Questions

Module 7: The Nature of Light

7.1 Electromagnetic Spectrum

Multiple-choice questions: 1 mark each

1. How do light waves differ from mechanical waves?

(A) Light waves cause particles in solids to vibrate and mechanical waves do not.

(B) Mechanical waves only occur on Earth, whereas light waves occur throughout the universe.

(C) Light waves can pass through space from the Sun to Earth, whereas mechanical waves cannot.

(D) Light waves can travel through fluids and solids, whereas mechanical waves can only travel through fluids.

2. What is meant by the term 'electromagnetic spectrum'?

(A) The visible spectrum from low frequency waves (red) to high frequency waves (violet).

(B) The entire range of electromagnetic radiation with frequencies from gamma rays to radio waves.

(C) The range of high frequency waves that are produced by accelerating charges.

(D) A range of waves including visible light, UV light and infra-red radiation only.

3. What are electromagnetic waves?

(A) Transverse waves made up of oscillating electric and magnetic fields that are at 45° to each other.

(B) Longitudinal waves in which the oscillating electric and magnetic fields are parallel to each other.

(C) Longitudinal waves in which the oscillating electric and magnetic fields are perpendicular to each other.

(D) Transverse waves made up of oscillating electric and magnetic fields that are perpendicular to each other.

4. Many observations of electric and magnetic fields were made prior to the work of James Maxwell. Which of these statements correctly summarise the work of Maxwell?

(A) His mathematical equations provided the link between electric and magnetic fields.

(B) He showed the link between light waves and sound waves.

(C) He demonstrated that all waves carry energy from one place to another.

(D) His mathematical equations showed that sound waves will induce a magnetic field.

5. Which of these predictions came about as a result of Maxwell's work?

(A) Electromagnetic waves lose energy as they travel.

(B) Electromagnetic waves can propagate through space at the speed of light.

(C) Electricity travels in the form of magnetic waves at the speed of light.

(D) A luminiferous aether was the medium through which electromagnetic waves travelled.

6. What principle is used in spectroscopy to split light into its component colours?

(A) Dispersion

(B) Refraction

(C) Polarisation

(D) Reflection

7. Which entry in the table correctly describes the relative wavelengths of the electromagnetic waves given?

	Shortest wavelength	*Longest wavelength*
(A)	Red visible light	Blue visible light
(B)	Infra-red light	Ultraviolet waves
(C)	Ultraviolet waves	Radio waves
(D)	Radio waves	X-rays

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Short-answer questions

8. **Describe TWO things that led Maxwell to suggest that light was a form of electromagnetic radiation.**

1995 HSC Q32B(d)(i) ... 2 marks

9. **What are TWO features of Maxwell's theory of light?**

1997 HSC Q32B(d)(i) ... 2 marks

10. **Describe how the spectrum of a star can be used to determine its temperature, chemical composition and aspects of its motion.**

2004 HSC Q30(c) ... 7 marks

11. Outline the role of spectroscopy in the discovery of elements, such as helium.

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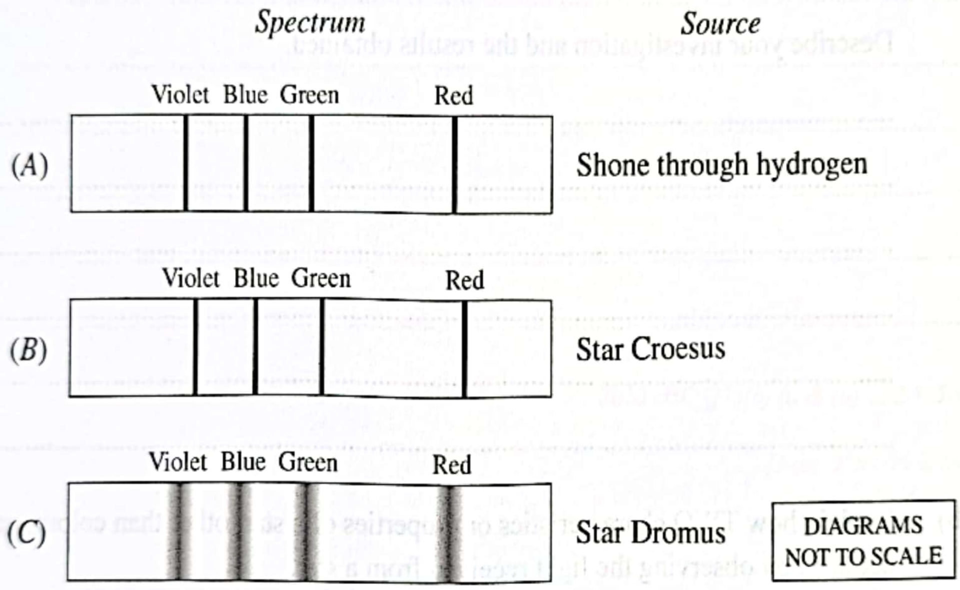
... 2 marks

12. Part *A* of the figure below shows the absorption spectrum of light, produced by an incandescent filament, after it has been shone through a quantity of hydrogen gas.

Also shown in the figure are the spectra obtained from two stars, Star Croesus in part *B* and Star Dromus in part *C*. The dark lines are absorption bands in *A*, *B* and *C*.



(a) For each star, Croesus and Dromus, identify how its spectral lines differ from the spectrum shown above in diagram (*A*).

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(b) For each star, Croesus and Dromus, state what its spectrum tells us about the motion of that star.

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Adapted from 2005 HSC Q30(a) ... 2 + 3 = 5 marks

13. Explain how the spectrum of a star is produced, and how it can be used to determine the star's composition.

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Adapted from 2006 HSC Q30(b)(ii) ... 4 marks

14. (a) In your study of this topic, you will have examined a variety of spectra produced by different sources.

Describe your investigation and the results obtained.

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(b) Explain how TWO characteristics or properties of a star, other than colour, can be deduced by observing the light received from a star.

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Adapted from 2007 HSC Q30(b) ... 2 + 4 marks

15. Properties of stars, including their surface temperature and chemical composition, can be measured by using their spectra.

(a) Identify other properties of stars that can be determined from their spectra.

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(b) Explain how surface temperatures and chemical compositions of stars can be determined from their spectra.

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2010 HSC Q35(b) (i) & (ii) ... 2 + 5 = 7 marks

[Note: Part (b) is the same as 2016 HSC Q33(c)]

16. Describe how the Doppler effect helps scientists to determine the characteristics of stars.

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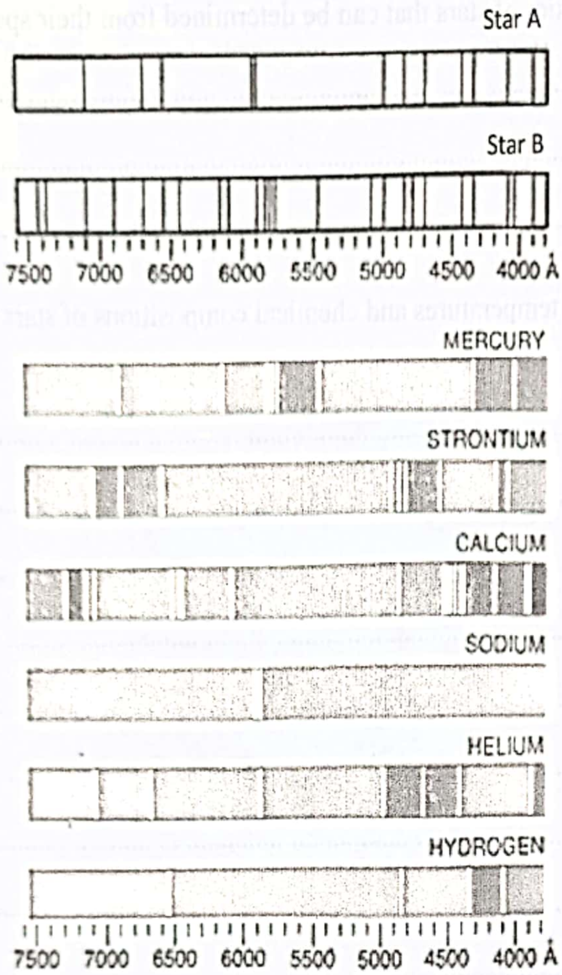
... 4 marks

17. The diagram below shows the spectra of two stars, A and B. Beneath the spectra of the stars are the spectra of some common elements.



[Credit: NASA 2004]

(a) What wavelengths are found in the hydrogen spectrum?

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(b) (i) Does hydrogen occur in Star A? ....

(ii) Does hydrogen occur in Star B? ....

(c) Which elements occur in the atmosphere of Star A?

....

(d) Which elements occur in the atmosphere of Star B?

....

(a) Which elements do not occur in the atmosphere of either Star A or Star B?

....

... *6 marks*

Answers

Module 7: The Nature of Light

7.1 Electromagnetic Spectrum

Multiple choice: 1 mark each

1. C **2.** B **3.** D **4.** A **5.** B **6.** A **7.** C

Explanations:

1. C Light waves are electromagnetic waves within a narrow frequency range. They propagate as oscillating electric and magnetic fields – each generating the other as they propagate. They can travel through space and do not require a material medium like mechanical waves. So (C) is the answer. Light waves do not cause particles to vibrate, so (A) is incorrect. Mechanical waves can occur anywhere there is a medium to vibrate, e.g. moonquakes involve mechanical waves. So (B) is incorrect. Both light and mechanical waves can travel through all states of matter. So (D) is incorrect.

2. B The electromagnetic spectrum covers all electromagnetic waves, ranging in frequency from long wavelength, low frequency radio waves to extremely energetic, very short wavelength, high frequency gamma waves. So (B) is the answer. Visible light, UV light and infrared waves only comprise small parts of the electromagnetic spectrum, so (A) and (D) are incorrect. Accelerating charges can produce electromagnetic waves, but are not the only source. So (C) is incorrect.

3. D Electromagnetic waves are transverse waves, as in (A) and (D). They are not longitudinal waves, so (B) and (C) are incorrect. The angle between the electric and the magnetic field vectors is 90°, not 45°. So (D) is the answer, and (A) is incorrect.

4. A Maxwell's theoretical equations provided the link between electric and magnetic fields, so (A) is the answer. He did not investigate mechanical waves such as sound waves. So (B) and (D) are incorrect. He only demonstrated that 'electromagnetic waves' carry energy from place to place. So (C) is incorrect.

5. B Maxwell's theoretical mathematical equations gave rise to a speed of propagation for electromagnetic waves, $c = 3.00 \times 10^8$ m s^{-1}. Accurate experimental measurements of c gave the same value for the speed of light. This suggested that light was a type of electromagnetic wave. So (B) is the answer. He did not show that electromagnetic waves lose energy, nor that electricity travels at the speed of light, nor the need for the aether to exist. So (A), (C) and (D) are all incorrect.

6. **A** The principle involved in spectroscopy is *dispersion*. Spectroscopes are used to examine light spectra and use any process that disperses light according to its wavelengths, e.g. a prism or diffraction grating. So (A) is the answer. The other choices are various properties of light and are not used to separate light into its constituent colours ... so (B), (C) and (D) are all incorrect.

7. **C** In increasing length of wavelength, the electromagnetic spectrum consists of gamma rays, X-rays, ultraviolet, visible light, infra-red, microwaves, radiowaves. So (C) is the only correct answer.

Short-answer questions

8. Fizeau experimentally determined that the speed of light on Earth was 3.1×10^8 m s^{-1}. Maxwell's calculations indicated that his theoretical electromagnetic waves would conserve energy at only one velocity, i.e. 3.1×10^8 m s^{-1}. This matched Fizeau's experimental value, and so Maxwell realised that light must be a form of electromagnetic radiation.

9. 1. Electromagnetic waves exist with many different frequencies.
   2. Electromagnetic waves can propagate through space at the speed of light.

10. The *surface temperature* of a star is indicated by the frequency (and wavelength) at which the peak intensity occurs in the spectrum of the light from a star. The pattern of this can then be compared against reference stellar spectra.

    The *chemical composition* of a star is indicated by the spectral lines in its spectrum, as each element present produces a unique series of lines in the spectrum. These lines are matched with those produced by various elements under laboratory conditions. Measurement of the intensities of the spectral lines allows the relative abundance of the elements present to be determined.

    The *rotational velocity* of a star is determined by the width of the absorption lines in its spectrum. The broader the line, the greater is the rotational speed.

    The *translational velocity* of a star relative to Earth is determined using the red or blue-shift of the star's spectral lines, amongst other means.

    The *density* of a star is calculated from its mass and volume, which are determined using the surface temperature of the star.

11. A spectroscope can be used to observe the spectral lines in the spectra of stars. Each element present in a star produces a unique series of lines in the star's spectrum. This enables the elements present in a star to be revealed using spectroscopy. New spectral lines that are discovered can indicate an undiscovered element, as when helium was discovered in the solar spectrum.

12. (a) STAR CROESUS – the spectral lines have been red-shifted.

STAR DROMUS – the spectral lines have become broader and blue-shifted.

(b) STAR CROESUS – red-shifted spectral lines indicate the star is moving away, while the thin lines show that it is not rotating.

STAR DROMUS – broader spectral lines indicate the star is rotating on its own axis causing both red- and blue-shifting, while the star is also travelling towards the observer as it is blue-shifted.

[Remember: In the Doppler effect, red-shifted (= moving away), while blue-shifted (moving towards).]

13. The hot inner part of a star emits light of all frequencies out towards the exterior layers of gases around the star. The visible light that is emitted from the star forms its spectrum. Each element present in a star produces a unique series of lines in the spectrum. This enables the elements present in a star to be determined. Measurement of the intensities of the spectral lines allows the relative abundance of the elements present to be determined.

14. (a) We used a spectroscope to examine the light from an incandescent bulb and found that it produced a continuous 'rainbow-like' spectrum. We also used a spectroscope to examine the light from a discharge tube (e.g. a sodium vapour lamp) and found that it produced an emission spectrum with two bright lines on a dark background.

(b) The *surface temperature* of a star is indicated by the frequency (and wavelength) at which the peak intensity occurs in the spectrum of the light from a star. The pattern of this can then be compared against reference stellar spectra.

The *chemical composition* of a star is indicated by the spectral lines in its spectrum, as each element present produces a unique series of lines in the spectrum. Measurement of the intensities of the spectral lines allows the relative abundance of the elements present to be determined.

[Note: Some other characteristics or properties of a star that you could have explained include: density, rotational motion, translational motion.]

15. (a)
- density
- rotational velocity (i.e. its speed of rotation on its axis)
- translational velocity (i.e. its speed of approach or recession)

(b) Stars emit light and so spectroscopes can be used to observe the spectral lines in their spectra. The *surface temperature* of a star is indicated by the frequency (and wavelength) at which the peak intensity occurs in the spectrum of the light from a star. The pattern of this can then be compared against reference stellar spectra. The *chemical composition* of a star is indicated by the lines in the star's spectrum, as each element produces characteristic spectral lines. The lines observed are matched with those produced by various elements under laboratory conditions. Measurement of the intensities of the spectral lines allows the relative abundance of the elements present to be determined.

16. The Doppler effect is used to determine if a star is moving toward or away from Earth. A star's spectral lines are shifted towards the blue end of the spectrum if the star is moving towards us and towards the red end if the star is moving away. The greater the shift, the faster the star is moving.

The Doppler effect is also used to measure the speed of a star's rotation on its axis. Light emitted from the side rotating towards an observer is blue-shifted, while it is red-shifted from the side rotating away (unless its axis of rotation happens to be pointed exactly toward us). This results in a broadening of the bands in a star's spectrum. The degree of broadening indicates the rate of rotation.

17. (a) 4100 Å, 4350 Å, 4850 Å, 6550 Å

(b) (i) Yes

(ii) Yes

(c) Helium, hydrogen and sodium

(d) Helium, hydrogen and mercury

(e) Calcium and strontium