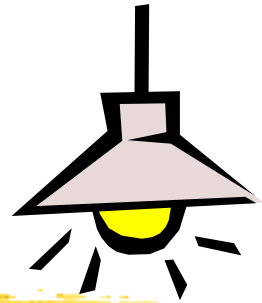
Contents

- Light Sources
  - Incandescent
  - Fluorescent
  - High Intensity Discharge (HID)
  - Low Pressure Sodium
  - Light Emitting Diode (LED)
- Ballasts and Luminaire
- Lighting Maintenance

Examples of light sources for general lighting

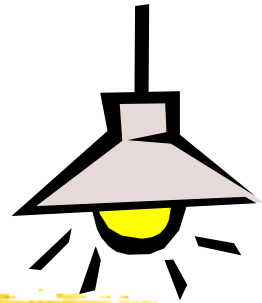
(Source: Advanced Lighting Guidelines, www.algonline.org)

Light Sources



- Commonly used light sources (abbrev./code)
  - Incandescent filament (I or GLS = general lighting service)
  - Tungsten-halogen (TH or H)
  - Fluorescent (F)
  - High intensity discharge (HID)
    - Metal halide (MH or MBI or M)
    - Mercury vapour (MBF or HPMV or Q)
    - High pressure sodium (HPS or S or SON)
  - Low pressure sodium (LPS or LS or SOX)

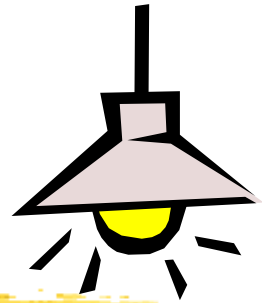
Light Sources



- Other light sources
  - Induction lamps
  - Light emitting diodes (LEDs)
  - Electroluminscent lamps
  - Lasers
  - Combustion sources
    - Candle flame
    - Gas light (e.g. using kerosene)

(* See also http://en.wikipedia.org/wiki/List_of_light_sources)

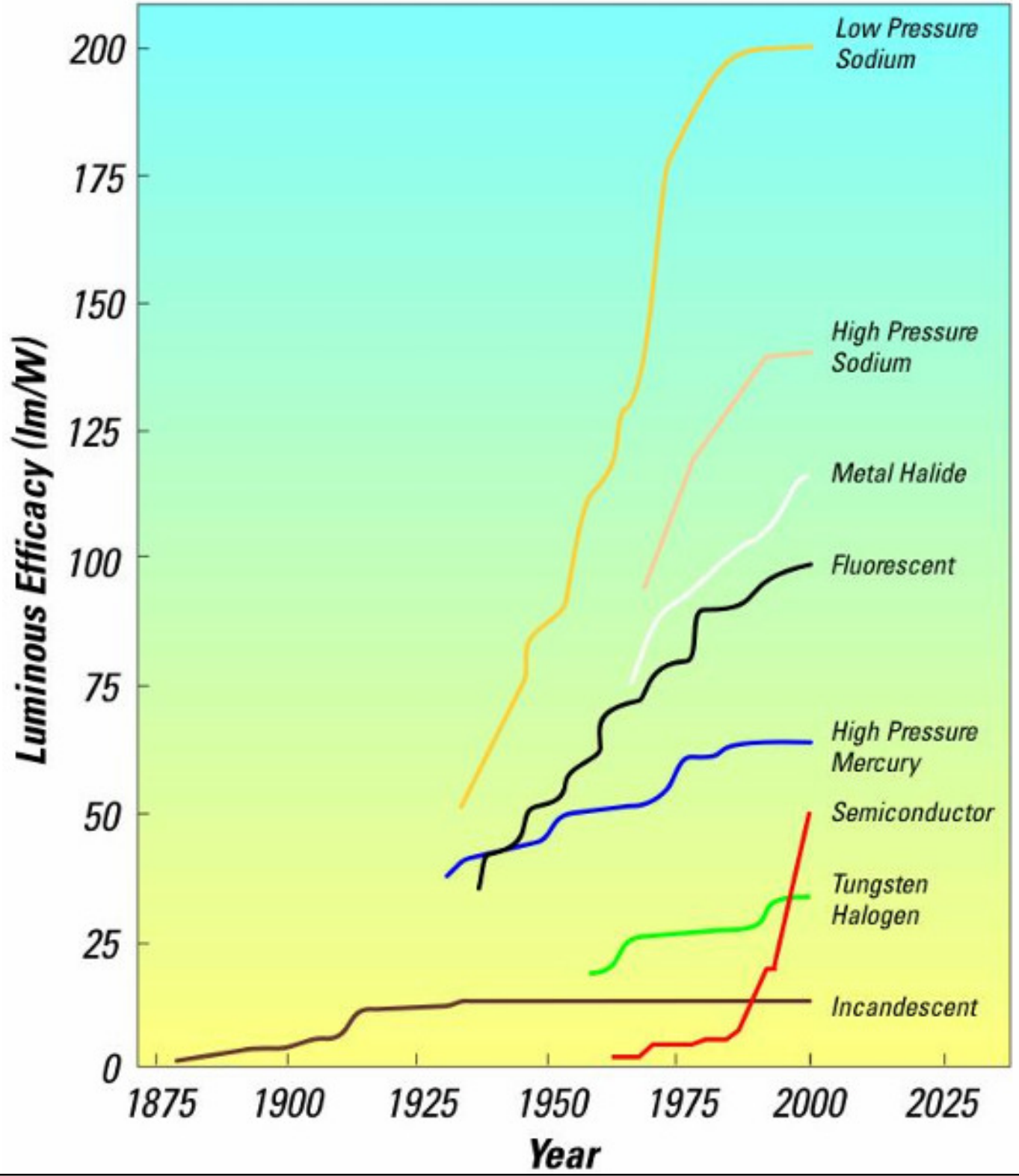
Light Sources



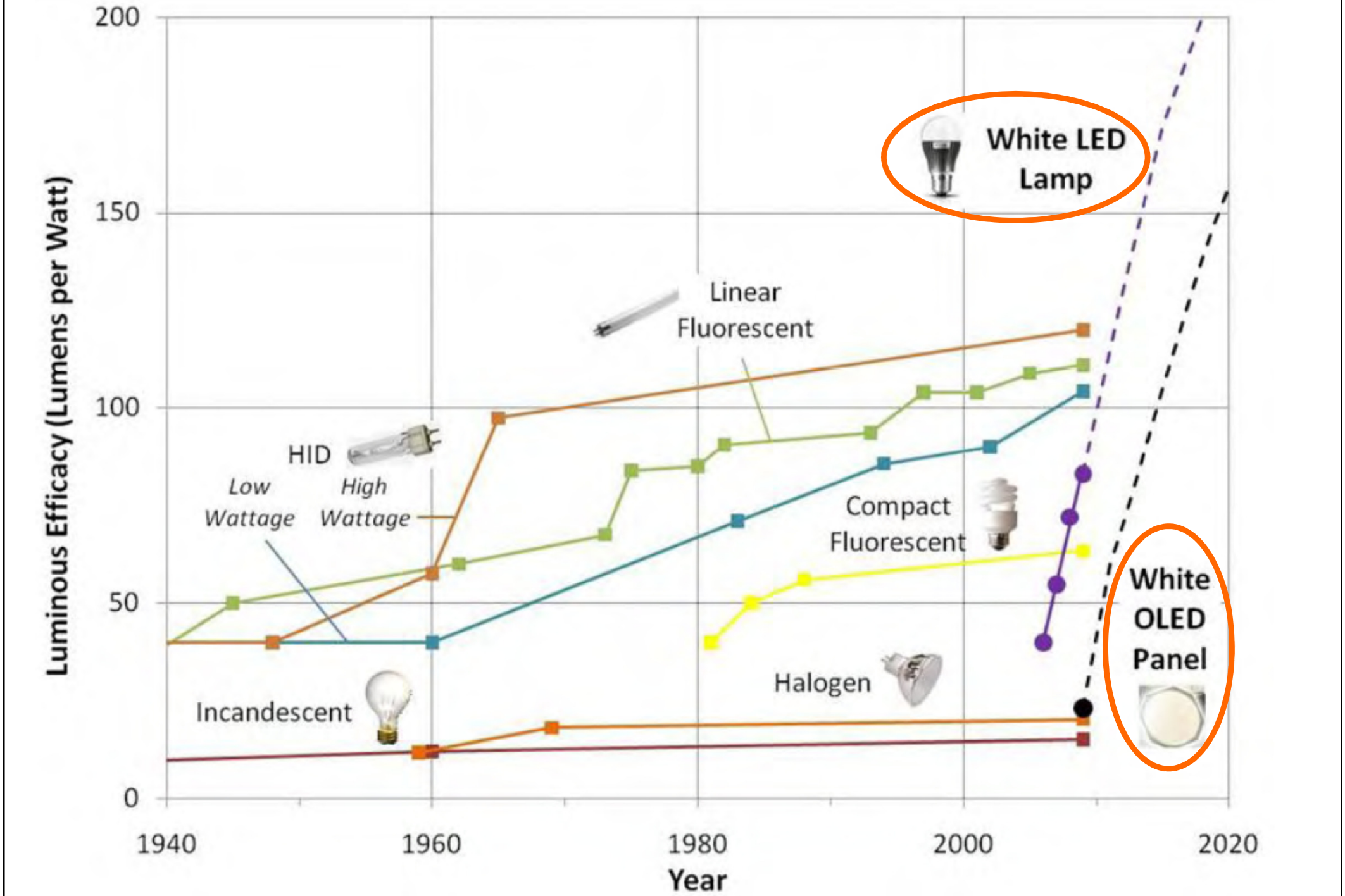
- 10 principal families of lamps (according to the manner of light emission) [*CIBSE/SLL Lighting Code*]
  - 1. Tungsten filament
  - 2. Tungsten halogen
  - 3. Metal halide
  - 4. Low pressure mercury (fluorescent)
  - 5. High pressure mercury
  - 6. Compact fluorescent (CFL)
  - 7. Low pressure sodium
  - 8. High pressure sodium
  - 9. Light emitting diodes (LED)
  - 10. Induction (mercury, sodium & sulphur)

Trends in luminous efficacy of lamps

(Source: LampTech, http://www.lamptech.co.uk/)



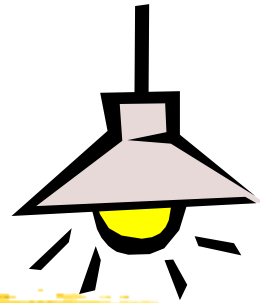
Q: Do you know which one is the most efficient lamp and when to use it?



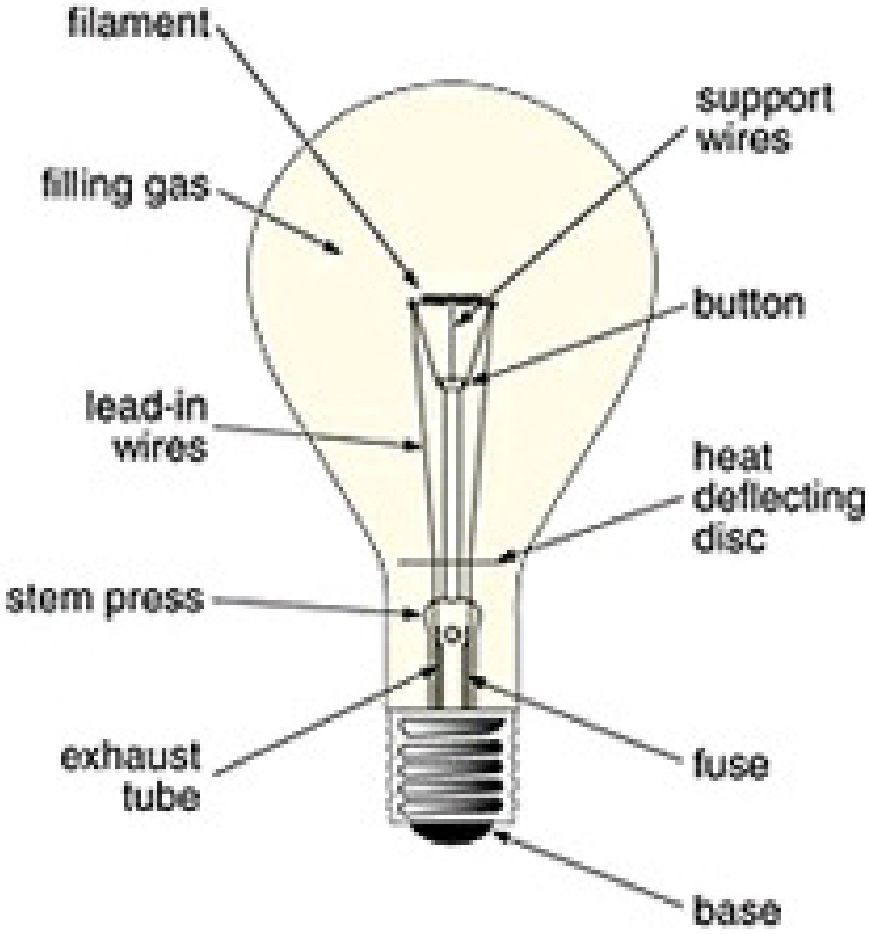
Historical and predicted efficacy of light sources

(Source: US Department of Energy)

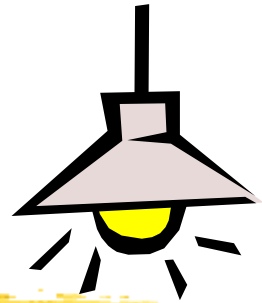
Incandescent



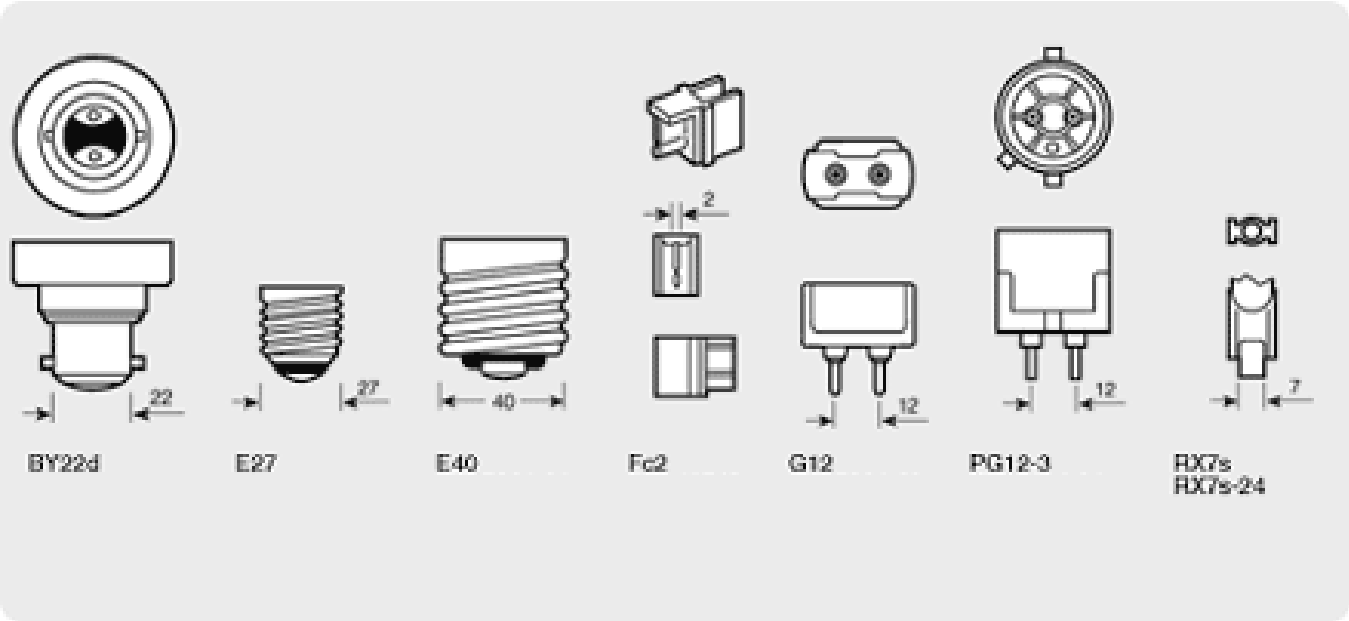
- Advantages
  - Low initial cost
  - Inexpensive to dim
  - High colour rendering
  - Can enhance texture
- Disadvantages
  - Lowest efficacy
  - Voltage sensitive
  - Short life
  - Heat generation



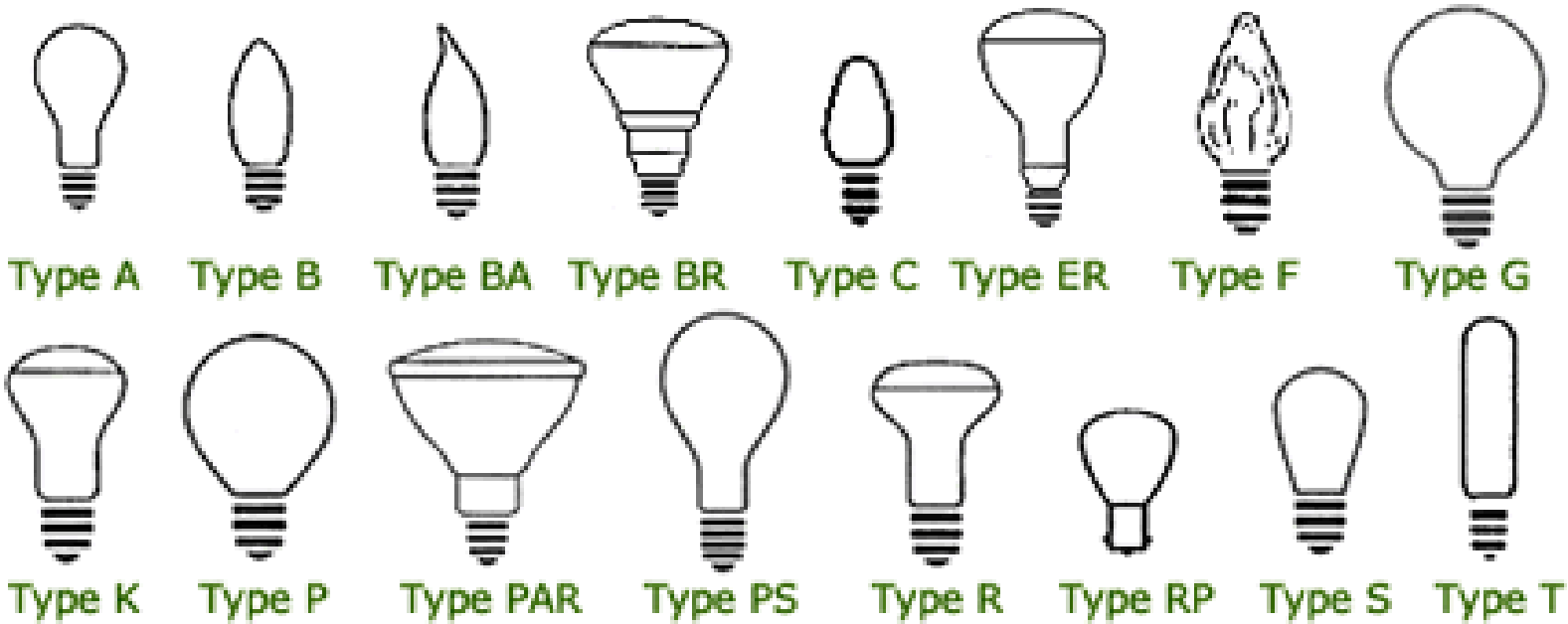
Incandescent

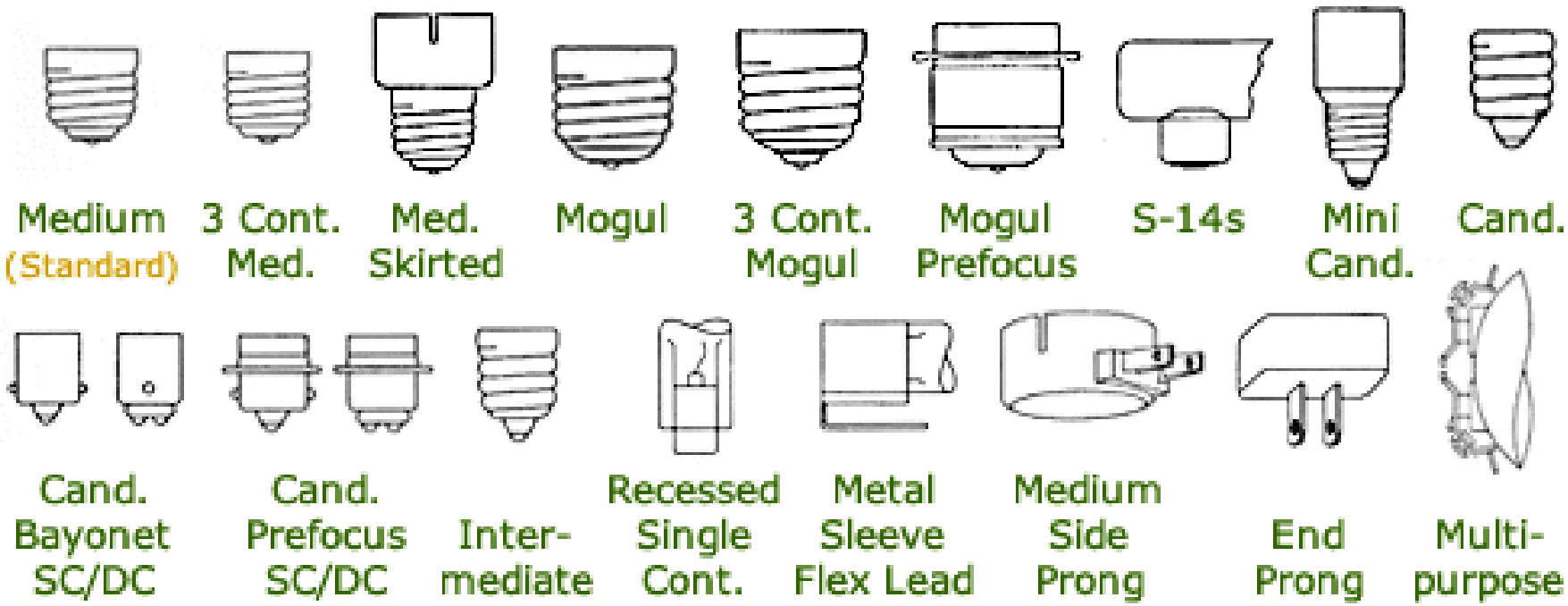


- Specification
  - Lamp/Bulb shape designations
  - Typical filament construction
  - Common lamp bases

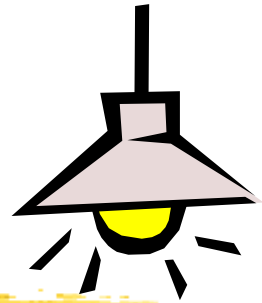


Lamp shapes and bases



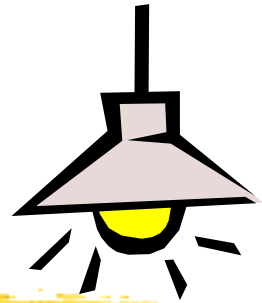


Incandescent

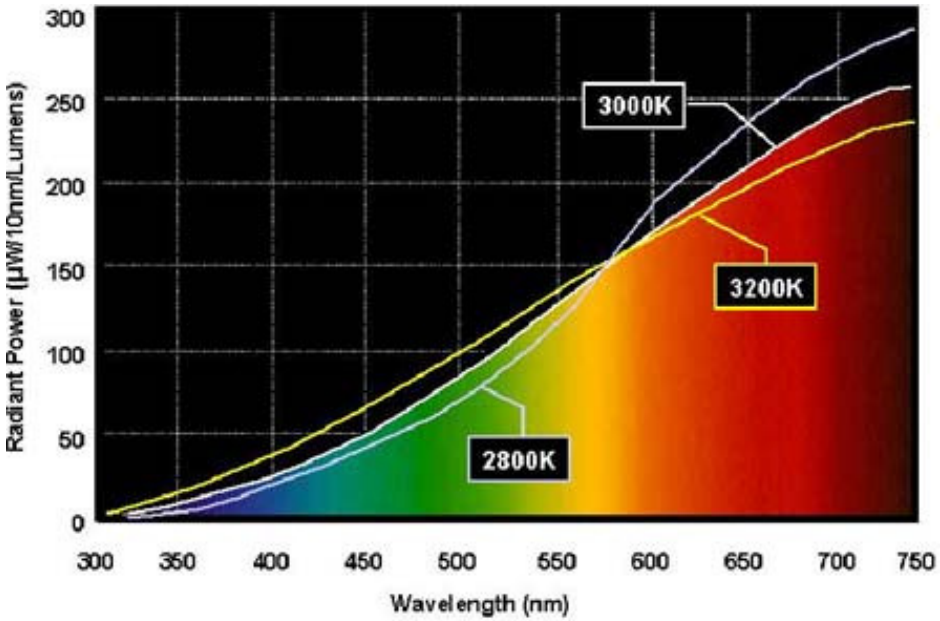


- Construction
  - Glass envelope
    - Lime glass, borosilicate (hard glass)
  - Fills
    - Vacuum, nitrogen, argon, krypton
  - Coatings
    - Acid etch, silica smoke, ceramic, paint
  - Basing
    - Aluminum, brass, nickel plated brass

Incandescent

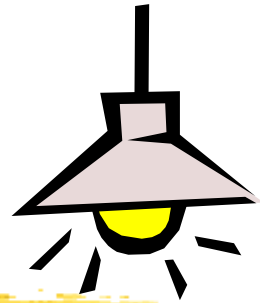


- Lamp characteristics
  - Colour temperature
  - Depreciation
  - Mortality
  - Life / lumens / colour / voltage relationships
  - Bulb & socket temperature



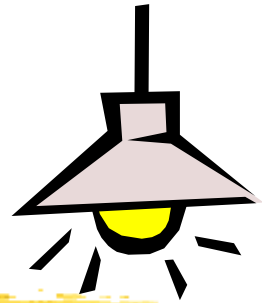
Spectral power distribution (incandescent)

Incandescent



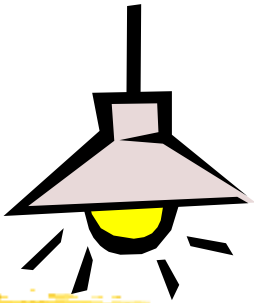
- Major types of incandescent lamps
  - Standard general service (GLS)
  - Decorative
  - Rough service
  - Vibration service
  - Sign lamps
  - Indicator
  - Three way

Incandescent

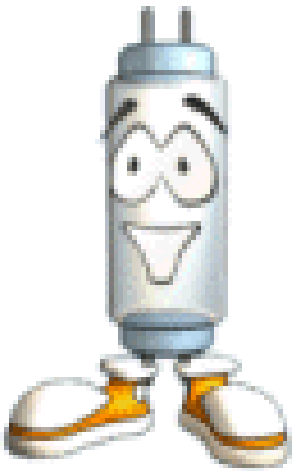


- Tungsten-halogen lamp, or quartz-halogen lamp (line voltage or low voltage)
  - Advantages
    - Compact size
    - Whiter light
    - Excellent lumen maintenance
    - Longer life
  - Disadvantages
    - More costly

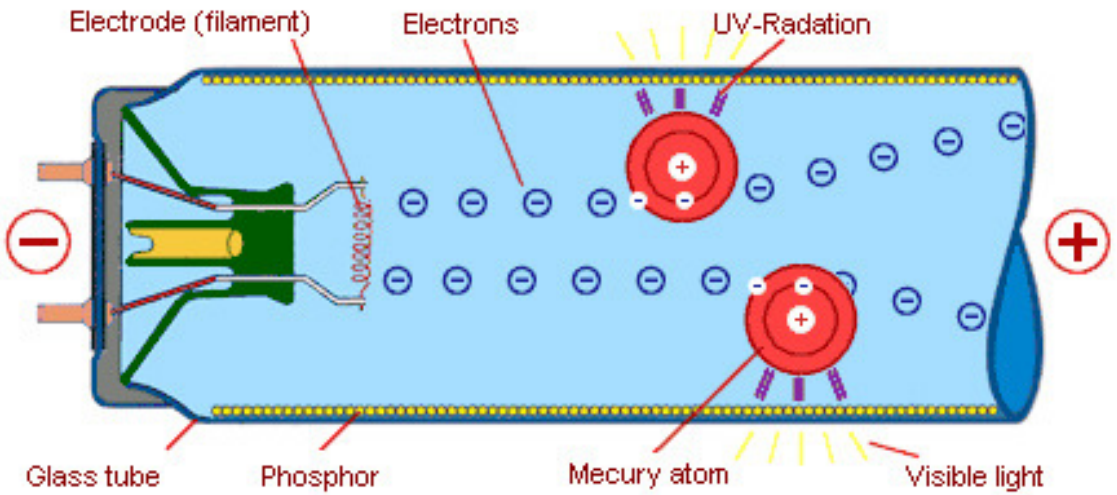
Fluorescent



- Advantages
  - High efficiency
  - Super efficacy at high frequency operatio
  - Wide range of colour choices

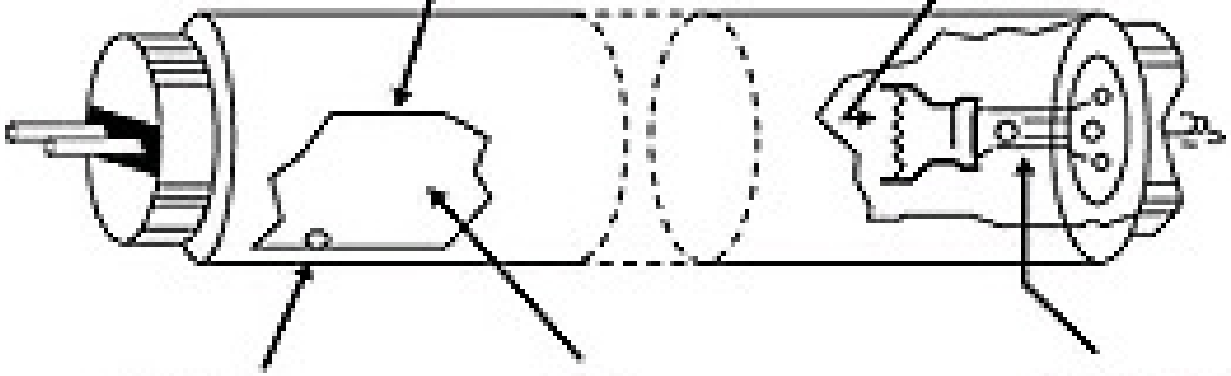


- Disadvantages
  - Require ballast
  - Temperature sensitivity



Phosphor
Coating inside the bulb transforms ultraviolet radiation into visible light. Light color properties depend on composition of phosphor.

Electrode
Electrodes at each end of lamp emits electrons. Usually made of single-coil tungsten wire.



Mercury
A minute quantity of liquid mercury is placed in the bulb to furnish mercury vapor.

Gas
Usually argon or a mixture of inert gasses at low pressure. Krypton is sometimes used.

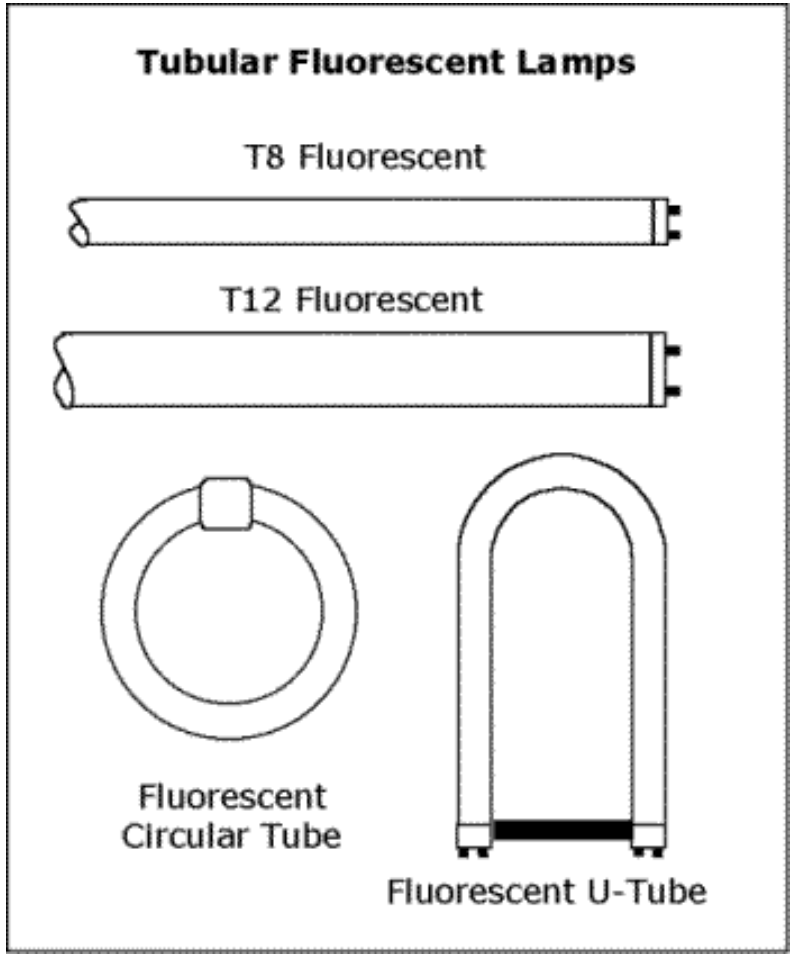
Lead-in Wires
Connect to the base pins and carry the current to and from the electrodes and the mercury are.

Construction and operation of fluorescent lamp

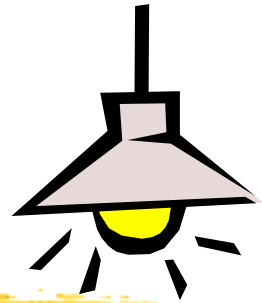
(Source: LampTech, http://www.lamptech.co.uk/ and http://osram.no)

Fluorescent

- Types of fluorescent lamps
  - Linear (tubular)
  - Compact
  - Circline
  - U shape
  - Subminiature
  - Reflector
  - Cold cathode

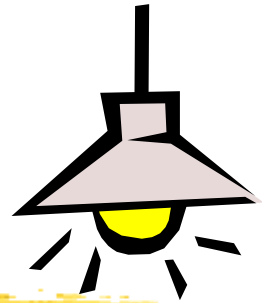


Fluorescent



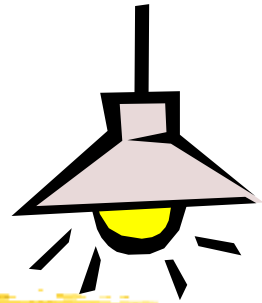
- Fluorescent lamp identification
  - Example: F30T12/CW/RS
    - "F" … fluorescent
    - "30" … rated nominal wattage
    - "T" … tubular shape
    - "12" … diameter in eighths of an inch; 12/8 = 1.5 in.
    - "CW" … color; this lamp is a cool white lamp
    - "RS" … mode of starting; rapid-start lamp

Fluorescent



- Classification of fluorescent lamps
  - Lamp shapes
  - Lamp bases
  - Coating technology for (double- & tri-) Phosphor
- Lamp characteristics
  - Efficacy (longer the lamp, higher the efficacy)
  - Temperature effects
  - Strobe effect (flicker)
  - High frequency operation

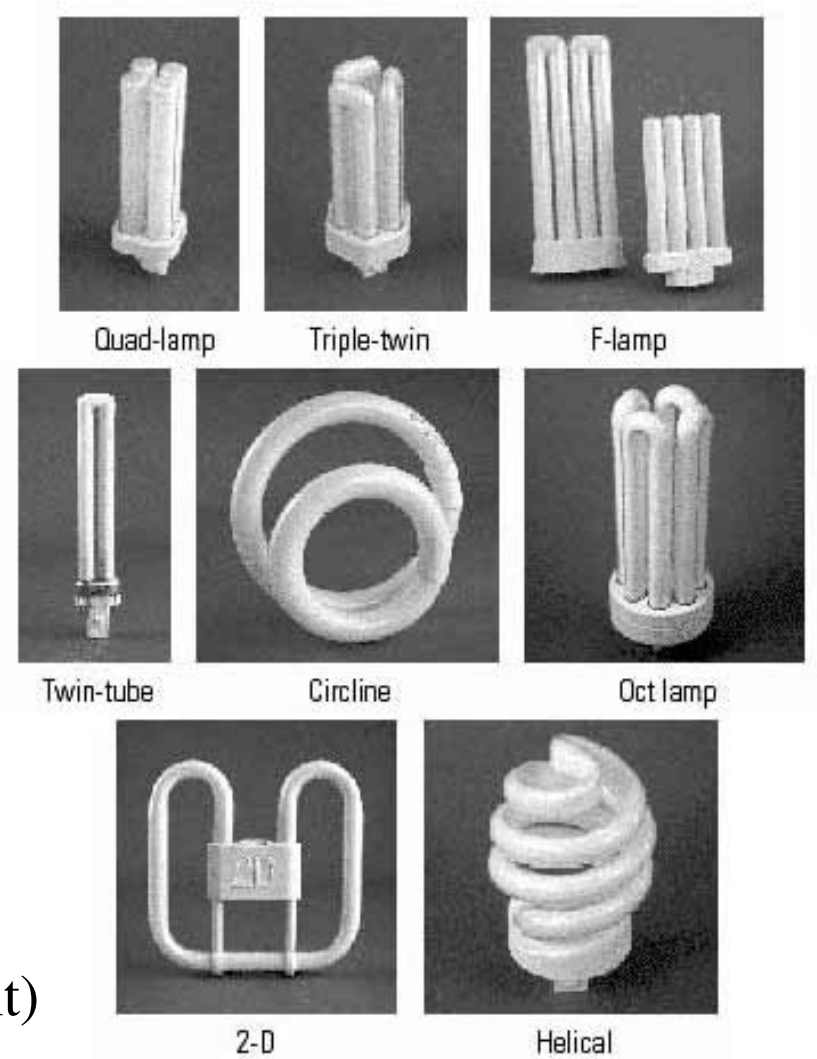
Fluorescent



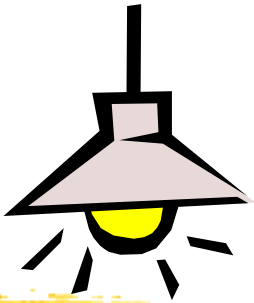
- Operating characteristics
  - Light output vs. ambient temperature
    - Optimal at 25 ºC (highest lumens per lamp)
    - Also affect the colour of the light produced
  - Lumen maintenance
    - Initial lumens decrease w/ operating hours
  - Effect of starting frequency on lamp life
    - Loss of the electron emissive coasting on electrodes
    - Rated average life = based on 3 hrs operation per start

Fluorescent

- Compact fluorescent
  - Advantages
    - Compact size
    - High efficacy
    - High CRI
    - Long life
    - Dimmable (some)
    - High frequency operation
    - Excellent lumen maintenance
  - Disadvantages
    - Position sensitive
    - Thermal sensitivity
    - Require ballast
    - Higher initial cost (over incandescent)



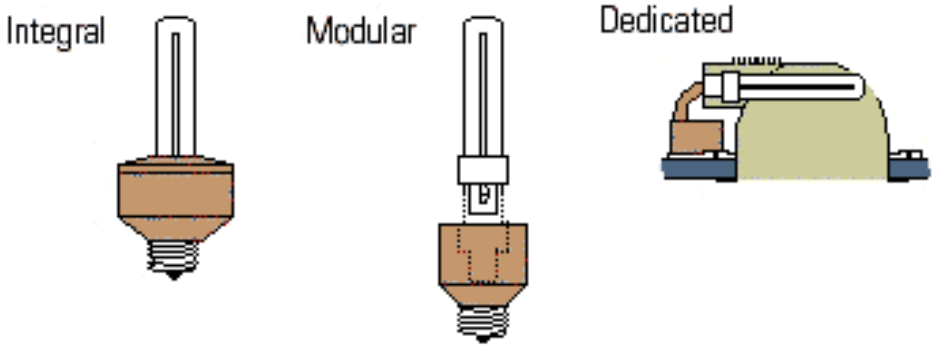
Fluorescent



- Compact fluorescent
  - Types
    - Twin tubes
    - Quads
    - Triples
    - Globes
    - Reflectors
  - Adapter ballasts
  - Self-ballasted

Fluorescent

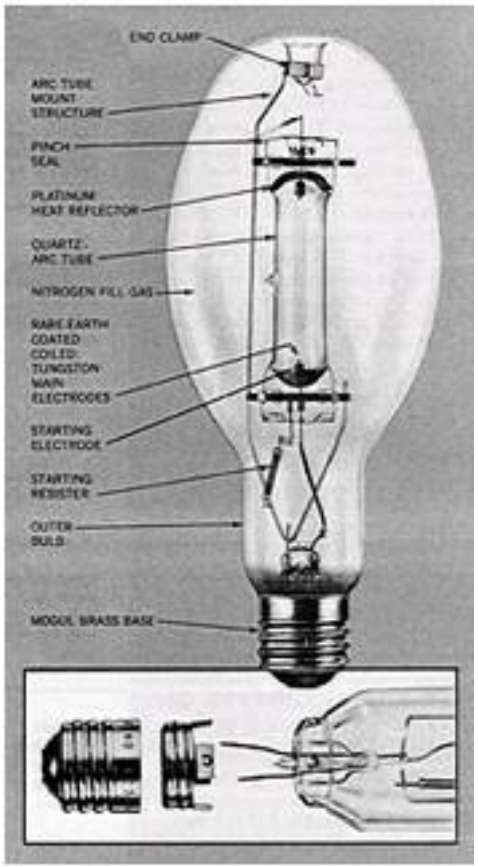
- Compact fluorescent
  - Thermal factor affecting light output & performance
  - Bulb wall temperature
    - Lamp positioning
    - Luminaire design (e.g. ventilation)
    - Plenum temperature
    - Ambient temperature
    - Amalgam temperature
  - Ballasting



High Intensity Discharge (HID)

- High intensity discharge (HID)
  - Mercury vapour
  - Metal halide
  - High pressure sodium

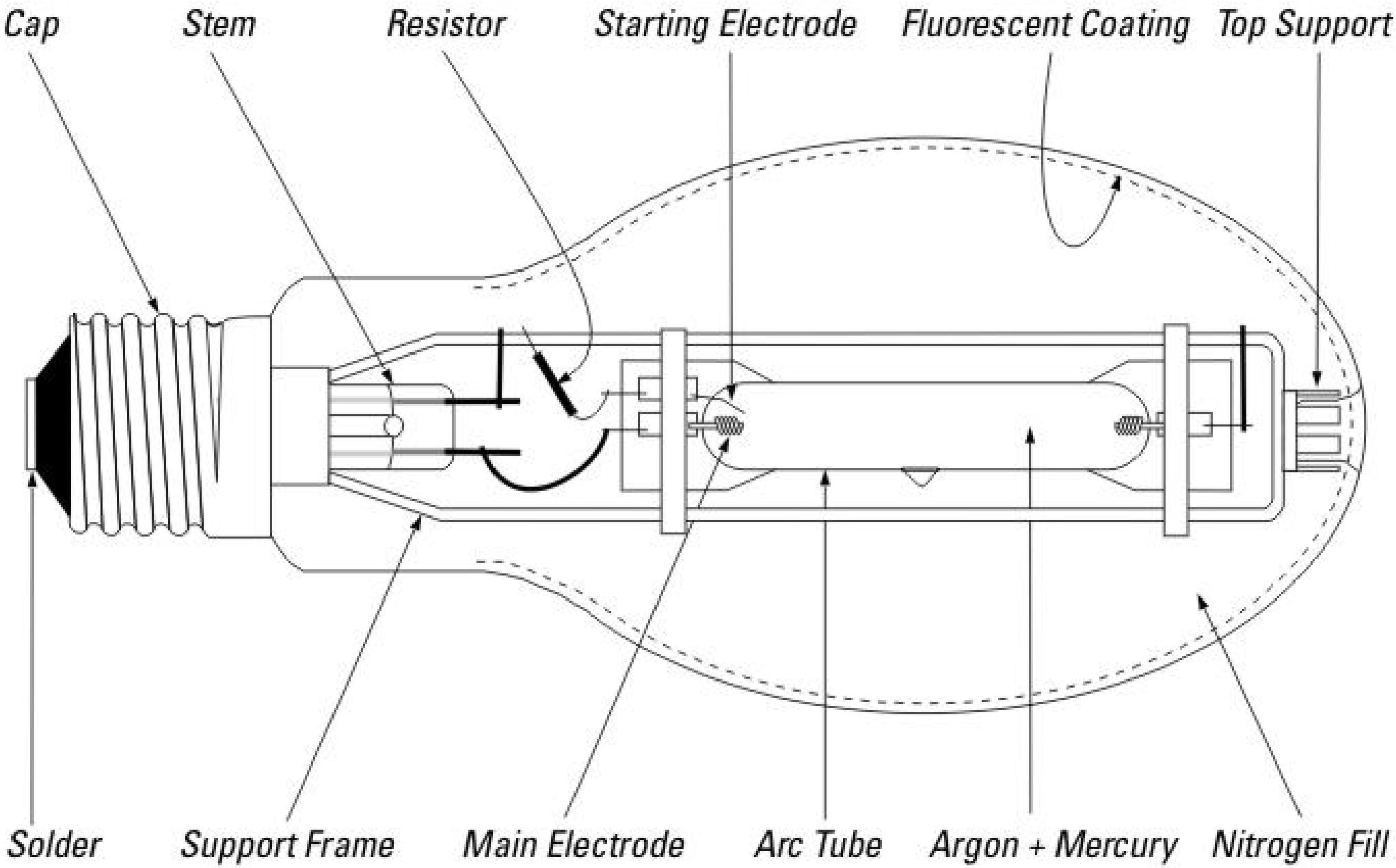
  - * See example in LampTech website
    - http://www.lamptech.co.uk/



High Intensity Discharge (HID)

- Mercury vapour
  - Advantages
    - Good for landscape lighting
  - Disadvantages
    - Lowest HID efficacy
    - Poor lumen maintenance
    - Poor colour

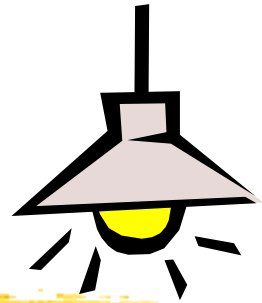
  - (* historical, use less nowadays)



Mercury vapour lamp

(Source: LampTech, http://www.lamptech.co.uk/)

High Intensity Discharge (HID)



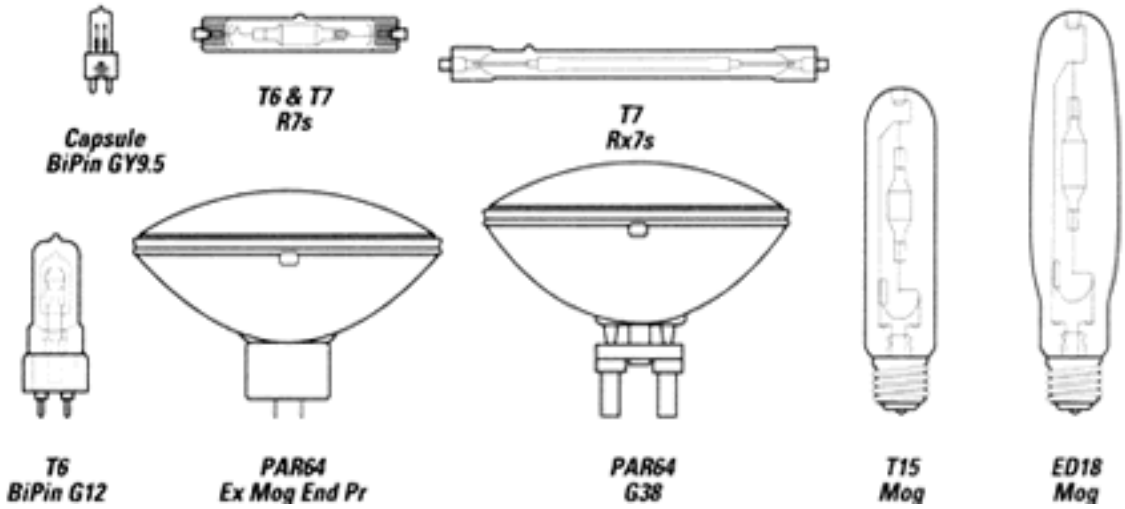
- Mercury vapour
  - Lamp types
    - Standard, PAR (parabolic), R (reflector), Safety
  - Operating characteristics
    - Starting characteristics
    - Lamp operating position (vertical/horizontal)
    - Lamp life & lumen maintenance
    - Temperature effects
    - Flicker & strobe

High Intensity Discharge (HID)

- Metal halide
  - Advantages
    - High efficacy
    - Good to excellent colour
    - Good lumen maintenance
    - Wide range of wattages
  - Disadvantages
    - Colour shift
    - Hot restrike time

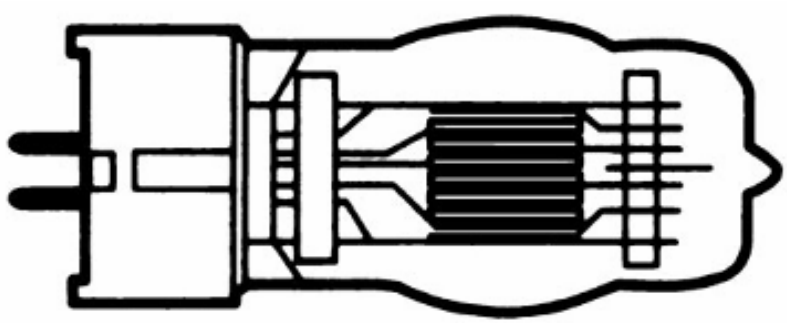
High Intensity Discharge (HID)

- Metal halide
  - Lamp types
    - Standard
    - High output
    - PAR (parabolic)
    - Open luminaires
    - Safety
    - Double ended



High Intensity Discharge (HID)

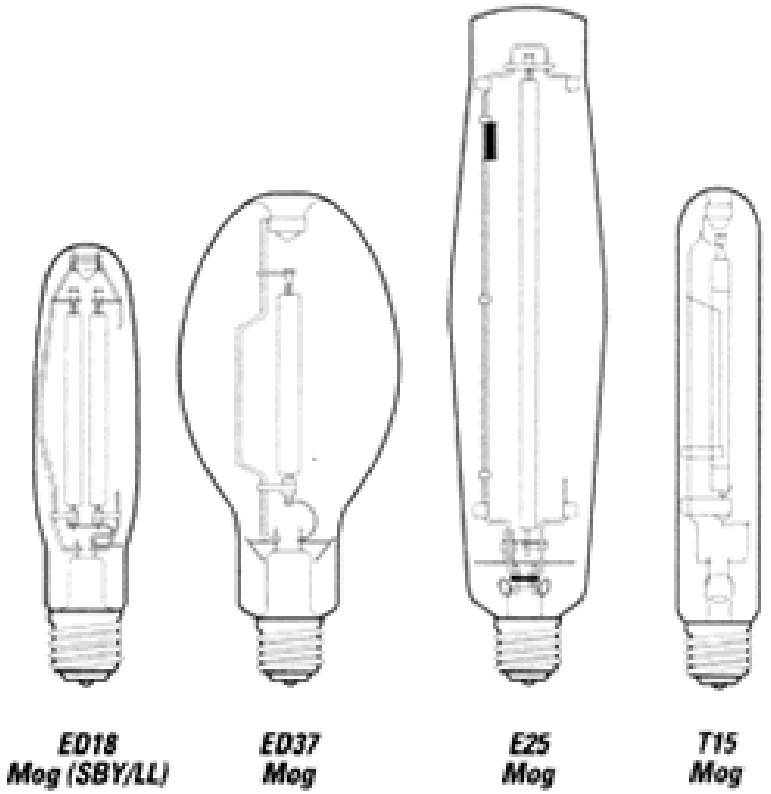
- Metal halide
  - Operating characteristics
    - Starting characteristics
    - Lamp operating position (vertical/horizontal)
    - Lamp life & lumen maintenance
    - Temperature effects
    - Flicker & strobe



For theatre projection

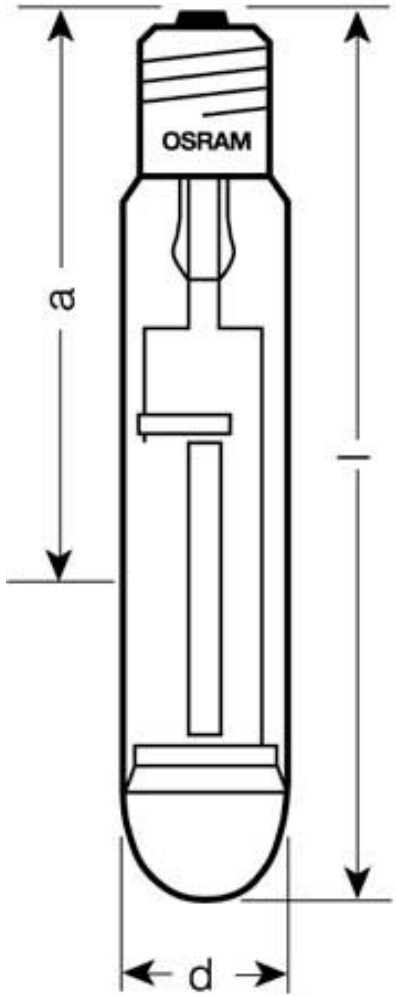
High Intensity Discharge (HID)

- High pressure sodium
  - Advantages
    - High efficacy
    - Long life
    - Universal burning position
    - Wide range of wattages
    - Good lumen maintenance
  - Disadvantages
    - Colour (standard lamp)
    - Require ballast
    - Cycling (standard lamp)

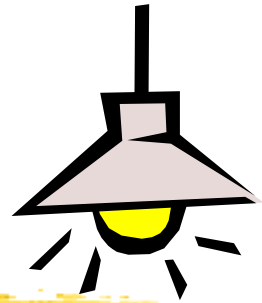


High Intensity Discharge (HID)

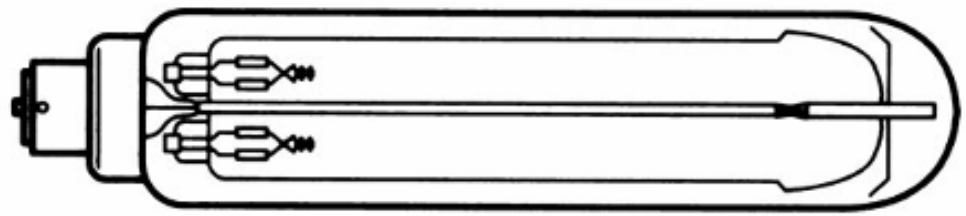
- High pressure sodium
  - Lamp types
    - Standard
    - Standby/instant restrike
    - High output
    - Non-cycling
    - Deluxe colour
    - Double ended
    - Self-ballasted
    - Mercury retrofit
  - Operating characteristics
    - Starting characteristics
    - Lamp operating position (vertical/horizontal)
    - Lamp life & lumen maintenance
    - Temperature effects
    - Cycling

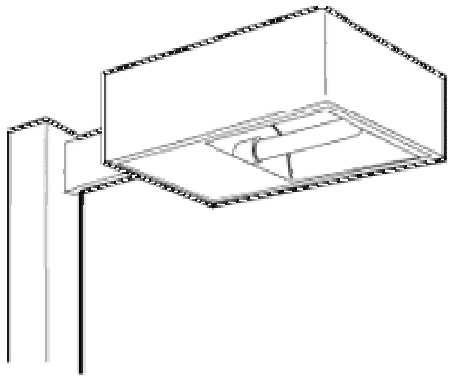


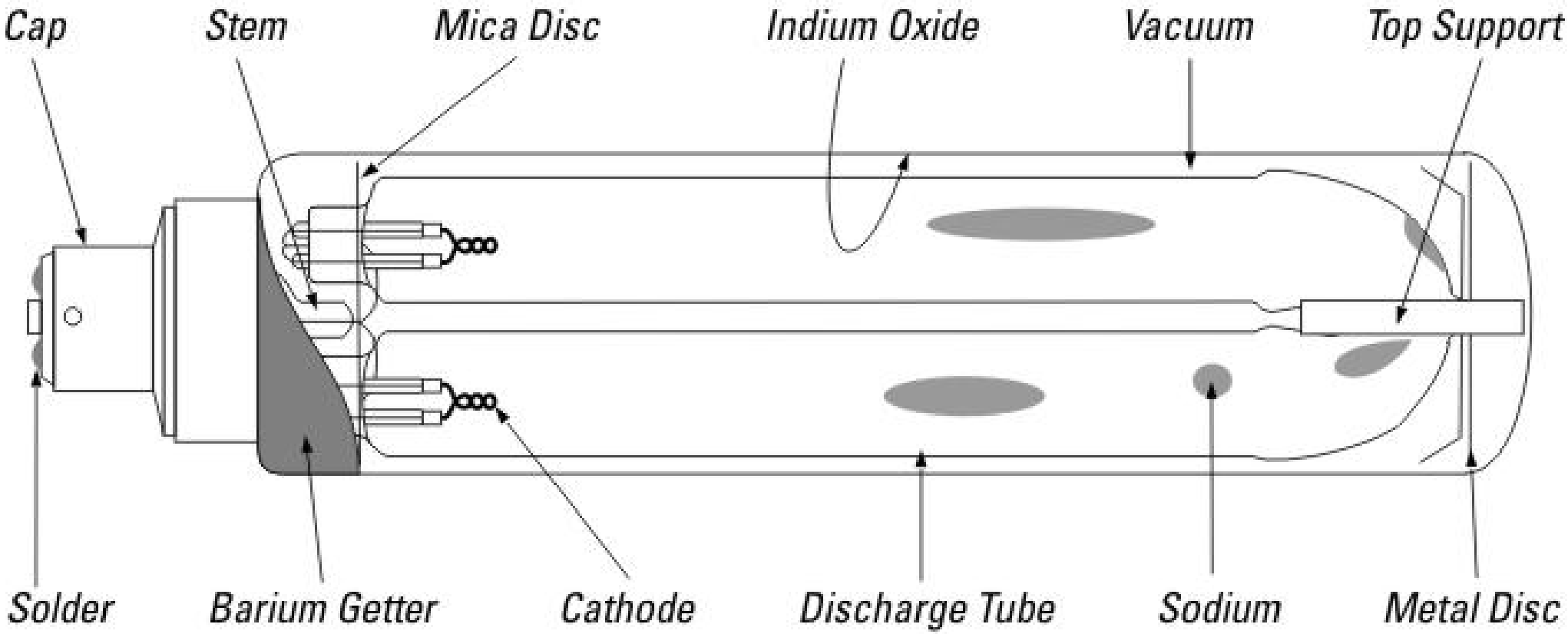
Low Pressure Sodium



- Low pressure sodium
  - Advantages
    - Highest efficacy
    - Hot restrike
  - Disadvantages
    - Monchromatic
    - Optical control
    - Lamp disposal
    - Increased wattage over life



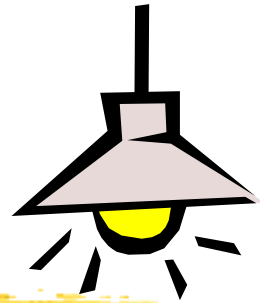




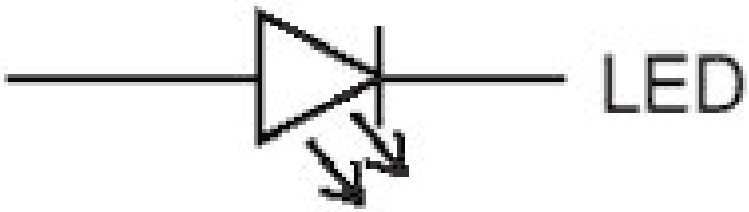
Low pressure sodium lamp

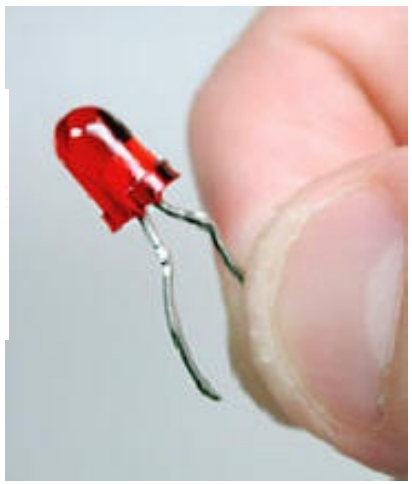
(Source: LampTech, http://www.lamptech.co.uk/)

Light Emitting Diode (LED)



- Light emitting diode (LED)
  - Produces light by electroluminescence at low voltage “p-n” junction (e.g. indicator lights)
  - Development of white light & high output LEDs enables wider use in lighting systems





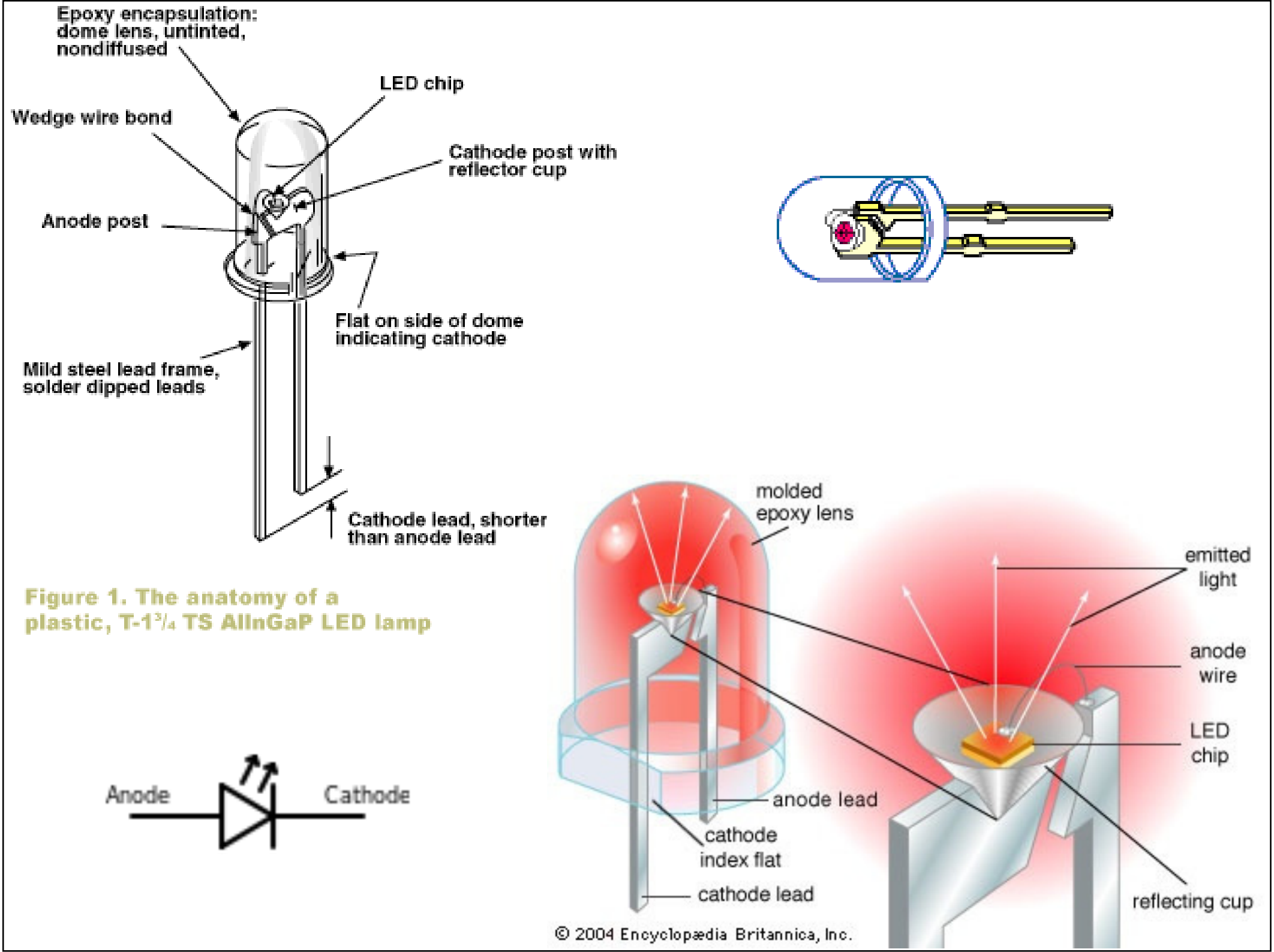
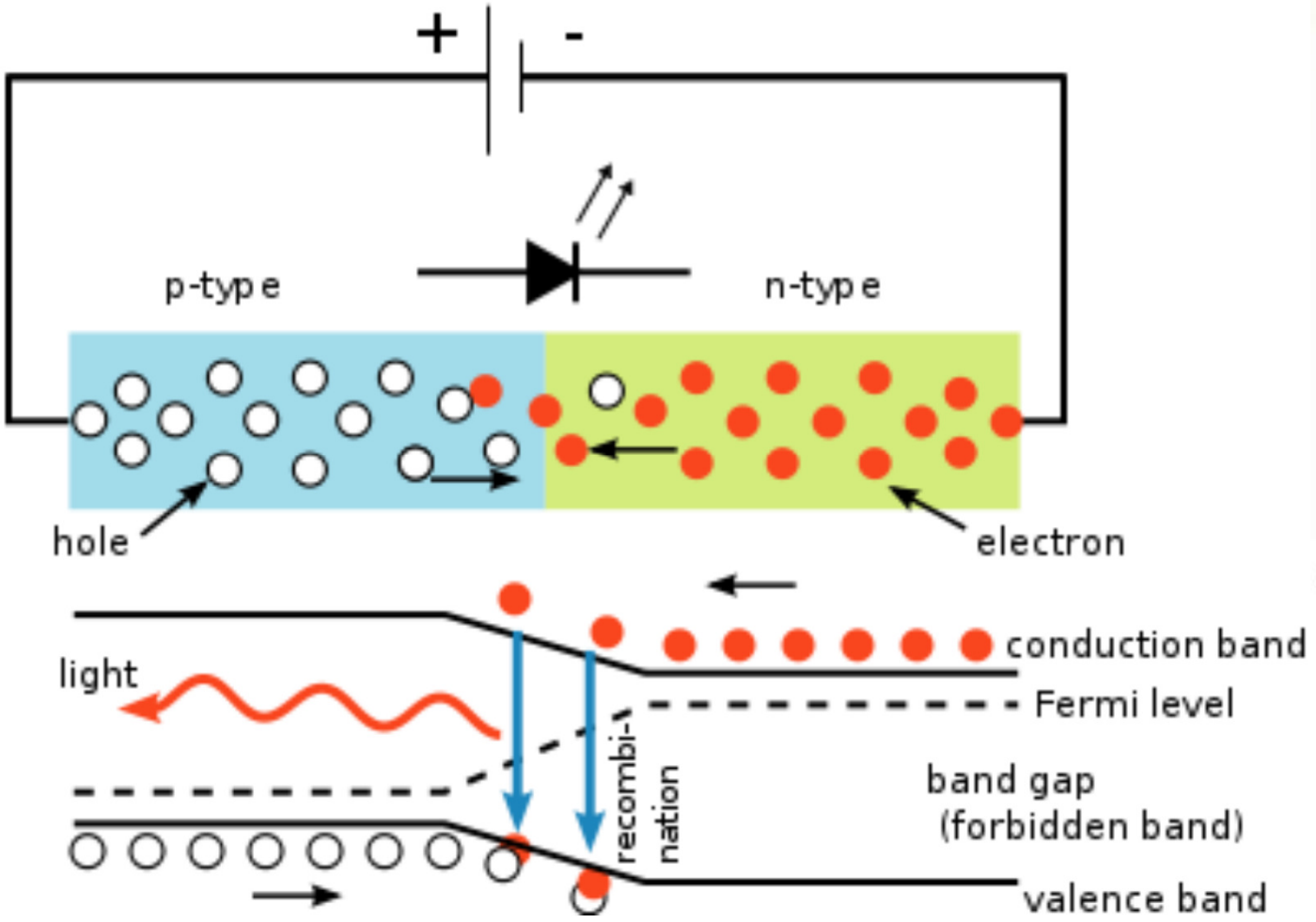
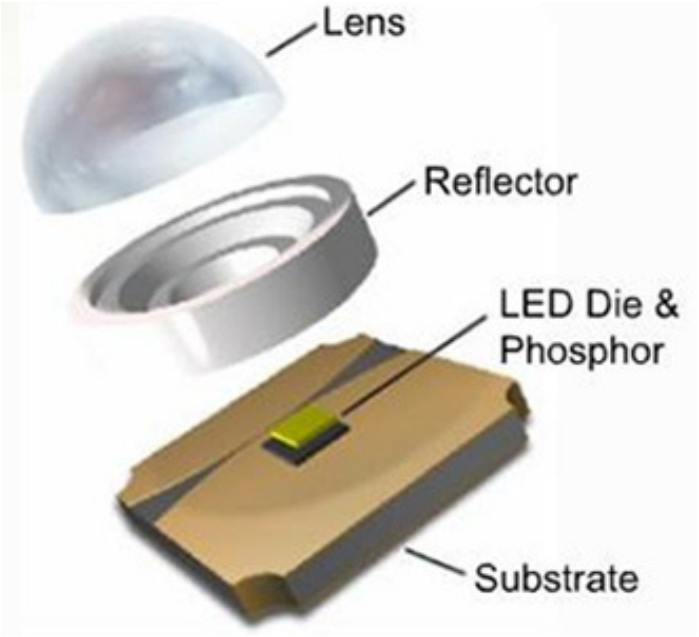


Figure 1. The anatomy of a plastic, T-1¾ TS AlInGaP LED lamp

Principle of LED and structure of high power white LED*



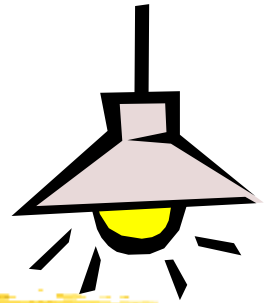


Structure of high power white LED

(* See How LED Works, http://www.omslighting.com/ledacademy/)

Examples of LED lamp application

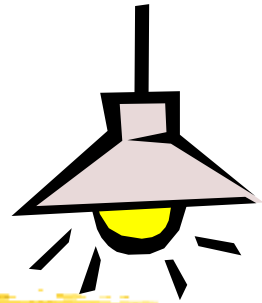
Light Emitting Diode (LED)



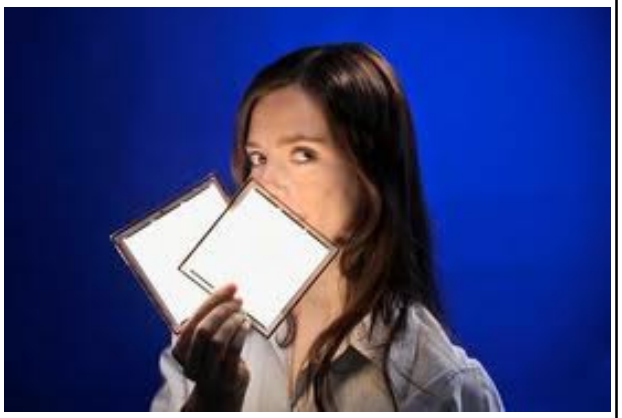
- Light emitting diode (LED)
  - Advantages
    - Low power consumption
    - Long lasting (long useful life)
    - Durable (withstand impact & vibration)
    - Cool (little heat produced)
    - Modular design & compact size
    - Controllability (colour balance & intensity)
    - Instant on, frequent switching
    - No annoying flicker
    - Low cost of manufacture
    - No ultraviolet & infrared radiation
    - Mercury free
  - Disadvantages
    - Focused, directional light
    - Need different optics design
    - May need heat sink (thermal management)

LED candles

Light Emitting Diode (LED)



- Solid state lighting (SSL)
  - Emits light from semi-conductor (solid)
    - Light emitting diode (LED)
    - Organic light-emitting diodes (OLED)
    - Polymer light-emitting diodes (PLED)
  - Advantages:
    - Low power consumption
    - Reduced heat generation
    - Greater resistance to shock, vibration, and wear
  - LED retrofits (not ideal), versus LED luminaires



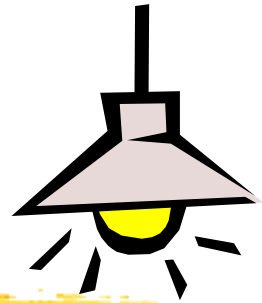
Ballasts and Luminaire

(* See also http://en.wikipedia.org/wiki/Electrical_ballast)

- Ballasts* (e.g. electromagnetic and electronic ballasts)
  - For operation of gas discharge lamps (e.g. fluorescent, HID)
  - Provide several functions:
    - Deliver proper voltage to start or ignite the lamp(s)
    - Current limiting (to safely sustain operation)
    - Compensate for variations in line voltage
    - May offer electrode preheat, dimming or power quality adjustment

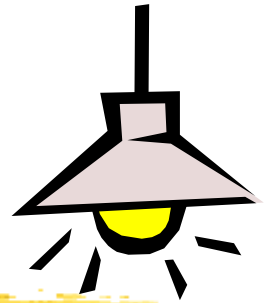
  - Consume power & reduce overall lumens per watt rating
  - Ballast factor (BF) (range from 0.7 to 1.2)
    - It is a measure of actual lumen output for a specific *lamp-ballast* system relative to the rated lumen output measured with a reference ballast under test conditions

Ballasts and Luminaire

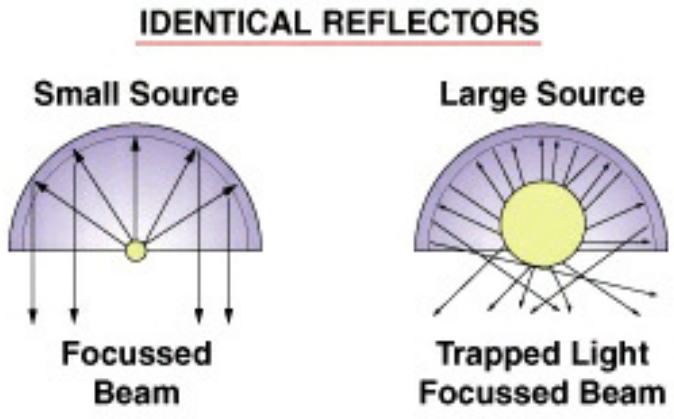


- Ballast efficacy factor (BEF)
  - = Ballast factor (BF) x 100 / Input Watts
- Harmonics caused by electronic ballasts
  - Switching techniques in solid-state electronic ballasts may cause line current harmonics
  - Total harmonic distortion (THD)
    - Distorted wave from superimposing harmonic sine waves (multiples of the fundamental)
  - Consequences of harmonics:
    - Contribute to resistive heating in wiring, insulation, etc
    - Cause lower power factors
    - Produce overheating in transformers
    - Cause excessive current in neutral conductor

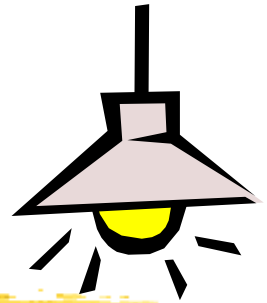
Ballasts and Luminaire



- Luminaire (light fixture)
  - A complete lighting system:
    - A housing and lampholders
    - Lamps (w/ a ballast/transformer)
    - Optical system
      - Reflector, and either a lens, louver or diffuser
      - For controlling brightness
  - It may also include some type of electrical control dimmers, hilo switching, daylight sensors, etc.

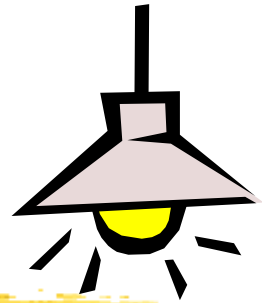


Ballasts and Luminaire

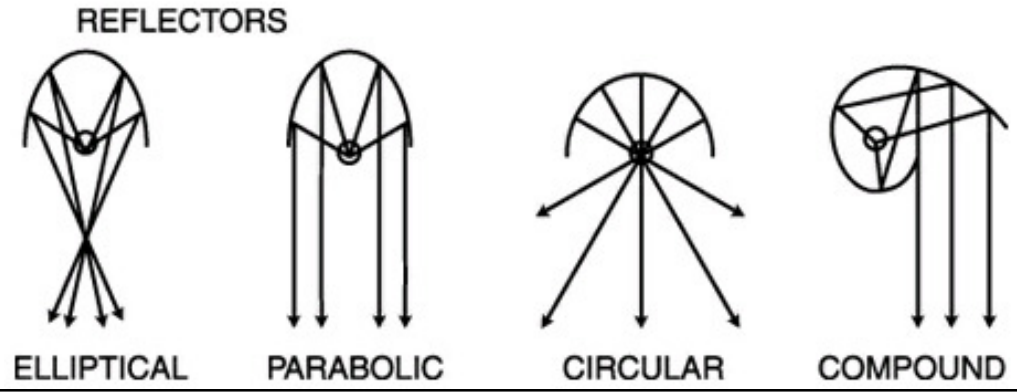


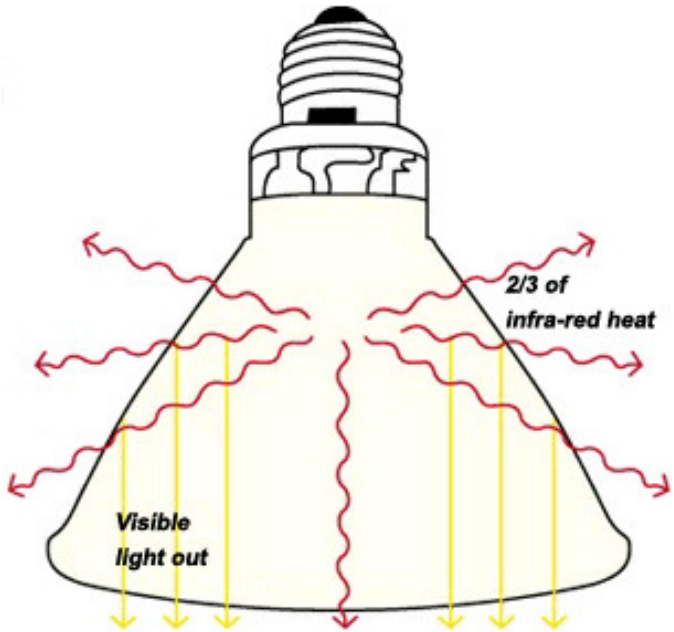
- Six basic classifications of luminaires:
  - Direct luminaire where all the light is directed down
  - Semi-direct luminaire where the majority of the light is directed down
  - General diffuse luminaire where light is distributed in all directions
  - Direct-indirect luminaire where light is distributed equally up and down
  - Semi-indirect luminaire where the majority of light is directed up
  - Indirect luminaire where all the light is directed up

Ballasts and Luminaire



- Optical systems
  - Typical methods of controlling light
    - Reflection
      - Specular, diffuse, spread, selective
    - Transmission
      - Direct, diffuse, spread, selective
    - Refraction





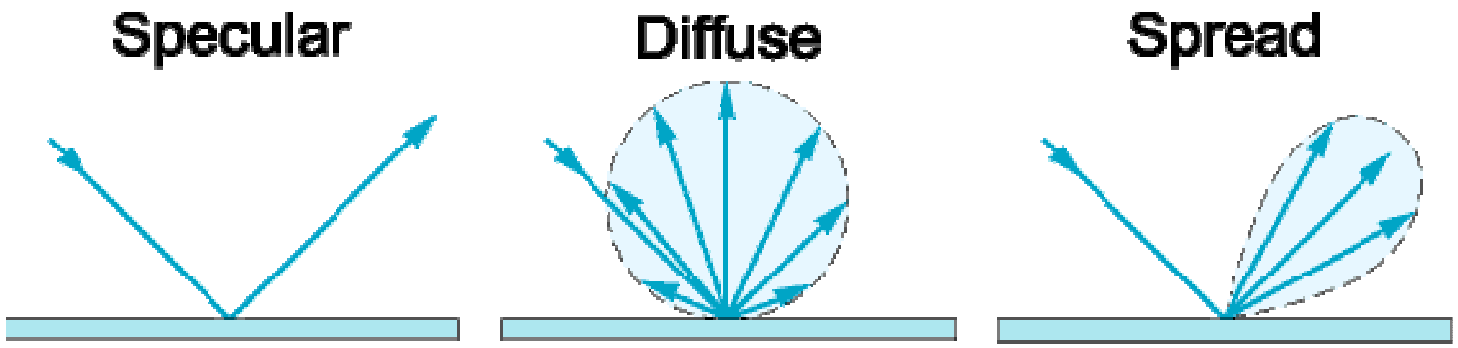


Fig. 3.2 Specular, diffuse, and spread reflection from a surface.

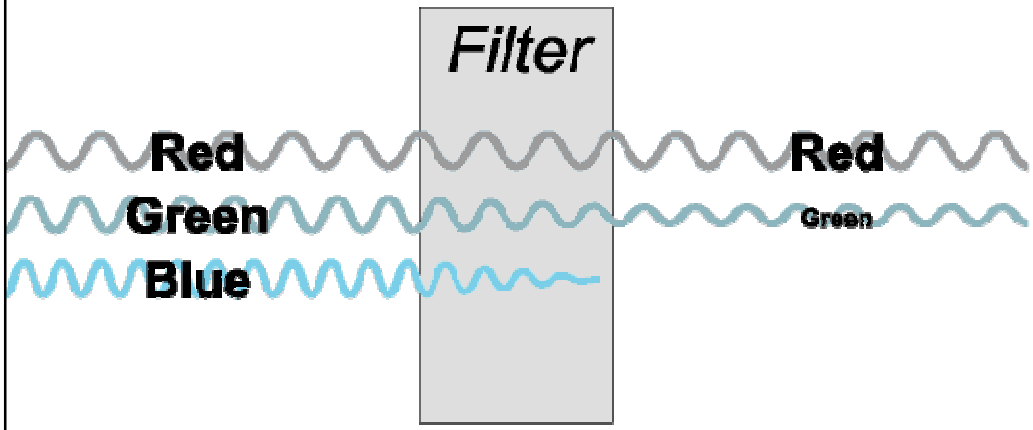


Fig. 3.3 Transmission through an optical filter.

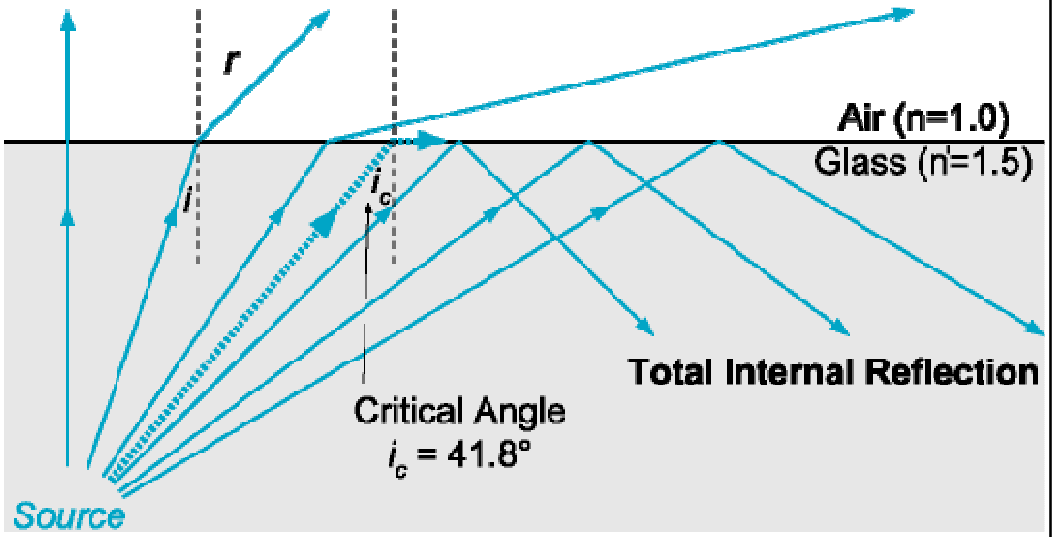
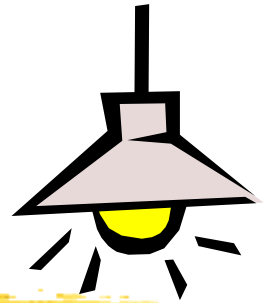


Fig. 3.5 Refraction and total internal reflection.

Methods of controlling light

(Source: IESNA Handbook 9th ed.)

Ballasts and Luminaire



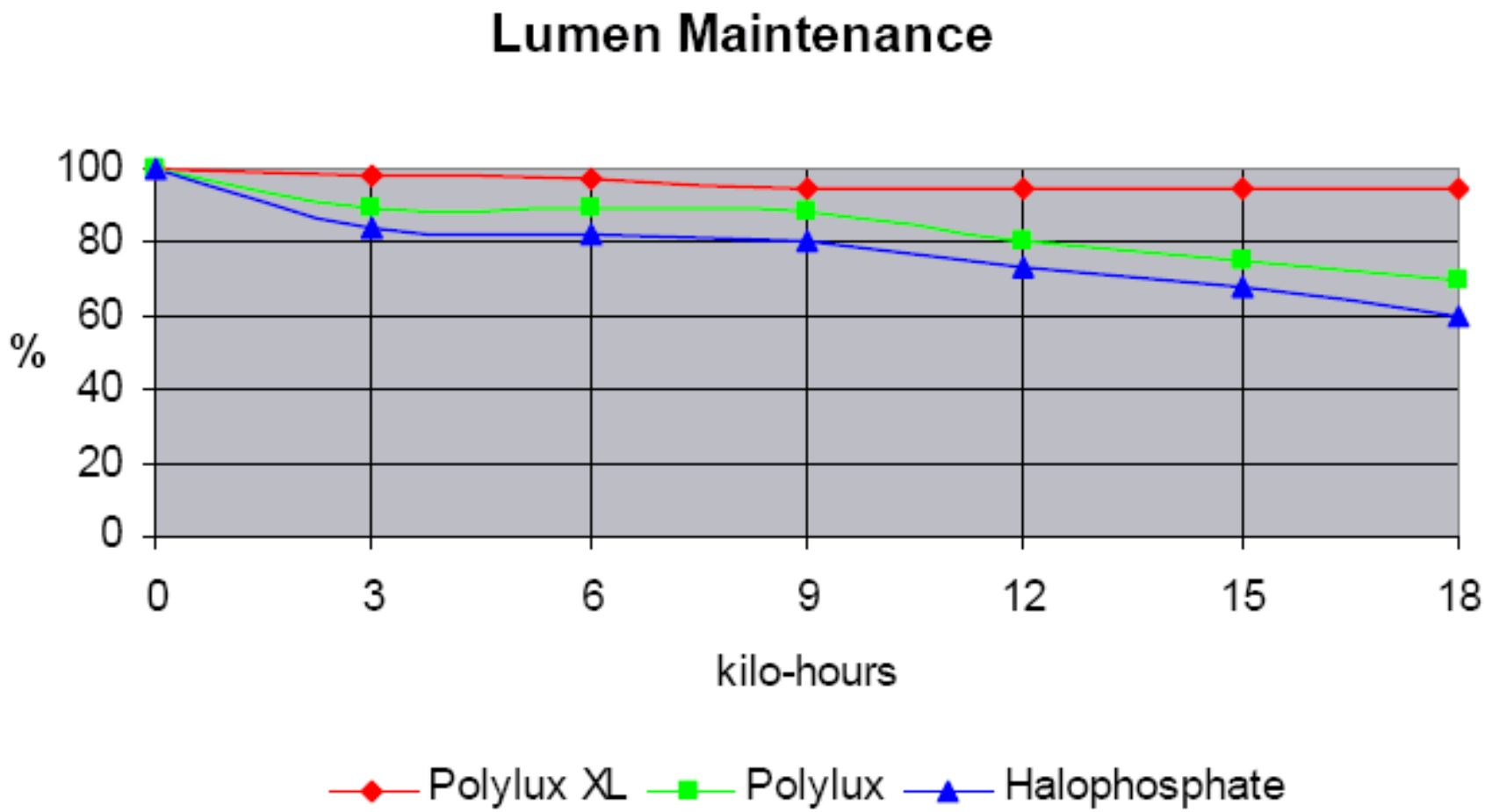
- Luminaries Efficacy Rating (LER)
  - LER = (Photometric Efficiency x Total Lamp Lumens x Ballast factor) / Luminaire Input Watts
- How to classify fluorescent luminaires & systems
  - Mounting: recessed, surface (ceiling or wall) & suspended
  - Distribution: direct, indirect, direct/indirect
  - Type of fluorescent lamp: T12, T8, T5
  - Nominal dimensions: 1 x 4, 2 x 4, etc
  - Application: commercial, industrial, residential, special purpose

Lighting Maintenance

- Maintenance of lighting system
  - Periodic cleaning of lighting fixtures & lamps
    - Decreases light loss & improve light levels
  - Spot or group replacement of lamps based on the economics of the system
  - Periodic repainting or cleaning of the room surfaces (ceiling, walls, and floor) to maintain optimum light reflection characteristics

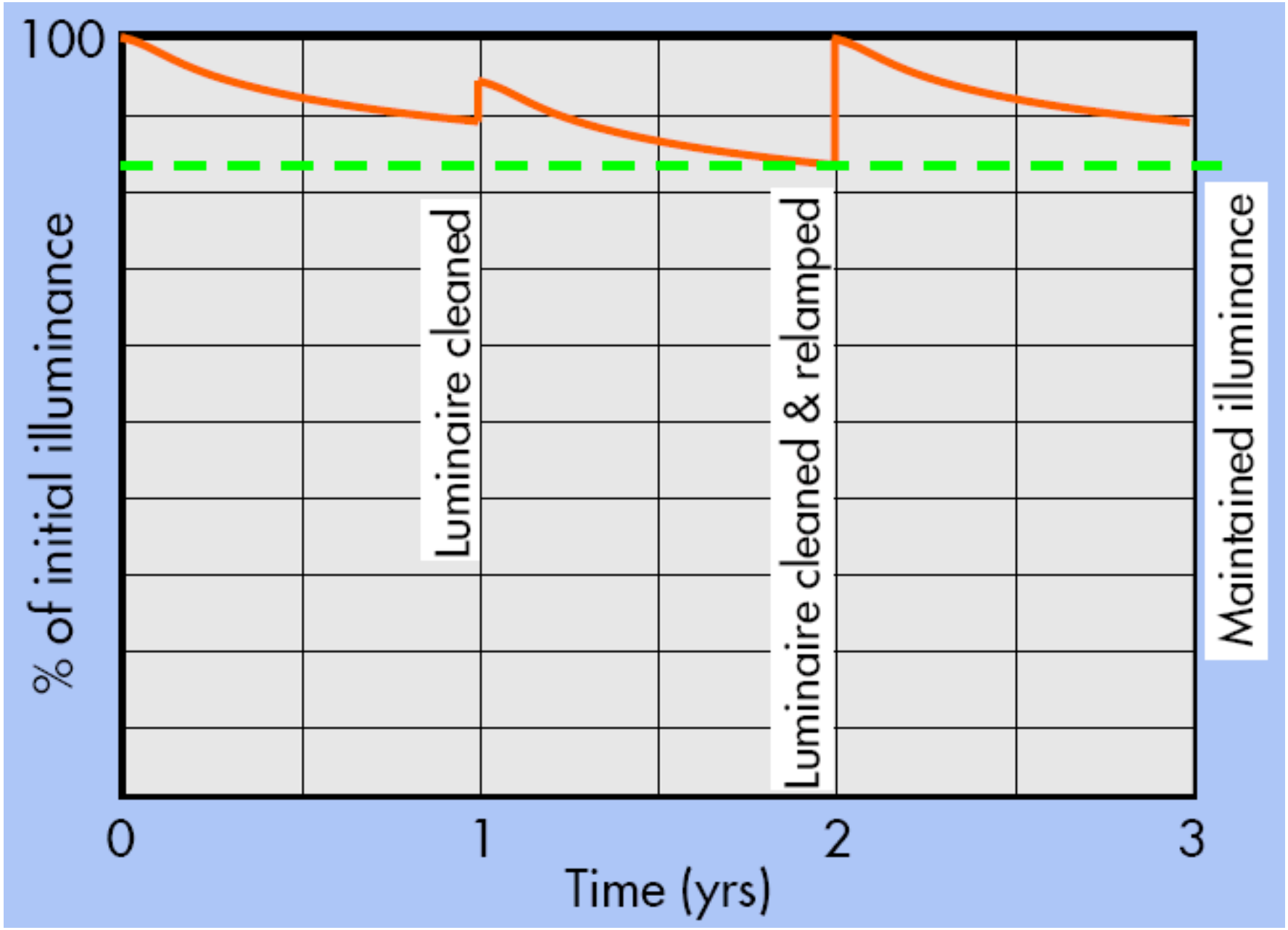
Lumen depreciation: decline in lumen output over time due to reductions in lamp emissions and changing surface properties --- lamp, luminaire, and room, if applicable.

Lumen maintenance: the amount of light provided from the source at a specific time in the future (% of the original light output).



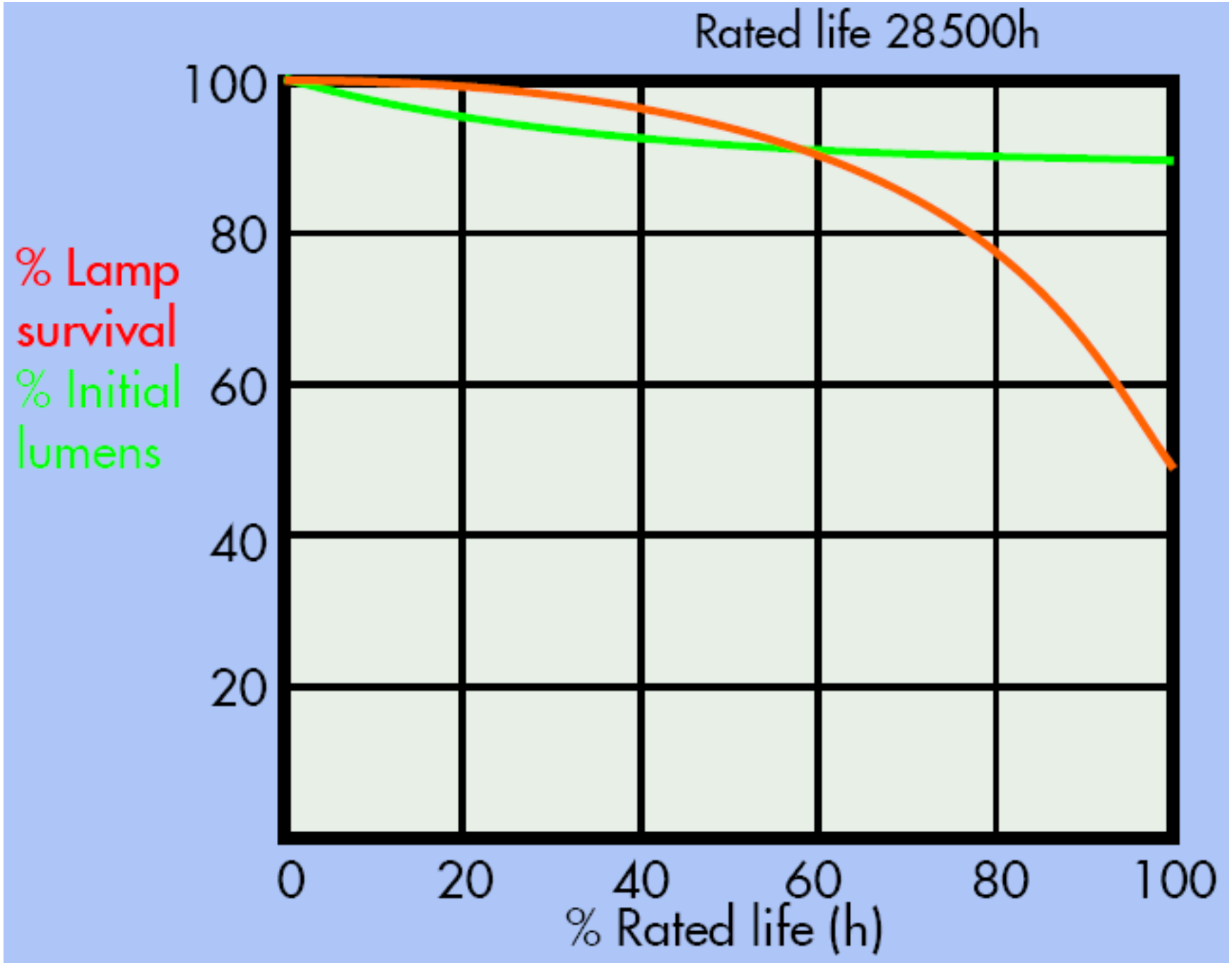
(* See also http://ateam.lbl.gov/Design-Guide/DGHtm/lumenmaintenance.htm)

[Source: Thorn Lighting]



Lamp maintenance effect

[Source: Thorn Lighting]



Lamp maintenance effect

[Source: Thorn Lighting]

Lighting Maintenance

- Common lighting upgrade strategies
  - Upgrade with reduction in light levels
    - If original design is excessive
  - Increase light levels
  - Maintain light levels
  - Focus light levels
    - Task lights or accent lighting
  - Reduce hours of use
    - Add time schedule or automatic controls

Lighting Maintenance

- Environmental aspects of lighting
  - Disposal
    - Lighting waste disposal (e.g. lamp & ballast)
  - Green lights
    - Minimum efficacy standards for lamps
  - Emissions (e.g. mercury)
    - During manufacturing
    - During operation