CORPUS CHRISTI COLLEGE SEQUERE DOMINUM	**Year 12** ***ATAR*** **Physics 4** **2018** ***Evaluation and Analysis*** ***3.0%*** **NAME:** ....Sol'ns........ Data: See Data Sheet Approx. marks shown. ***(48 marks)***

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

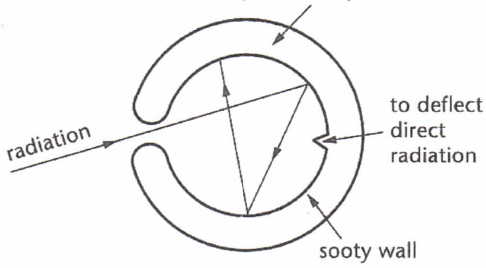
When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Part B Quiz

1. (a) A black body in the laboratory may consist of a hollow porcelain sphere with a small hole in it.

The inside is blackened with soot. A beam of light is directed at the sphere so that it strikes the hole at an angle. The beam of a variety of wavelengths bounces around the inner walls and is entirely absorbed by the sphere.

Explain why the hole is considered to be a black body. [1]



Laboratory black body

The hole allows all radiation to pass through it & so it effectively "absorbs" all radiation, as would a body that is black in colour

(b) In 1896, Wien found that the product of the temperature of a black body and the wavelength of the emitted radiation, in metres m, produced a constant: 2.90 x 10^{-3}. This relationship is known as Wien's displacement law.

(i) Write this formula as a mathematical relationship. [1]

$T \cdot \lambda = 2.90 \times 10^{-3}$ (K m)

(ii) Calculate the peak wavelength, in metres m and nanometers nm, which corresponds to 1400 K using Wien's displacement law. [2]

$\lambda = \frac{2.90 \times 10^{-3}}{1400}$ ✓

$= 2.07 \times 10^{-6}$ m

$= (2.07 \times 10^{3}) \times 10^{-9}$ ✓

$\lambda = 2070$ nm

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(c) In 1900, another scientist described the process more accurately by including the constant ***h*** with a mean value of 6.626×10^{-34} Js. It was from this radiation equation that this scientist developed the basis for what we know as quantum theory.

Suggest the name of this scientist. [1]

(Max) Planck

2. As a blackbody heats up, it emits all of the energy it has received back into space. Although all wavelengths are emitted, the dominant wavelength directly corresponds to the effective surface temperature of the black body according to Wien's displacement law.
The table below was the result of an experiment in black body radiation. The coordinate pairs give a curve corresponding to an effective surface temperature (T_{eff}) of 1400 K.

E	1.5	4.5	8.0	5.5	3.0	1.0
λ	1000	1500	2000	3000	4000	5000

where E = the emissive power in $Wm^{-2}\ nm^{-1} \times 10^{-9}$, and
λ = wavelength in nanometres.

(a) On the grid on pg 3 draw a graph of the black body radiation curve for 1400 K, plotting emissive power on the y axis and wavelength on the x-axis. [3]

(b) Use the answer to question 1 (b) (ii) to estimate the turning point of the curve. [1]

3. (a) Use Wien's displacement law to establish the peak wavelengths, in nanometers nm, to 2 significant figures, when:

	E	T_{eff}	λ (2sf)
(i)	18	1600	1.813×10^{-6} = 1800 nm
(ii)	4	1200	2.417×10^{-6} = 2400 nm
(iii)	2	1000	2.90×10^{-6} = 2900 nm

where E = the emissive power in $Wm^{-2}\ nm^{-1} \times 10^{-9}$, and
T_{eff} = is in Kelvin. [3]

(b) Plot these points on the same graph as in question 2 and join them up with a curved line. This represents the peak radiation for a given temperature. [3]

4. Earth, however, is not a perfect black body but a grey body which absorbs and emits about 90% of the radiation it receives from the sun. Earth is therefore regarded as having an emissivity (ε) of 0.90. ← 2sf.

↙ 2sf

Given that the mean surface temperature (T_{eff}) of Earth is 290 K *estimate* the total outgoing radiation using $P = A\,\varepsilon\,E$ where A is the area of the surface, $4\pi r^2$ and E is the energy derived from Stefan's Law, $E = \sigma T^4$. Stefan's constant (σ) has the value 5.75×10^{-8} W m^{-2} K^{-4}. [3]

$P = A \epsilon E$

$= 4\pi r^2 \times \epsilon \times (\sigma T^4)$

$= 4\pi (6.37\times10^6)^2 \times 0.90 \times (5.75\times10^{-8} \times 290^4)$

$= 1.866 \times 10^{17}$ W

$= 1.9 \times 10^{17}$ W (2sf)

[Units $P = A\epsilon E = m^2 \times - \times \frac{W}{m^2} = W$]

$A = 4\pi r^2$
$= 4\times\pi\times(6.37\times10^6)^2$
$= 5.10\times10^{14}\ m^2$

$E = 5.75\times10^{-8}\times290^4$
$= 406.7\ Wm^{-2}$

Note units.

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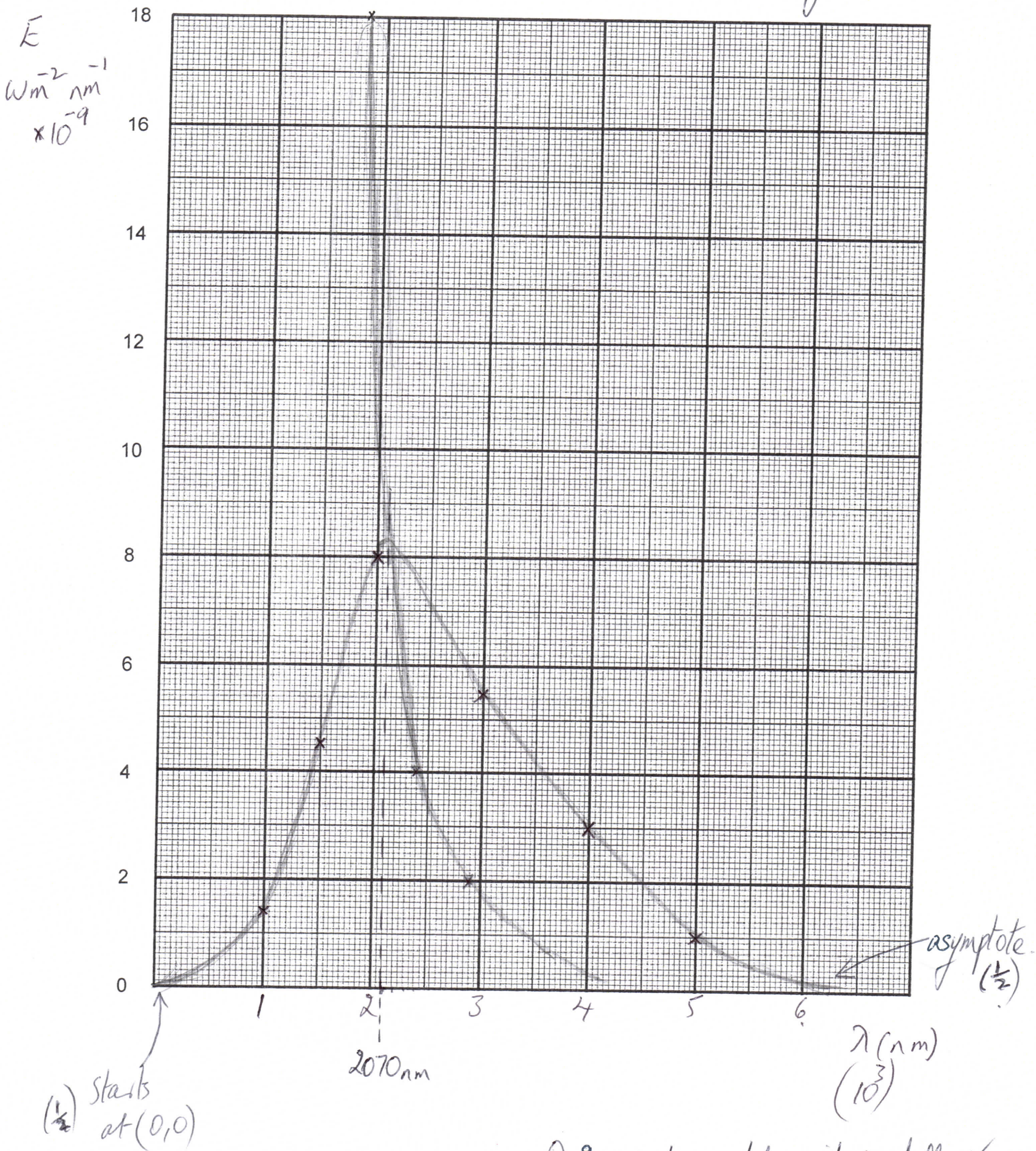
Emissive Power vs λ for Black body radiation



Q 2 graph – plot points carefully ✓
– curve of best fit ✓ (2×½ above)
– turning pt at 2070 ✓

Q 3 – labels & units on axes ✓
– Plot points carefully ✓
– curve of best fit ✓

5. Use the Data Sheet to complete the table below relating the wavelength ranges, in m, associated with ultraviolet (uv), visible, infrared, and microwave spectra. [4]

EM radiation spectrum	Min wavelength (m)	Max wavelength (m)
Ultraviolet	3×10^{-9}	3.5×10^{-7}
Visible	4×10^{-7}	7.5×10^{-7}
Infrared	7.5×10^{-7}	1.5×10^{-3}
Microwave	7.5×10^{-4}	0.5

Know this already *

From Data Sheet
$f \approx 9 \times 10^{4}$ Hz
$\lambda = \frac{3 \times 10^{8}}{9 \times 10^{4}}$
$= 3.33 \times 10^{-7}$ m.

($\frac{1}{2}$ each)

6. What wavelength spectrum is associated with heat radiation? Give an example of a device that relies upon detecting these wavelengths. [2]

Infrared radiation

Night vision goggles (used by police) detect infra-red radiation

7. Convert a normal human body temperature of 37°C to Kelvin. Only whole numbers are required. [2]

$37^{o} + 273 = 310$ K (Note: No degree symbol for K (-1))

8. Use the blackbody spectrums on the following pages to complete the table below. ***Remember to include units.***
Note that the *peak wavelength* is the x-axis value corresponding to the maximum of the blackbody intensity curve. [8]

$\mu m = 10^{-6}$ m

Object	Temperature	Peak wavelength	The primary peak spectrum region
Sun	5745	0.50 μm ✓	$= 5 \times 10^{-7}$ visible
Light bulb	3050	0.95 μm ✓	$= 9.5 \times 10^{-7}$ infrared
Oven	570	5.2 μm ✓	$= 52 \times 10^{-7}$ infrared
Yourself	310	9.0 μm ✓	$= 90 \times 10^{-7}$ infrared
Earth	298	9.5 μm ✓	$= 95 \times 10^{-7}$ infrared.

✓ ✓

2sf accuracy expected. ✓

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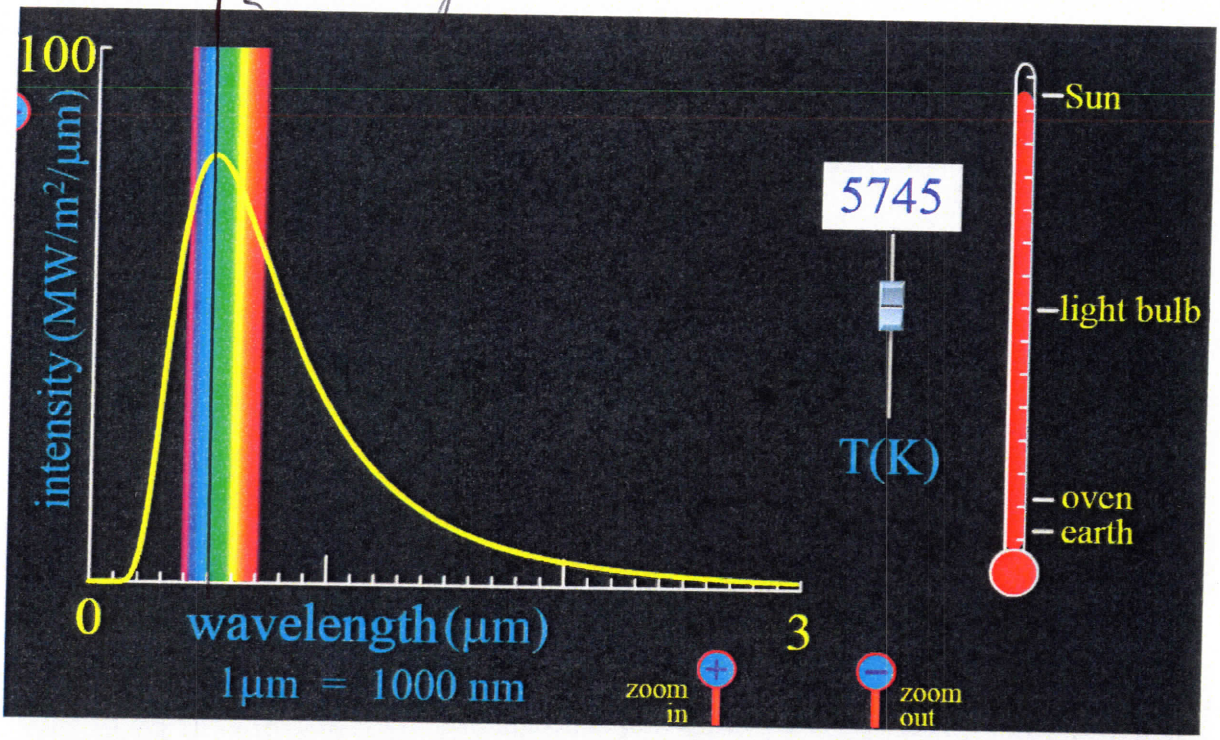
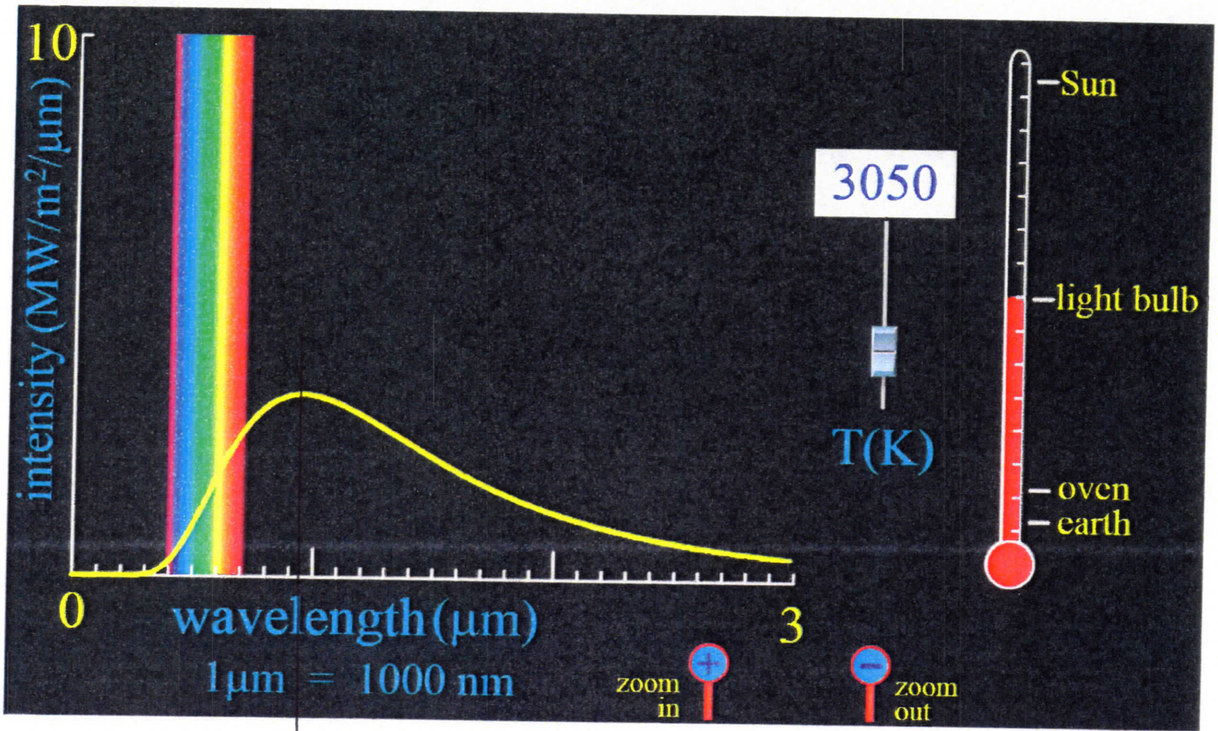
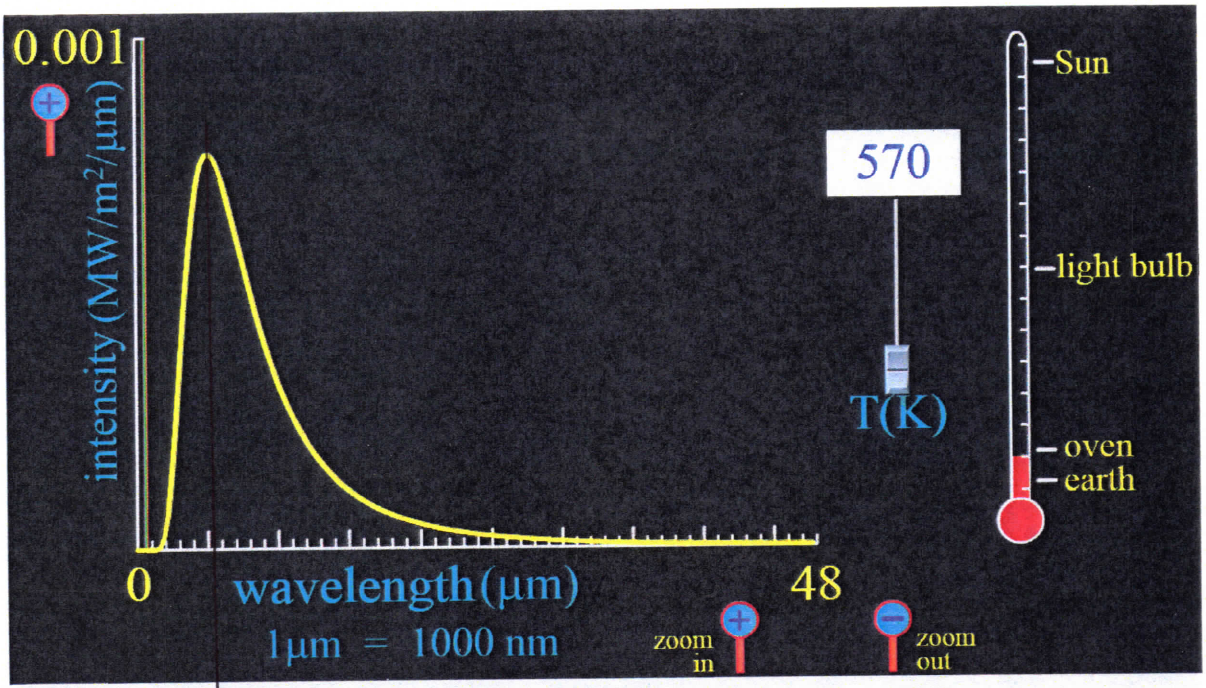
Black body Spectra

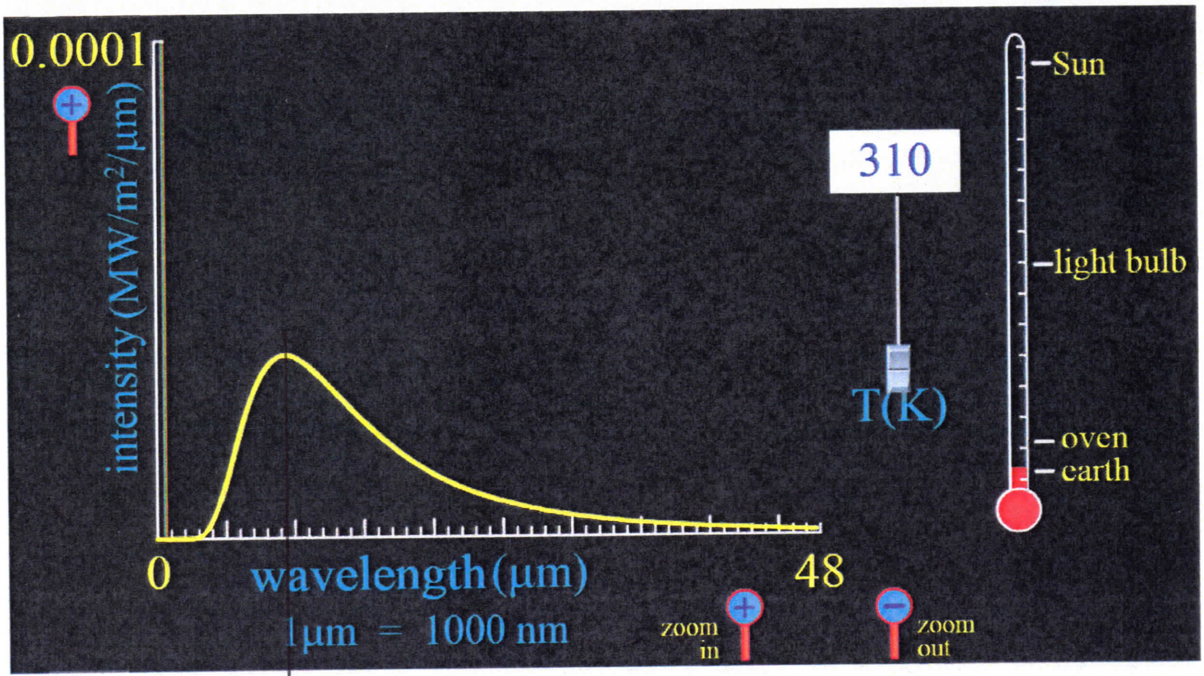
working line





working line.


0.001
intensity (MW/m²/μm)
570
T(K)
Sun
light bulb
oven
earth
0
wavelength (μm)
48
1μm = 1000 nm
zoom in
zoom out


0.0001
intensity (MW/m²/μm)
310
T(K)
Sun
light bulb
oven
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wavelength (μm)
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1μm = 1000 nm
zoom in
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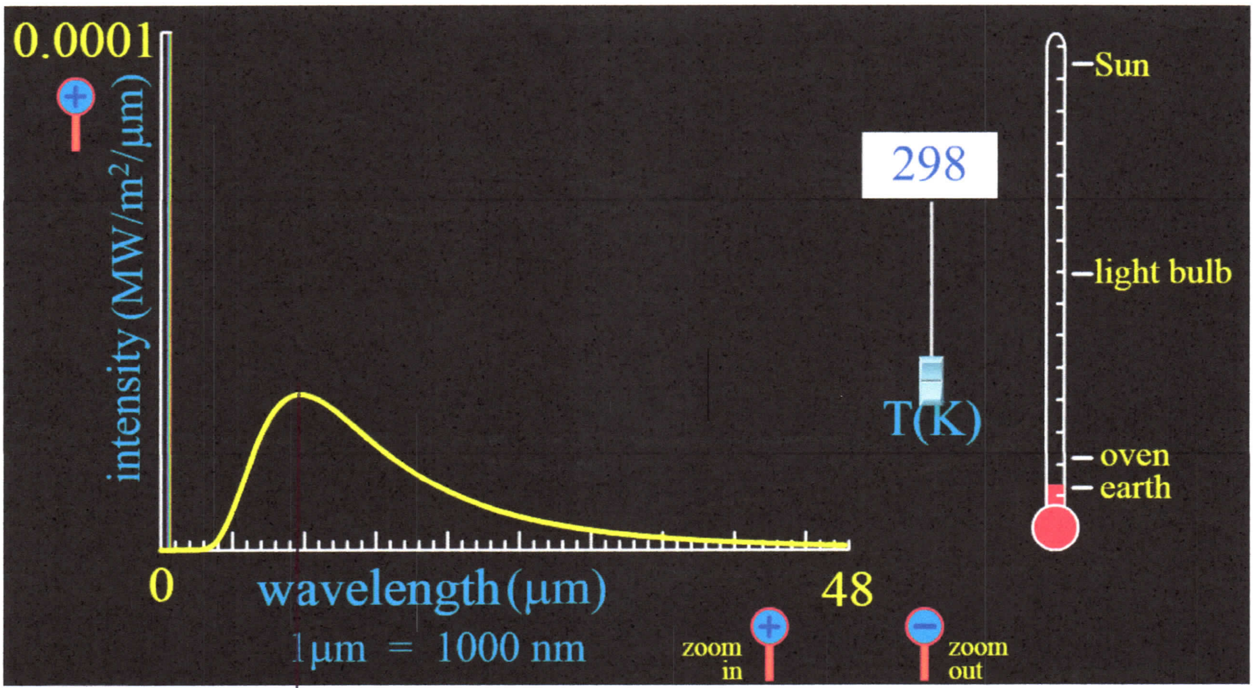

9. (a) By considering the units on the axes of the above graph what does the area under the curve (i.e. the size of the space under the yellow curve) represent? [2]

Shape ≈ triangle ∴ $A = \frac{1}{2} b \times h$
Units = $A = \mu m \times MW/m^2/\mu m$
∴ $A = MW/m^2$
$A = \frac{P}{A}$ = Intensity

(b) Do incandescent light bulbs radiate more light or more heat? Refer to the spectrum of the light bulb in your answer. [2]

These radiate more heat since there is a much greater area under the graph in the infrared region than in the visible light region.

10. In summer people are advised to stay out of the sun with SunSmart Campaigns such as

Slip! Slop! Slap! Throw on a hat!

By referring to the spectrum of the Sun, explain the need for this campaign. [2]

Some of the area under the curve is in the U.V. region of EMR. U.V. causes sunburn ✓ skin cancer ✓ hence protection from the Sun's radiation is needed.

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11. Astronomers regard stars as near-perfect black bodies. A perfect black body will absorb all incoming radiation and emit all outgoing radiation.

(a) Use Wien's displacement law to find the effective surface temperature of the star Rigel if the peak wavelength is 263 nm. [2]

$T\lambda = 2.90 \times 10^{-3}$ Km

$T = \frac{2.90 \times 10^{-3}}{263 \times 10^{-9}} = 11030$ K

$= 1.10 \times 10^{4}$ K

(b) When observing Rigel what colour would one expect to see? Explain: [2]

A A red star

B A yellow star

C A blue star

263×10^{-9}

$= 0.263 \times 10^{-6}$ m $= 0.263\ \mu m$

Peak $\lambda \approx$ UV region – closest to blue.

12. Briefly explain the ultraviolet catastrophe originally associated with Blackbody radiation. [4]

From Pearson:

Classically, thermal radiation is emitted by accelerating charges near the surface of a material. The charges have a distribution of accelerations that leads to a range of thermal energies. The classical expression, known as the Rayleigh–Jeans law, gives the average energy per oscillating or vibrating charge proportional to temperature. The radiated energy can be considered to be produced by standing waves or resonant modes within the cavity. At long wavelength, λ, there is a reasonable agreement between the experimental data and the calculation, as shown in Figure 7.4.6.

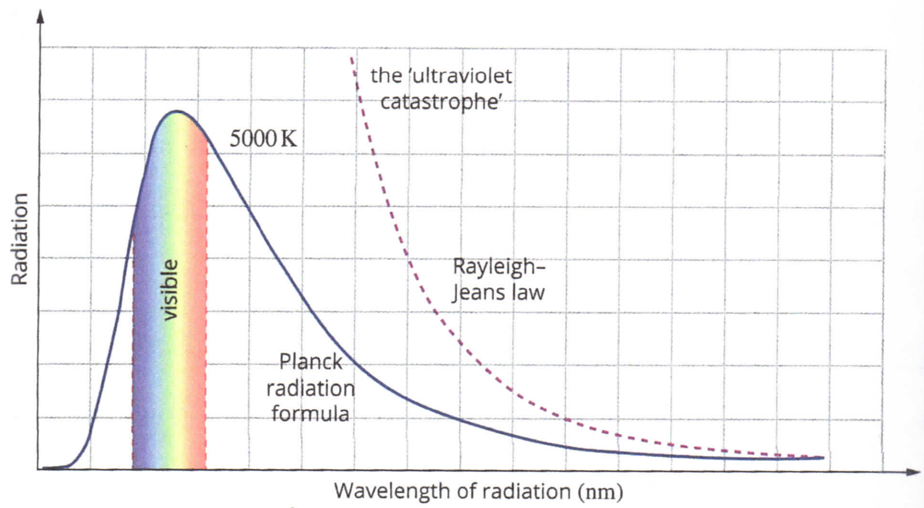

FIGURE 7.4.6 Comparison of the experimentally observed blackbody radiation intensity and the Rayleigh–Jeans classical calculation.

However, as the wavelength gets shorter (or the frequency gets higher) the number of modes continues to get larger and larger, so the energy density increases and approaches infinity; this is known as the ultraviolet catastrophe.

End of Quiz

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