inkPhysics

ANSWER BOOK

Black-body radiation and spectral classes

Astrophysics · Year 13

AQA 3.9.2.3, 3.9.2.4

11 questions · 32 marks

NAVY EDITION

SECTION A · Warm-up

A1 Stefan: $P = \sigma A T^4$, with A the surface area and T the surface temperature in kelvin. Wien: $\lambda_{max} T = 2.9 \times 10^{-3}$ m K, the constant carrying the product unit metre kelvin. [2]

A2 O B A F G K M, hottest to coolest. The Sun, at about 5800 K, is a class G star. [2]

A3 The star radiates as a black body, and the light travels to the telescope without absorption on the way (by dust or atmosphere). Real work corrects for both. [2]

SECTION B · Standard

B1 $\lambda_{max} = 2.9 \times 10^{-3}/10\,000 = 2.9 \times 10^{-7}$ m: in the ultraviolet, so the star looks blue-white. [3]

B2 $T = 2.9 \times 10^{-3}/9.7 \times 10^{-7} = 2990$ K, just below 3500 K: a red class M star. [3]

B3 $A = 4\pi r^2 = 4\pi \times (1.39 \times 10^9)^2 = 2.4 \times 10^{19}$ m^2. $P = \sigma A T^4 = 5.67 \times 10^{-8} \times 2.4 \times 10^{19} \times 9000^4 = 9.1 \times 10^{27}$ W. [4]

B4 Balmer absorption needs hydrogen atoms already excited to the n = 2 level. In cool stars almost all atoms sit in the ground state, so the lines are weak; in the hottest stars the hydrogen is ionised, so no bound electrons remain to absorb. Class A, 7500 to 11 000 K, is the productive middle. [3]

B5 $P \propto T^4$ at fixed area, so the power rises by $3^4 = 81$: nearly two orders of magnitude from one tripling. [3]

SECTION C · Stretch

C1 $A = P/\sigma T^4 = 3.9 \times 10^{28}/(5.67 \times 10^{-8} \times 3480^4) = 4.7 \times 10^{21}$ m^2. $r = \sqrt{(A/4\pi)} = 1.9 \times 10^{10}$ m ≈ 28 solar radii: cool, yet vastly luminous, because it is enormous. [5]

C2 X, below 3500 K, peaks toward the infrared and looks red; Y, between 7500 and 11 000 K, peaks toward the ultraviolet and looks blue-white. With equal areas, $P \propto T^4$, so Y out-radiates X by a factor of hundreds. [3]

C3 Measure the wavelength at which the star's black-body spectrum peaks; Wien's law $\lambda_{max} T = 2.9 \times 10^{-3}$ m K then gives the surface temperature directly. [2]