# Ex6

## Laws of radiation

Object: To measure the radiant intensity of a blackbody as a function of temperature

Theory:

An ordinary property of every object is its ability to emit and absorb electromagnetic radiation. The phenomenon is called thermal radiation because it involves an interchange between radiation energy in the electromagnetic fields around the object and thermal energy owing to the motion of particles within the object. The interchange is assumed to be an equilibrium process occurring at a certain temperature. Some of the features of this complex problem appeal to common sense. The familiar observation that an incandescent solid glows "red-hot" when heated , and "white-hot" when heated more ,suggests a correlation between the temperature of the solid and the frequency of the emitted radiation.

The radiant emittance $M(T)$ refers to the total energy radiated by the object at Kelvin temperature T per unit time per unit area. This quantity is a temperature-dependent function, given in units $W/m^2$ . A continuous frequency spectrum is also defined since the emittance has contributions in every frequency interval 00. We express this distribution of by writing

$$M(T) = \int_0^\infty M_\nu(T)d\nu \qquad (6\text{-}1)$$

The integrand $M_\nu(T)$ identifies the spectral radiant emittance, or total energy radiated per unit ime per unit area per unit frequency interval. Our notation stresses the dependence of this spectral quantity on the variables, $\nu$ as well as T.

The emission of radiation is simultaneous with the incidence of radiation for an object at equilibrium. Incident energy may be either reflected or absorbed, and so two separate incident quantities are specified at frequency $\nu$ and temperature T, the spectral reflectance $\rho_\nu(T)$ and the spectral absorptance $\alpha_\nu(T)$. These fractions of the energy incident per unit time per unit area frequency interval must satisfy the equality

$$\rho_\nu(T) + \alpha_\nu(T) = 1 \qquad (6\text{-}2)$$

We are concerned with the equilibrium situation where the rates of emission and absorption are equal by definition. A perfect absorber reflects no incident radiation and therefore satisfies $\alpha_\nu(T)$=1. This ideal radiator is a perfect emitter and is called a blackbody. Figure6.1 shows a model of a blackbody constructed in the form of an evacuated cavity with walls at temperature T and with a hole in one of the walls.

The hole is very small so that rays entering the cavity have essentially no chance to be reflected back out. The spherical shape shown in the figure is not a necessary feature of the model. A blackbody is a useful idealization, which we can employ as a standard by introducing the associated spectral emittance $M_\nu^b(T)$ as a standardizing function. We can use this fundamental fictitious quantity to define the spectral emissivity

$$\varepsilon_\nu(T) = \frac{M_\nu(T)}{M_\nu^b} \qquad (6\text{-}3)$$

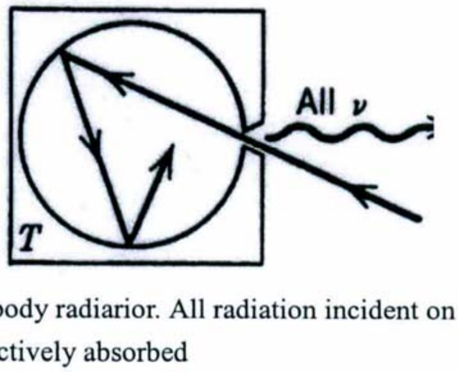
this ratio then provides a measure of the radiating efficiency for a real object whose spectral emittance is $M_\nu(T)$ .

In 1884 Boltzmann proved the conjecture theoretically, but only in the case of blackbody. Their conclusion, the Stefan-Boltzmann law , was expressed as

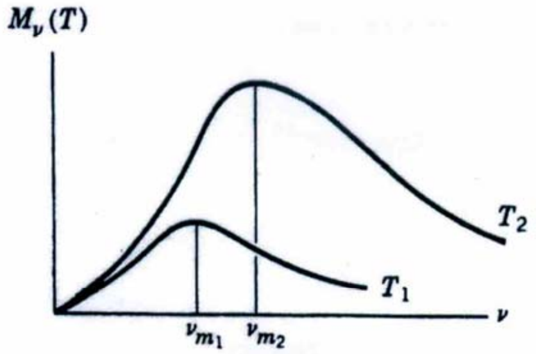
$$M^b(T) = \int_0^\infty M_\nu^b(T)d\nu = \sigma T^4 \qquad (6\text{-}4)$$

with $\sigma = 5.67*10^{-8}\, W/m^2 \cdot K^4$ for the value of the Stefan-Boltzmann constant.

This brief summary sets the stage for Planck's contribution. The great importance of his idea warrants a detailed analysis of the entire blackbody problem. We concentrate on the idea blackbody radiatior and suppress the superscript on $M_\nu^b(T)$, as we have already done in Figure6.2. Our system is the cavity model in Figure6.1whose shape, we have noted, can be arbitrary. The derivation of the spectrum requires several steps, the most important of which is the use of Planck's quantum hypothesis. Any desired property of the resulting blackbody solution may also be deduced, including particularly the Stefan- Boltzmann $T^4$ law in Equation6-4.




6-1 Model of a blackbody radiarior. All radiation incident on the hole in the wall of the cavity is effectively absorbed




6-2 Blackbody frequency spectra for temperatures $T_1 \prec T_2$.According to Wien's law ,$\nu_m$ is proportional to T.

Wien's law $\lambda_m T = 2.898 * 10^{-3} K \cdot m$

Apparatus:

Black body accessory
Electric oven, 230v
Support for electric oven
Safety connection box with ground
Digital thermometer with one input
Moll's thermopile
Microvoltmeter
Small optical bench
Stand base, V-shape,28cm
Setup

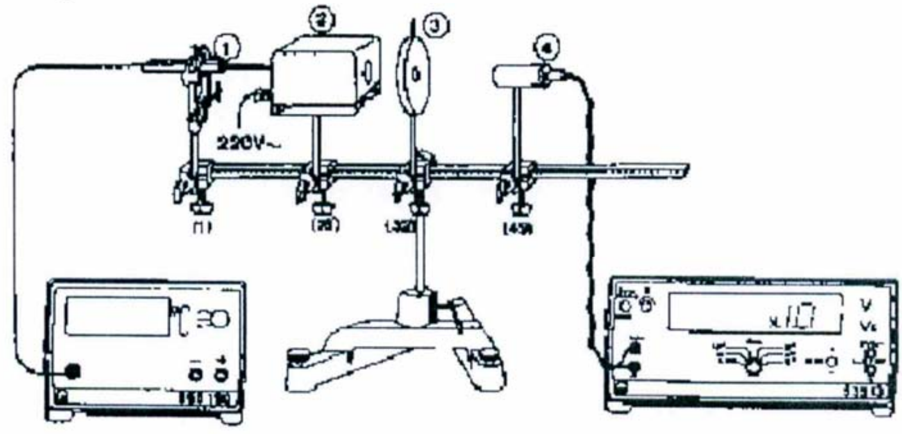



圖 6-5（1）溫度探針 （2）Oven 加熱器 （3）隔板 （4）Moll's 熱偶

注意 ：溫度探針切勿與 Oven 接觸。

步 驟：

1. 將 Microvoltmeter 調至適當的刻度範圍(約$10^{-3}$ Volt) 。
2. 加熱 Oven，注意切勿超過 400˚C。
3. Oven 加熱約至 350˚ 時，關閉加熱電源。
4. 記錄數據前，至少等 5 分鐘後熱源溫度達穩定的程度，再開始記錄。
5. 由高溫到低溫記錄熱偶之輸出電壓(Utherm)與輻射體之溫度數值（每隔 10˚C 記錄一組，需 20 組數據）。
6. 繪出熱偶之輸出電壓(Utherm)對輻射絕對溫度四次方的圖形。