Physics - Key Stage 4

Space

Cosmic Microwave Background Radiation (CMBR)
Students’ downloadable resources

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Question slides from video

Wave calculations using standard form - EXAMPLE

A microwave oven uses electromagnetic waves of frequency 2450 MHz.

(a) Write this value in Hz in standard form to 3 sf.

(b) Calculate to 3 sf the wavelength of the microwaves in this oven.

Speed of light = 3.0×10^8 m/s

Independent task 1

Speed of light for all of these questions = 3.0 x 10^8 m/s - all answers to 2sf

(1) Calculate the **frequency** of the following electromagnetic waves, given their **wavelengths**:

(a) Microwaves: 9.5cm (b) Green visible: 540nm (c) x-ray: 2.5 x 10^{-10}m

(2) Calculate the **wavelength** of the following electromagnetic waves, given their **frequencies**:

(a) Radio: 98.2kHz (b) ultraviolet 1.25 x 10^{15}Hz (c) gamma: 3.4 x 10^{20}Hz

Independent task 2

Answer these questions.

(1) What is meant by the term ‘Big Bang’ when explaining the origin of the universe?

(2) What type of instrument detected the CMBR in the 1960s?

(3) Why could light (electromagnetic radiation) not travel through the early universe?

(4) Why does the light from the early universe now have a very long wavelength compared to when it was emitted?

(5) The age of the universe is around 13.8 billion years. The CMBR was first emitted 380,000 years ago. Calculate this length of time as percentage of the age of the universe to 2sf.

EXAM STYLE QUESTIONS (1)

(1) Astronomers have accepted that the universe is expanding.

(a) Describe the evidence that has been collected to support this. (2 marks)

The cosmic microwave background (CMBR) is radiation that can be found in every direction in space. The wavelength of this radiation is 3.5mm.

(b) Name a device that can detect microwaves. (1 mark)

(c) Calculate the frequency of the CMBR. (2 marks) (Speed of light = 3.0×10^8 m/s)

(d) Explain how the CMBR supports a 'Big Bang' origin of the universe. (2 marks)

EXAM STYLE QUESTIONS (2)

2. Dark matter and dark energy are not fully understood by science. They have been suggested to try to fit the observations.

(a) Explain which observation led scientists to suggest that dark matter and dark energy existed.(1 mark)

(b) Explain how peer review can assist science's quest for the correct theories to describe reality. (2 marks)

The CMBR matches the black body spectrum of an object at -270^{o}C.

(c) What is a black body?(2 marks)

Answers

Wave calculations using standard form - EXAMPLE

A microwave oven uses electromagnetic waves of frequency 2450 MHz.

(a) Write this value in Hz in standard form to 3 sf. **2.45×10^9 Hz**

(b) Calculate (to 3 sf) the wavelength of the microwaves in this oven. Speed of light = 3.0×10^8m/s

$v=f\lambda$ $3.0 \times 10^8 = 2.45 \times 10^9 \times \lambda$

$\lambda = 3.0 \times 10^8 \div 2.45 \times 10^9 = 0.12245 =$ <u>0.122m</u>

Independent task 1 SOLUTIONS 1

Speed of light for all of these questions = 3.0 x 10^8 m/s - all answers to 2sf

(1)

(a) Microwaves: 9.5cm

$v = f \lambda$ $3.0 \times 10^8 = f \times 0.095$ $f = 3.0 \times 10^8 \div 0.095 = 3.2 \times 10^9$Hz

(b) Green visible: 540nm

$v = f \lambda$ $3.0 \times 10^8 = f \times 540 \times 10^{-9}$ $f = 3.0 \times 10^8 \div 540 \times 10^{-9} = 5.6 \times 10^{14}$Hz

(c) x-ray: 2.5 x 10^{-10}m

$v = f \lambda$ $3.0 \times 10^8 = f \times 2.5 \times 10^{-10}$ $f = 3.0 \times 10^8 \div 2.5 \times 10^{-10} = 1.2 \times 10^{18}$Hz

Independent task 1 SOLUTIONS 2

Speed of light for all of these questions = 3.0 x 10^8 m/s - all answers to 2sf

(2) Calculate the **wavelength** of the following electromagnetic waves, given their **frequencies**:

(a) Radio: 98.2kHz

$v = f \lambda$ $3.0 \times 10^8 = 98.2 \times 10^3 \times \lambda$ $\lambda = 3.0 \times 10^8 \div 98.2 \times 10^3 = 3.1 \times 10^3$m

(b) ultraviolet 1.25 x 10^{15}Hz

$v = f \lambda$ $3.0 \times 10^8 = 1.25 \times 10^{15} \times \lambda$ $\lambda = 3.0 \times 10^8 \div 1.25 \times 10^{15} = 2.4 \times 10^{-7}$m

(c) gamma: 3.4 x 10^{20}Hz

$v = f \lambda$ $3.0 \times 10^8 = 3.4 \times 10^{20} \times \lambda$ $\lambda = 3.0 \times 10^8 \div 3.4 \times 10^{20} = 8.8 \times 10^{-13}$m

Independent task 2 - SOLUTIONS

(1) What is meant by the term ‘Big Bang’ when explaining the origin of the universe? **Universe started as small, hot and dense and has been expanding since**

(2) What type of instrument detected the CMBR in the 1960s? **antenna/aerial**

(3) Why could light (electromagnetic radiation) not travel through the early universe? **The universe was opaque/light interacted with electrons/particles**

(4) Why does the light from the early universe now have a very long wavelength compared to when it was emitted? **It has been red shifted**

(5) The age of the universe is around 13.8 billion years. The CMBR was first emitted 380,000 years ago. Calculate this length of time as percentage of the age of the universe to 2sf. **$380\,000 \div 13.8 \times 10^9 \times 100\% = 0.0028\%$ (or $2.8 \times 10^{-3}\%$)**

EXAM STYLE QUESTIONS (1a) - SOLUTIONS

(1) Astronomers have accepted that the universe is expanding.

(a) Describe the evidence that has been collected to support this.

Red shift data for distant galaxies (1) shows that recessional velocity ∝ distance (1) OR furthest galaxies are travelling the fastest

The cosmic microwave background (CMBR) is radiation that can be found in every direction in space. The wavelength of this radiation is 3.5mm.

(b) Name a device that can detect microwaves. **aerial/antenna (1)**

EXAM STYLE QUESTIONS (1b) - SOLUTIONS

(c) Calculate the frequency of the CMBR. (Speed of light = 3.0 x 10^8m/s)

$v = f \lambda$ $3.0 \times 10^8 = f \times 0.0035$ (1) $f = 3.0 \times 10^8 \div 0.0035 = 8.6 \times 10^{10}$ Hz (1)

(d) Explain how the CMBR supports a 'Big Bang' origin of the universe.

Any two from: The temperature/wavelength/frequency of the radiation matches that of a black body (1) (around -270°C), due to the expansion of the universe (1) the wavelengths of light from the early universe (1) have been red shifted (1) (to microwave wavelengths)

EXAM STYLE QUESTIONS (2) - SOLUTIONS

2. Dark matter and dark energy are not fully understood by science. They have been suggested to try to fit the observations.

(a) Explain which observation led scientists to suggest that dark matter and dark energy existed. **Universe expansion rate is increasing (1)**

(b) Explain how peer review can assist science's quest for the correct theories to describe reality. **Work/data/etc. is checked for errors (1) to remove bias (1)**

The CMBR matches the black body spectrum of an object at -270^{o}C.

(c) What is a black body? **Absorbs all radiation (incident upon it)/ perfect absorber (1) perfect emitter (1)**