Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2024

Centre Number

Candidate Number

Physics

Assessment Unit AS 2
assessing
Module 2: Waves, Photons and Astronomy

[SPH21]

SPH21

WEDNESDAY 22 MAY, AFTERNOON

TIME

1 hour 45 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
You must answer the questions in the spaces provided.
Do not write outside the boxed area on each page or on blank pages.
Complete questions in black ink and use a dark HB pencil for drawings and graphs.
Do not write with a gel pen.
Answer **all nine** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 100.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
You may use a scientific calculator.
A Data and Formulae Sheet is included in this question paper.

14133

1 **(a)** The first column of **Table 1.1** shows four properties of waves.

Place a tick (✓) in each row to indicate if the property applies to sound waves, electromagnetic waves, or both.

Table 1.1

Property	Sound waves	Electromagnetic waves	Both
Transfer energy			
Can be refracted			
Can be polarised			
Require a medium to travel through			

[4]

(b) A wave of frequency 6.0 Hz travels at a speed of 2.5 km s^{-1}.

(i) Calculate the wavelength of the wave.

Wavelength = ________________ m [4]

(ii) Calculate the phase difference between two points on the wave that are 50 m apart. State the unit of phase difference.

Phase difference = ____________________

Unit = ____________________ [3]

2 Water waves created in a ripple tank can be used to demonstrate some of the properties of waves.

Fig. 2.1 shows a ripple tank set up to create waves.

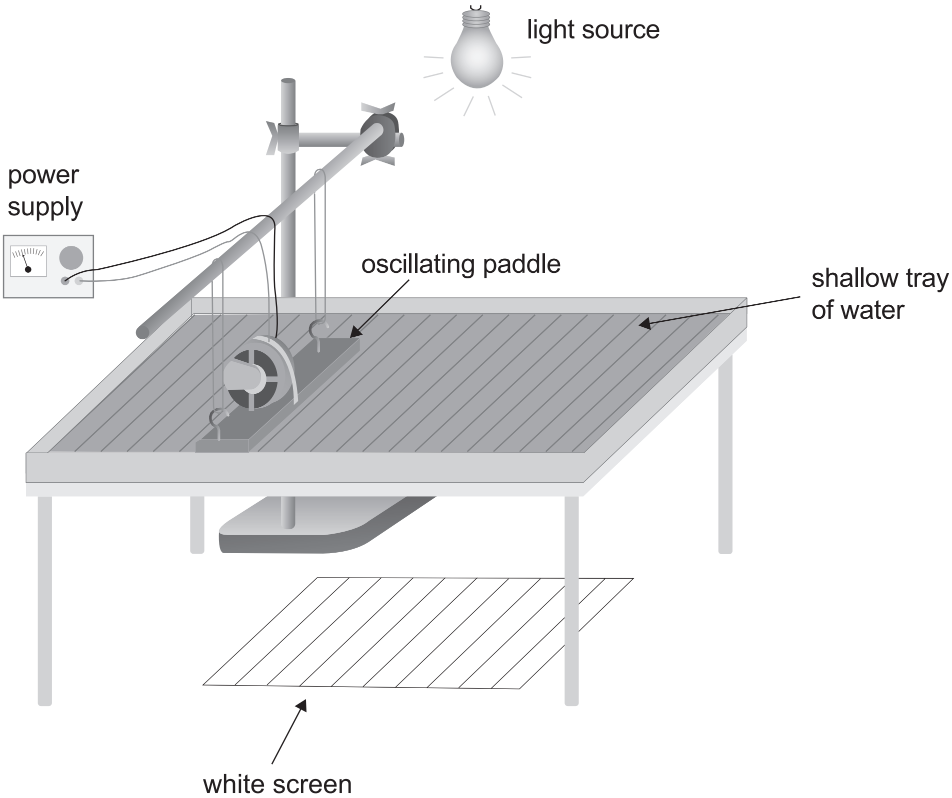

Fig. 2.1

The ripple tank consists of a shallow tray of water with a transparent base, a light source directly above the tray and a white screen beneath the tray. The oscillating paddle creates waves that move across the tray and the shadows formed by the waves show up on the white screen as shown in **Fig. 2.1**.

(a) **Fig. 2.2** shows the wavefronts in a ripple tank approaching a gap in a barrier to demonstrate diffraction.

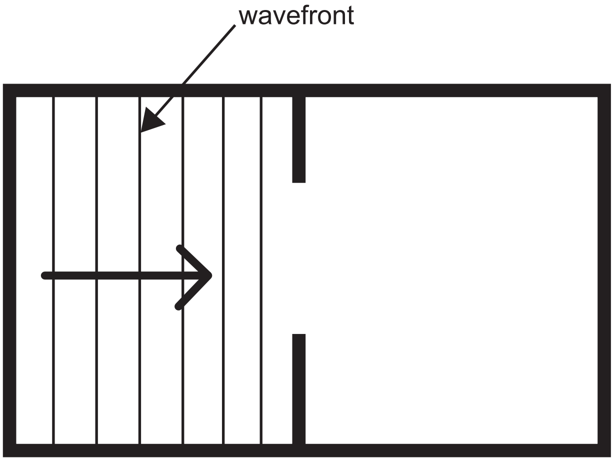

Fig. 2.2

(i) Draw **four** wavefronts on **Fig. 2.2** to show what happens to the water waves when they pass through the gap in the barrier. [3]

(ii) The gap is now adjusted so that it is one third of its previous width. State what will happen to the amount of diffraction and explain your answer.

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____ [2]

(b) In another demonstration, the wavefronts appear as shown in **Fig. 2.3**.

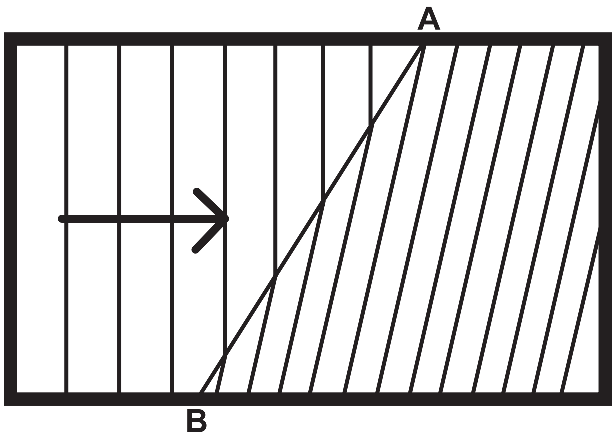

Fig. 2.3

(i) Describe what happens to the wavelength, speed and direction of the waves after passing into the region beyond the line AB.

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____ [3]

(ii) What property of waves is this demonstrating?

______________________ [1]

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(Questions continue overleaf)

3 (a) The Nobel Prize in Physics 1921 was awarded to Albert Einstein "for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect."

(i) Explain what is meant by the photoelectric effect.

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____ [3]

(ii) Describe the observations that led Einstein to use the photon model to explain the photoelectric effect.

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____ [3]

(b) (i) Calculate the energy, in eV, of a photon of electromagnetic radiation of frequency 2.97×10^{14} Hz.

Energy = ____________________ eV [4]

(ii) This radiation is shone on a metal with a threshold frequency of 2.42×10^{14} Hz. Calculate the maximum velocity of an emitted electron.

Velocity = ____________________ $m\ s^{-1}$ [3]

(iii) Why are other electrons released with a range of velocities lower than this?

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____ [1]

[Turn over

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4 (a) Describe the difference between cosmological red shift and Doppler red shift.

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____ [2]

(b) The red line emitted by a hydrogen discharge tube in the laboratory has a wavelength of 656.3 nm. The same line in the hydrogen spectrum of a moving star has a wavelength of 716.5 nm.

(i) Explain how it can be concluded that the star is moving away from Earth.

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____ [2]

(ii) Calculate the speed at which the star is moving away from Earth.

Speed = ____________________ $m\ s^{-1}$ [4]

[Turn over

5 **(a)** In an experiment to measure the critical angle of glass, a ray of light is directed towards the centre of the flat surface of a semicircular glass block as shown in **Fig. 5.1**.

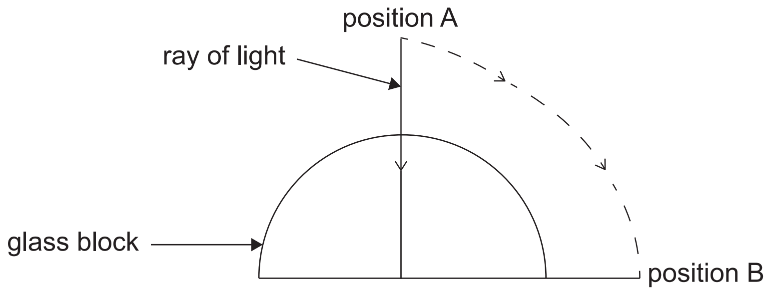

Fig. 5.1

(i) Describe what will happen to the ray of light at the flat surface of the glass block when the ray of light is at position A and as it is moved from position A to a point just before position B.

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____ [5]

(ii) The critical angle is found to be 44°. Calculate the refractive index of the glass.

Refractive index = ____________________ [3]

(b) Optical fibres are used to transmit information over long distances. Each fibre consists of a core of glass A coated with a layer of glass B as shown in **Fig. 5.2**.

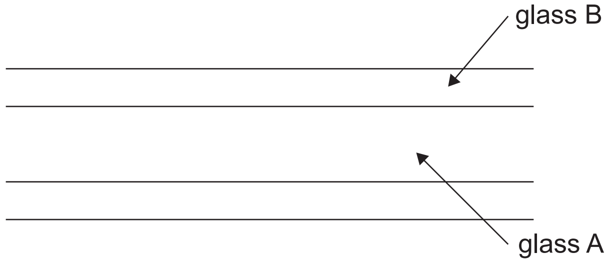

Fig. 5.2

Which glass, A or B, has a higher refractive index? Explain your answer.

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____

____ [3]

(c) Impurities in the glass used to make an optical fibre reduce the power transmitted by 20% every kilometre. The power of the light entering the fibre is 175 W. Calculate the power of the light when it has travelled 4 km through the fibre.

Power = ____________ W [3]

[Turn over

6 In an experiment to measure the wavelength of light from a laser, the light from the laser was directed along a normal onto a diffraction grating with 600 lines per mm.

A diffraction pattern consisting of bright spots was observed on a wall 2.50 m from the diffraction grating. The central bright spot and the first two spots on each side of it are shown in **Fig. 6.1**.

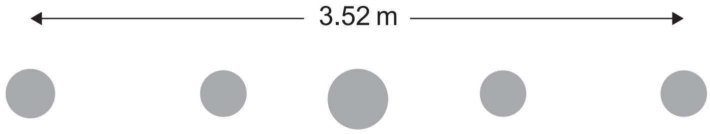

Fig. 6.1

(a) Calculate the wavelength of the light from the laser.

Wavelength = ___________________ m [5]

(b) What effect does each of the following changes have on the spacing of the bright spots formed if all other factors are kept the same?

(i) Using light of longer wavelength.

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____ [1]

(ii) Using a diffraction grating with fewer lines per mm.

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____ [1]

7 Noise-cancelling headphones have a microphone that picks up an incoming sound wave. A speaker then produces another sound wave which causes it and the incoming sound wave to destructively interfere and cancel each other out.

(a) **(i)** State the general conditions that are required for complete destructive interference.

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____ [3]

(ii) The noise cancellation is not perfect because there is a slight time delay between the incoming wave and the wave that is produced. In one set of headphones this delay is 1 ms.

Fig. 7.1 shows the incoming wave.

On **Fig. 7.1**, draw the wave produced by the speaker in the headphones. [2]

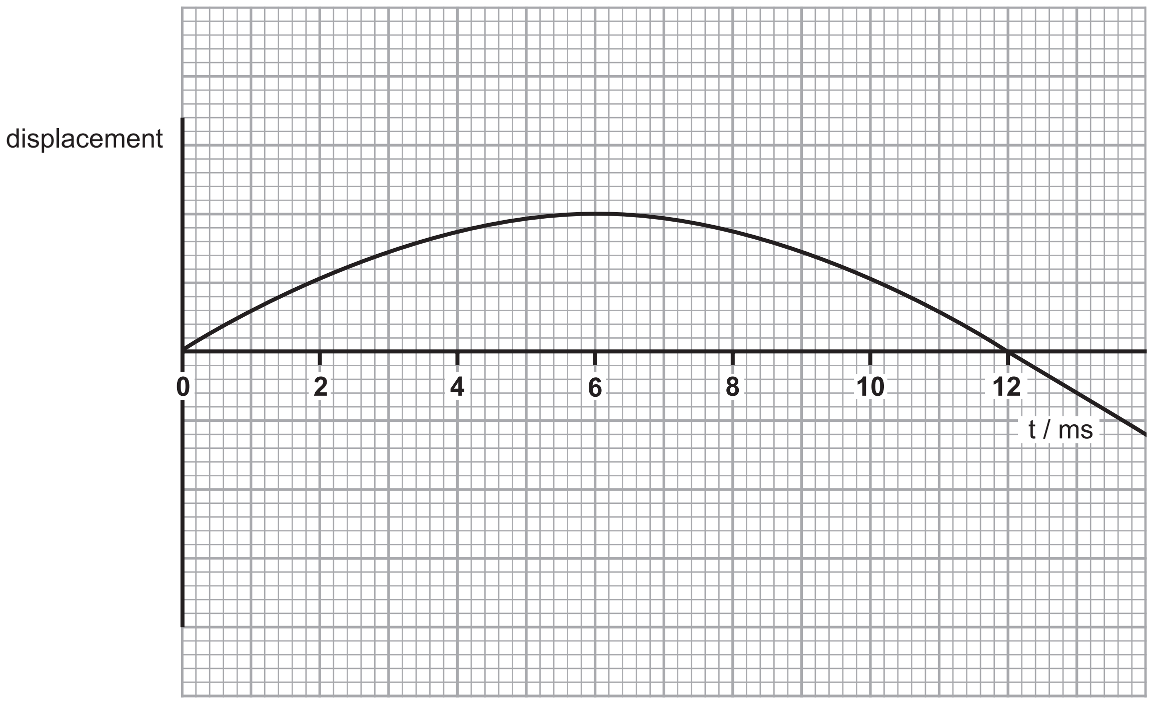

Fig. 7.1

(b) **Fig. 7.2** represents a standing wave in a pipe closed at one end. The length of the pipe is 60 cm.

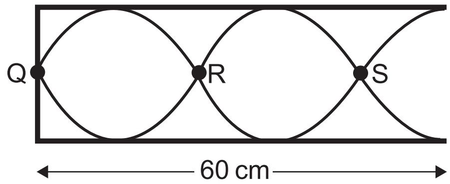

Fig. 7.2

(i) What name is given to the points on the wave labelled Q, R and S?

_____________________________ [1]

(ii) Calculate the wavelength of the standing wave.

Wavelength = ______________________ m [3]

(iii) Calculate the longest wavelength of a sound wave that can produce a standing wave in the pipe.

Wavelength = ______________________ m [2]

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8 (a) State two differences between the properties of white light and laser light.

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____ [2]

(b) Describe how laser light is produced, explaining any terms used in your answer.

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____ [6]

9 A small, upright object is placed in front of a screen and then a lens is placed between the object and the screen. The lens is moved until a focused image is formed on the screen.

The position of the object, screen and image is shown in **Fig. 9.1.**

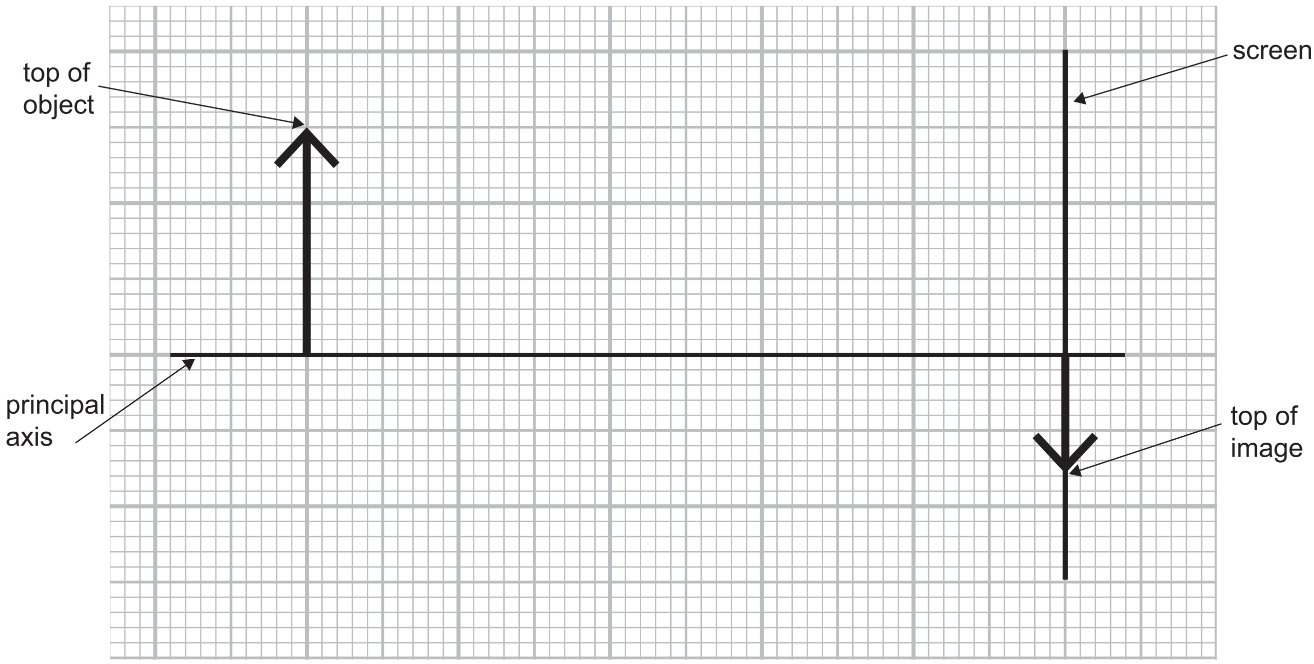

Fig. 9.1

(a) (i) Name the type of lens used to form the image.

_________________________ [1]

(ii) On **Fig. 9.1**, draw construction rays to find the position of the lens and the position of the principal focus.

Draw the lens in the correct position using the correct symbol and label the principal focus F. [5]

(b) **(i)** Use measurements from **Fig. 9.1** to calculate the magnification.

Magnification = ____________________ [4]

(ii) Explain why the ray diagram in **Fig. 9.1** does not need to be drawn to full scale to calculate the correct magnification.

____

____ [1]

(c) (i) Lenses are used to correct defects in sight. State the name of one defect that can be corrected by a lens. Identify the cause of the defect and the type of lens used to correct it.

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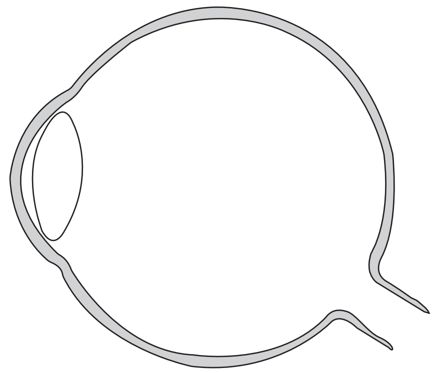
____

____ [3]

(ii) Complete both parts of **Fig. 9.2** to show how the lens works to correct the defect you have chosen in **(c)(i)**.

Before correction



After correction

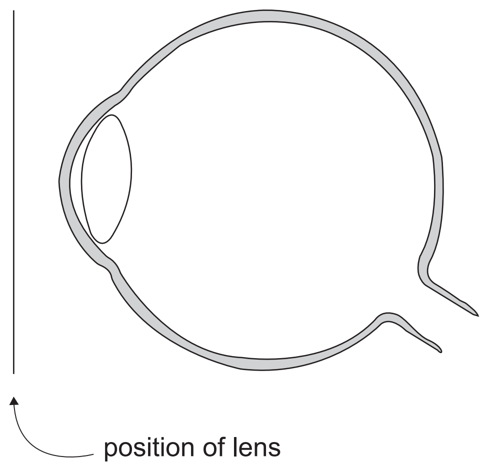


Fig. 9.2

[2]

(iii) Two lenses are compared. Lens A has a power of +3D and lens B has a power of –2D.

Describe two differences between the lenses.

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____ [2]

THIS IS THE END OF THE QUESTION PAPER

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For Examiner's use only	
Question Number	Marks
1	
2	
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Total Marks	

Examiner Number

SPH21/6
289961

Rewarding Learning

ADVANCED SUBSIDIARY
General Certificate of Education

Physics

Assessment Units AS 1 and AS 2

[SPH11/SPH21]

DATA AND FORMULAE SHEET

Data and Formulae Sheet for AS 1 and AS 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19}\ \text{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$
mass of electron	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
mass of proton	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
acceleration of free fall on the Earth's surface	$g = 9.81\ \text{m s}^{-2}$
electron volt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$
the Hubble constant	$H_0 \approx 2.4 \times 10^{-18}\ \text{s}^{-1}$

Useful formulae

The following equations may be useful in answering some of the questions in the examination:

Mechanics

conservation of energy $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$ for a constant force

Waves

two-source interference $\lambda = \frac{ay}{d}$

diffraction grating $d \sin\theta = n\lambda$

Light

lens equation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Electricity

terminal potential difference $V = E - Ir$ (e.m.f., E; Internal Resistance, r)

potential divider $V_{\mathbf{out}} = \frac{R_1 V_{\mathbf{in}}}{R_1 + R_2}$

Particles and photons

Einstein's equation $\frac{1}{2} m v_{\mathbf{max}}^{2} = hf - hf_0$

de Broglie equation $\lambda = \frac{h}{p}$

Astronomy

red shift $z = \frac{\Delta\lambda}{\lambda}$

recession speed $z = \frac{v}{c}$

Hubble's law $v = H_0 d$