Question 1

What is the Doppler effect?

(apparent) change in frequency 3

due to (relative) motion between source and observer 3

Explain, with the aid of labelled diagrams, how this phenomenon occurs.

Diagram:

labelled moving source of waves **(–1 if no label)** 3

shorter wavelength approaching observer 3

longer wavelength receding 3

correct reference to frequency change 3

(–1 if waves not clearly indicated/implied) 18

Describe a laboratory experiment to demonstrate the Doppler effect.

source of sound (e.g buzzer) 3

swing source attached to string 3

note frequency change instant source passes observer 3

(source may also be propelled longitudinally along a string, etc.) 9

What causes the red shift in the spectrum of a distant star?

stars move relative to earth 3

(longer λ if) star receding (from earth) 3

6

The yellow line emitted by a helium discharge tube in the laboratory has a wavelength of 587 nm as shown in the diagram. The same yellow line in the helium spectrum of a star has a measured wavelength of 590 nm.

What can you deduce about the motion of the star?

star is receding/moving away from earth 3

Calculate the speed of the moving star.

$\lambda' = \lambda\left(\frac{c+u}{c}\right)$ // $f' = f\left(\frac{c}{c+u}\right)$ 6

$u = c\left(\frac{\lambda'}{\lambda} - 1\right)$ // $u = c\left(\frac{f}{f'} - 1\right)$ 3

substitution [$f = 5.11073\times10^{14}$ and $f' = 5.08475\times10^{14}$] 3

$u = 1.5333\times10^{6}\ \text{m s}^{-1}$ 3

(–1 for omission of or incorrect units) 18

Give another application of the Doppler effect.

radar, medical imaging, blood flow measurement (echocardiogram), temperature measurement, (underwater) acoustics, etc. 5

Question 2

(*a*) Give two properties of radio waves.

travel at speed of light; electromagnetic radiation; travel through vacuum;
(can be) reflected; refracted; polarized; etc. — any two: 4+3

(*b*) In a three-minute phone call, 10 g of head tissue absorbs 0.36 J of radio frequency energy. Calculate the SAR value.

$$(\text{Power}=)\ \frac{0.36}{3\times60}\left(\text{J s}^{-1}\right)\ /\ =0.002\ (\text{W}) \qquad 4$$

$$\text{SAR}\left(\Rightarrow\frac{\text{W}}{\text{kg}}\right)=\frac{0.36}{(3\times60)\left(10\times10^{-3}\right)}\ /\ 0.20\left(\text{W kg}^{-1}\right) \qquad 3$$

(*c*) What happens to the radio frequency energy absorbed by the body?

converted into heat — 4
carried away by the body — 3

(*d*) Why are radio frequency waves not very penetrating?

low frequency / long wavelength / low energy — 7

(*e*) A mobile phone converts the received radio frequency waves to sound waves. What are the audible frequency limits for sound waves?

(lower value ≈) 20 Hz — 4
(upper value ≈) 20 000 Hz **(–1 for omission of or incorrect units)** — 3

(*f*) Give two safety precautions you should take when using a mobile phone.

keep phone at distance / use loudspeaker function / 'no hands etc.:
brief calls only: direct antenna away from your head: etc. — any two: 4+3

(*g*) A mobile phone transmits at 1200 MHz from its antenna. Calculate the length of its antenna, which is one quarter of the wavelength that it transmits.

$$\lambda\ =\frac{c}{f}\ /\ \frac{3\times10^{8}}{1.2\times10^{9}}\ /\ 0.25(\text{m}) \qquad 4$$

$$\text{length of antenna}=0.0625\approx0.06\ \text{m}\ \textbf{(–1 for omission of or incorrect units)} \qquad 3$$

(*h*) Name an electromagnetic wave which may induce cancer. Justify your answer.

γ rays / X-rays / UV — any one: 4
ionization of (body) cells — 3

(*b*) The pitch of a musical note depends on its frequency. On what does (i) the quality, (ii) the loudness, of a musical note depend?

(i) (number or relative strengths of) <u>overtones</u> /<u>harmonics</u> // wave form 3

(ii) amplitude / frequency/ λ / intensity / rate at which (acoustic) energy enters ear 3

What is the Doppler effect?

(apparent) change in frequency 3

due to *relative motion* (stated or implied) between source and observer 3

A rally car travelling at 55 m s^{-1} approaches a stationary observer. As the car passes, its engine is emitting a note with a pitch of 1520 Hz. What is the change in pitch observed as the car moves away?

$f' = \frac{f v_a}{v_a \pm v}$ (accept + or − format) 3

$f' = \frac{1520(340)}{340+55}$ || $f'_{in} = \frac{340 \times 1520}{340-55} = 1813.33\ \text{Hz}$ 3

$f' = 1308.35$ || $f'_{out} = 1308.35\ \text{Hz}$ 3

$\Delta f = 211.65\ \text{Hz}$ || $\Delta f = 504.98 \approx 505\ \text{Hz}$ 3

(-1 for omission of or incorrect units)

Give an application of the Doppler effect.

calculate speeds of stars or galaxies / reference to red (or blue) shift / radar / speed traps / etc. 4

Question 7

What is the Doppler effect?

apparent change in frequency / wavelength 3

due to relative motion between source and observer (state/imply: e.g. either S or O moving) 3

Explain, with the aid of labelled diagrams, how this phenomenon occurs.

non-concentric circles (-1 if not labelled as *waves*) 3

source and direction of motion (stated/implied) 3

position of observer indicated 3

shorter wavelength / higher frequency on approaching observer (or vice versa) 3

The emission line spectrum of a star was analysed using the Doppler effect. Describe how an emission line spectrum is produced.

(monatomic) gas (or atoms) 3

is heated / is excited /receives energy 3

electron(s) move/jump to higher level/state 3

electromagnetic radiation/energy/photon/quantum emitted on return 3

appropriate diagram may merit full marks (4 x 3)

Alternatively:

(monatomic) gas discharge tube / example, e.g. *Na* lamp (2 x 3)

spectrometer + prism/grating // a direct vision spectroscope // (diffraction) grating (3)

observation (e.g. a number of bright lines are seen) (3)

The red line emitted by a hydrogen discharge tube in the laboratory has a wavelength of 656 nm. The same red line in the hydrogen spectrum of a moving star has a wavelength of 720 nm.

Is the star approaching the earth? Justify your answer.

no 3

wavelength has increased // frequency has decreased 5

Calculate:

(i) the frequency of the red line in the star's spectrum

$f' = \frac{c}{\lambda'}$ or $c = f\lambda$ 3

$f' = \frac{3 \times 10^{8}}{720 \times 10^{-9}}$ or $f' = 4.17 \times 10^{14}$ Hz **(-1 for omission of or incorrect units)** 3

(no penalty here for use of 656 nm rather than 720 nm.

Accept answer: 4.57 x 10^{14} Hz)

(ii) the speed of the moving star.

(Similarly) $f = 4.57 \times 10^{14}$ Hz

formula: $f' = \frac{fc}{c + u}$ 3

substitution: $4.17 \times 10^{14} = \frac{(4.57 \times 10^{14})(3.00 \times 10^{8})}{3.00 \times 10^{8} + u}$ **(-3 for incorrect substitution)** 2 x 3

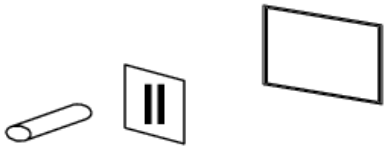
answer: $u = 2.92 \times 10^{7}$ m s^{-1} **(-1 for omission of or incorrect units)** 3

(speed of light = 3.00×10^{8} m s^{-1})

Question 5

Question 7
A student used a laser, as shown, to demonstrate that light is a wave motion.

(i) Name the two phenomena that occur when light passes through the pair of narrow slits. (6)



diffraction 3
interference 3

(ii) A pattern is formed on the screen. Explain how the pattern is formed. (12)

slits act as coherent sources 3

waves overlap / meet / path difference between waves (or shown on diagram) 3

constructive interference gives brightness / bright lines / bright fringes 3

destructive interference gives darkness / dark lines / dark fringes 3

(iii) What is the effect on the pattern when

(a) the wavelength of the light is increased. (4)

distance between fringes / lines / spots increases // pattern more spread out 4

(b) the distance between the slits is increased. (4)

distance between fringes / lines / spots decreases // pattern less spread out 4

Describe an experiment to demonstrate that sound is also a wave motion. (12)

two loudspeakers connected to signal generator // rotate vibrating (tuning) fork 3

walk in front of and parallel to speakers // near ear 3

observation: (e.g. sound loud and low / waxes and wanes) 3

conclusion: interference occurs showing that sound is a wave motion 3

Sound travels as longitudinal waves while light travels as transverse waves. Explain the difference between longitudinal and transverse waves. (9)

longitudinal waves: the direction of the vibrations (of medium) 3

is parallel to the direction of (propagation) of the wave 3

transverse wave: the direction (of the vibrations) is perpendicular to the (direction of the) wave 3

Describe an experiment to demonstrate that light waves are transverse waves. (9)

light source and two pieces of polaroid 3

rotate one polaroid relative to the other and light (intensity)decreases (to zero) 3

polarization indicates transverse waves 3

Question 6

(d) **A sound wave is diffracted as it passes through a doorway but a light wave is not. Explain why.** (7)

wavelength of light (much) less than wavelength of sound 7

Question 7

(d) **How is infra-red radiation detected?**

thermometer / temperature sensor(or probe) / photographic film(or plate) / (by its) heating effect, etc. (any one) 7