New Specification

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ADVANCED
General Certificate of Education
2018

Centre Number

Candidate Number

Physics

Assessment Unit A2 1

assessing

Deformation of Solids, Momentum, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics

APH11

[APH11]

MONDAY 4 JUNE, AFTERNOON

TIME

2 hours.

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 in black ink only. **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.
Quality of written communication will be assessed in Question **2(a)**.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.

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1 (a) The graph in **Fig. 1.1** shows how the binding energy per nucleon varies with the number of nucleons in the nucleus. Complete **Fig. 1.1** by adding appropriate numerical values to the axes of the graph. [2]

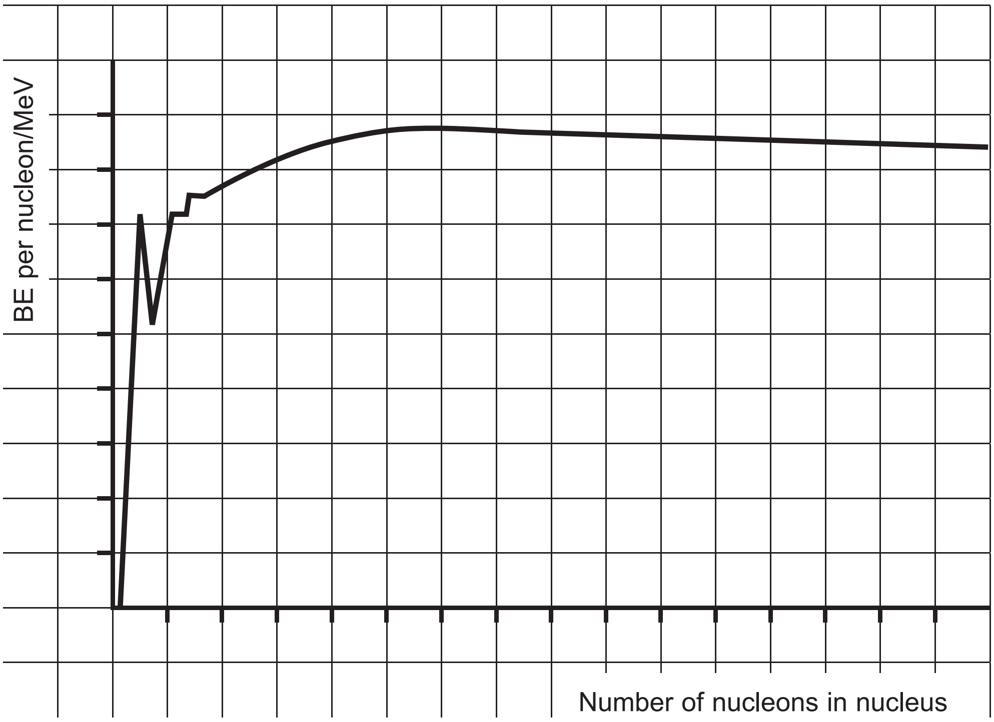

Fig. 1.1

(b) Describe the principles of fission and fusion. By referring to **Fig. 1.1**, explain how each process can lead to energy being released.

[5]

(c) (i) **Equation 1.1** shows an incomplete equation to describe a fission reaction. The number of neutrons that are released has been omitted.

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{56}Ba + {}^{90}_{36}Kr + \_\_\_\_ {}^{1}_{0}n \qquad \textbf{Equation 1.1}$$

How many neutrons are released in the reaction?

Number of neutrons = ____________________ [1]

(ii) **Equation 1.2** is another example of a fission reaction.

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{94}_{40}Zr + {}^{139}_{52}Te + 3\,{}^{1}_{0}n \qquad \textbf{Equation 1.2}$$

The mass of each nucleus and a neutron are given in **Table 1.1**.

Table 1.1

Nucleus	Mass / u
U-235	235.0439
Zr-94	93.9063
Te-139	138.9347
n	1.0086

Calculate the number of U-235 nuclei that need to undergo fission by the reaction in **Equation 1.2** to produce 1 joule of energy.

Number of nuclei = ____________________ [5]

2 Quality of written communication will be assessed in part (a) of this question.

(a) The control rods and the moderator are two components of a fission reactor. State a material from which each component can be made and describe how they function to produce nuclear power in a safe manner.

[6]

(b) The use of fossil fuels in power stations causes considerable environmental pollution due to the gases produced. The government is considering several alternative sources of power.

State one advantage and one disadvantage that nuclear power has over **the other alternatives** to fossil fuel power.

Advantage:

____

____

Disadvantage:

____

____ [2]

3 **(a)** Gold foil was used in the historic alpha particle scattering experiment conducted by Geiger and Marsden. Gold has atomic number 79 and mass number 199. Calculate the radius of the nucleus of a gold atom.
State your answer in metres.
($r_0 = 1.2$ fm)

Radius of gold atom = ____________________ m [2]

(b) **Fig. 3.1** shows an overhead view of part of the apparatus used in the alpha particle scattering experiment.

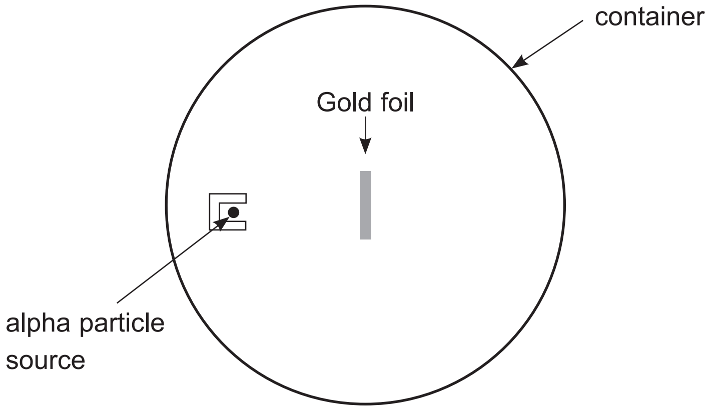

Fig. 3.1

(i) Complete **Fig. 3.1** by drawing and labelling any additional apparatus that was used when Geiger and Marsden carried out the experiment. [2]

(ii) Indicate, with the letter **P**, the position in which most alpha particles were detected in the experiment. [1]

(iii) Explain why the diameter of the container can be larger than 5 cm even though the range of alpha particles in air is less than 5 cm.

____

____ [1]

(c) **Fig. 3.2** shows the path of an alpha particle as it approaches a nucleus.

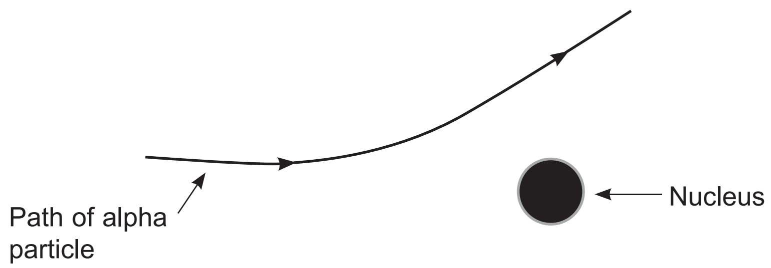

Fig. 3.2

The nucleus is replaced with one with a larger atomic number. On **Fig. 3.2**, sketch the new path taken by the alpha particle. [2]

4 (a) **Fig. 4.1** shows a fairground carousel where the horses move in a horizontal circle at a constant speed.

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Fig. 4.1

A 136 kg horse on the outside of the carousel travels in a circle of diameter 12.0 m. It takes 42 seconds for the horse to complete one full rotation.

(i) Use the definition of acceleration to explain why there must be a resultant force on the horse.

____

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____

____

____ [3]

(ii) Calculate the magnitude of the resultant force on the horse.

Force = ____________________ N [3]

(b) On another fairground ride, the rollercoaster, a carriage and passengers of combined mass 1200 kg approaches a vertical circular section as shown in **Fig. 4.2**. The diameter of the circle is 38 m.

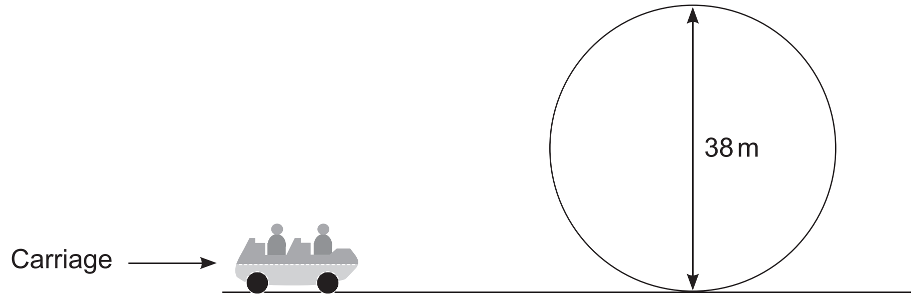

Fig. 4.2

(i) What is the minimum speed of the rollercoaster carriage for the passengers to feel weightless at the top of the loop?

Speed = ____________________ m s^{-1} [2]

(ii) Describe what happens to the rollercoaster carriage if the speed is less than that calculated in **(i)**.

____

____ [1]

(iii) If the rollercoaster carriage has fewer passengers and therefore less mass than in **(i)**, how will the speed at which weightlessness is experienced be affected?

____

____ [1]

5 **Equation 5.1** shows the relationship between the number of radioactive nuclei N left after time t. λ is the decay constant and N_0 is the initial number of radioactive nuclei.

$$N = N_0 \, e^{-\lambda t} \qquad \textbf{Equation 5.1}$$

One isotope of copper, Cu-62, can be used for medical imaging. The isotope is injected into the bloodstream and then a scan is carried out to detect the gamma rays emitted.

(a) **Fig. 5.1** shows a graph of the natural logarithm, Ln, of the percentage of radioactive Cu-62 nuclei remaining with time.

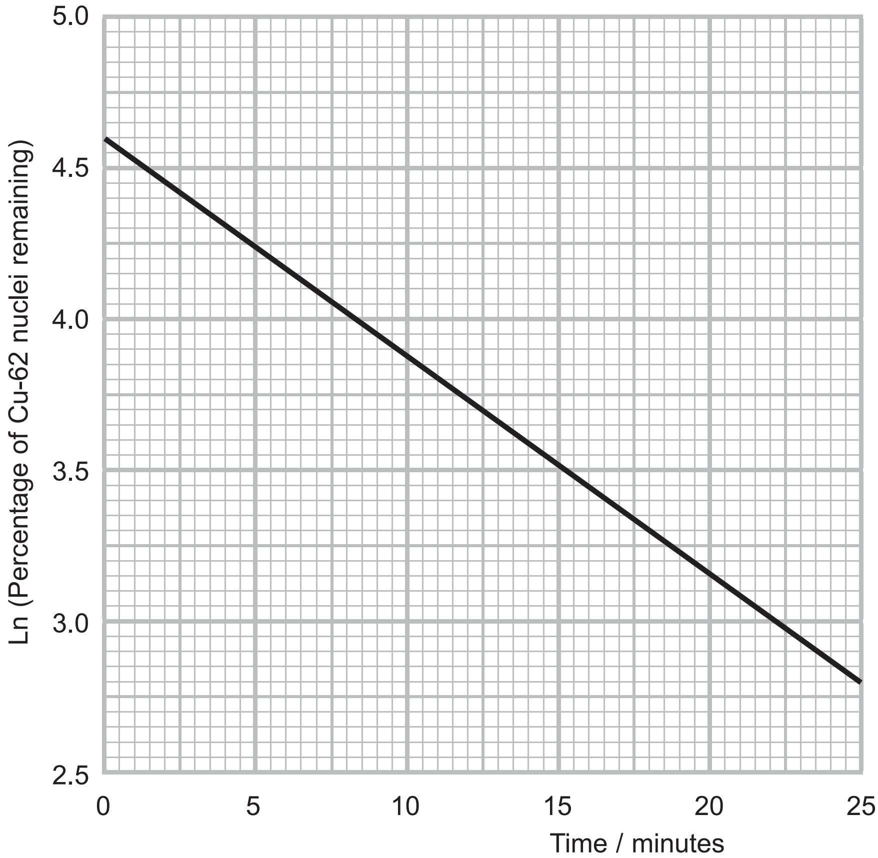

Fig. 5.1

(i) What is meant by the half-life of a radioactive source and why is it important to consider the half-life when a source is used for medical imaging?

____

____

____

____

____

____ [3]

(ii) Use **Fig. 5.1** to calculate the half-life of Cu-62.

Half-life = ____________________ minutes [3]

(b) After two hours the activity of the source has dropped to 0.46 Bq. Calculate the initial activity of the source.

Initial Activity = ____________________ Bq [2]

6 The Young modulus is an important property of the material from which contact lenses are made. Comfortable wearing of a lens is achieved using a more flexible contact lens that drapes easily over the cornea, but a high degree of flexibility can be a disadvantage when trying to achieve optimum vision. The Young modulus of two types of contact lens is shown in **Table 6.1**.

Table 6.1

Contact Lens	Young modulus / MPa
Type 1	1.1
Type 2	0.49

(a) Which contact lens would be most comfortable for the user? Explain your answer.

____

____

____ [1]

(b) To find a value for the Young modulus of a lens material, lenses made from the same material with powers ranging from –8.0 D to +4.0 D were tested.

(i) What was the range of focal lengths of the lenses tested in centimetres?

Focal lengths range from ______________ to ______________ cm [3]

(ii) Complete **Table 6.2** for lenses with positive and negative power.

Table 6.2

Power	Type of lens	Defect in vision that the lens is used to correct
negative		
positive		

[4]

(iii) In the test, a sample of the lens material that had a width of 2.5 mm and length of 12.0 mm, as shown in **Fig. 6.1**, was used. The Young modulus of one of the lenses tested was found to be 1.5 MPa. A force F of 4.2 mN in the direction shown produced a strain of 0.04.

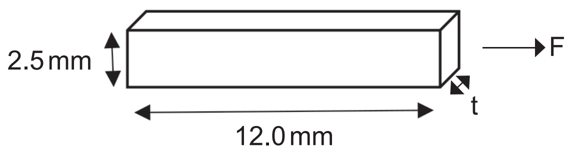

Fig. 6.1

Calculate the thickness t of the sample.

Thickness = ____________________ m [5]

7 (a) Describe an experiment to determine the specific heat capacity of a metal block. Include in your answer:

- a diagram of the apparatus used that will ensure an accurate result,
- the electrical circuit,
- the measurements taken,
- how the specific heat capacity is determined from the measurements.

[8]

(b) A kettle with a 2700 W heating element is used to boil 750 cm^3 of water. The water is initially at a temperature of 18 °C. Calculate the time taken for the water to boil if the heating element has an efficiency of 75%.

The specific heat capacity of water is 4.187 J g^{-1} °C^{-1} and its density is 1 g cm^{-3}.

Time = ________________ s [6]

8 A 0.25 kg mass on the end of a spring is pulled down a distance of 3 cm **below** equilibrium position and released so that it oscillates with simple harmonic motion. A graph of how the displacement of the mass varies with time is shown in **Fig. 8.1**.

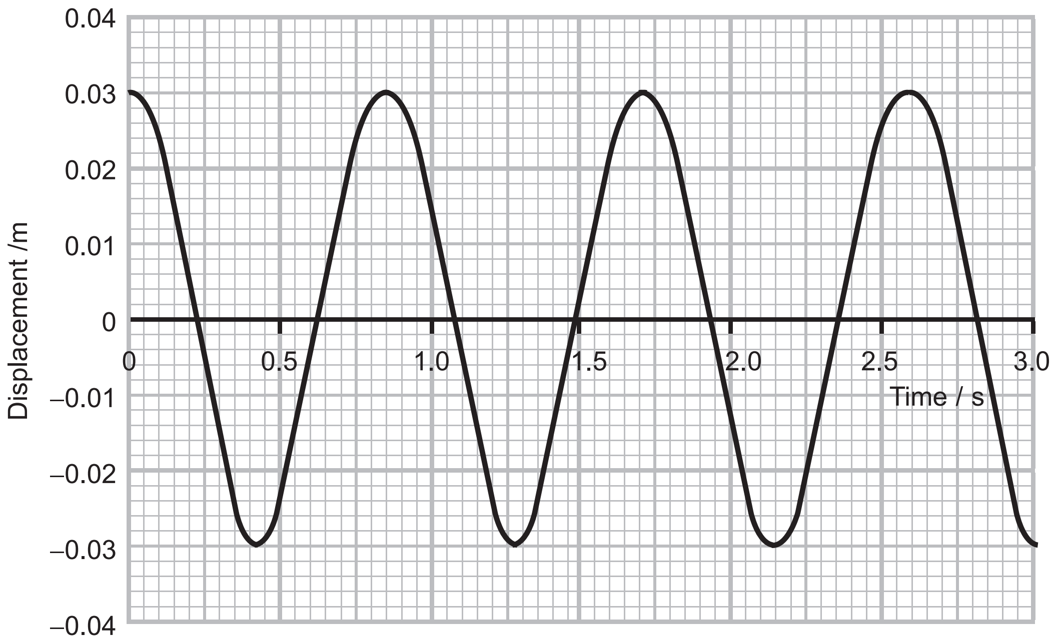

Fig. 8.1

(a) (i) Explain what is meant by simple harmonic motion.

____

____

____

____ [2]

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(ii) Calculate the displacement of the mass at a time of 12.5 seconds and state whether the mass is above or below the equilibrium position at this time.

Displacement = __________________ m

Position relative to equilibrium position = __________________ [6]

(iii) Calculate the maximum strain energy stored in the spring.

Energy = __________________ J [4]

(b) Describe how the maximum velocity of the mass could be determined from **Fig. 8.1**.

____

____

____ [3]

(c) **(i)** Describe how the mass on the spring could be forced to resonate.

____

____

____ [1]

(ii) How can you tell that the mass on the spring is resonating?

____

____ [1]

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(Questions continue overleaf)

9 **(a)** **(i)** What is the difference between the internal energy of a real gas and the internal energy of an ideal gas?

____

____

____

____ [2]

(ii) For a real gas to behave more like an ideal gas how should the pressure of the gas be adjusted?

____ [1]

(b) **Fig. 9.1** shows an airship with an envelope containing helium gas at a pressure of 1.03×10^5 Pa.

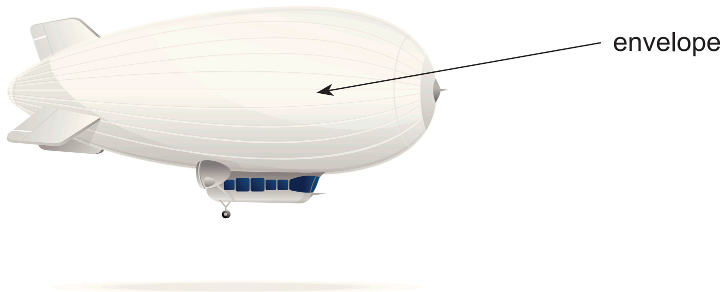

Fig. 9.1

(i) The envelope of the airship has a volume of $8230\,m^3$. If the temperature of the gas is $14\,°C$, calculate the mass of helium in the envelope of the airship.

The molar mass of helium $= 4.003 \times 10^{-3}$ kg mol^{-1}.

Mass of helium = ____________________ kg [3]

(ii) Calculate the root mean square speed of the helium gas atoms in the envelope of the airship.

Root mean square speed = ____________________ $m\,s^{-1}$ [3]

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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8	
9	
Total Marks	

Examiner Number

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Physics

Assessment Units A2 1 and A2 2

[APH11/APH21]

DATA AND FORMULAE SHEET

FOR USE FROM 2018 ONWARDS

12159.02

Data and Formulae Sheet for A2 1 and A2 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{F}^{-1}\ \text{m}\right)$
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
(unified) atomic mass unit	1 u $= 1.66 \times 10^{-27}$ kg
mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall on the Earth's surface	$g = 9.81$ m s^{-2}
electron volt	1 e$V = 1.60 \times 10^{-19}$ J
the Hubble constant	$H_0 \approx 2.4 \times 10^{-18}$ 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
Hooke's Law	$F = kx$ (spring constant k)
strain energy	$E = \frac{1}{2}\mathrm{Fx} = \frac{1}{2}kx^2$

Uniform circular motion

centripetal Force	$F = \dfrac{mv^2}{r}$

Simple harmonic motion

displacement	$x = A\cos\omega t$
simple pendulum	$T = 2\pi\sqrt{\dfrac{l}{g}}$
loaded spiral spring	$T = 2\pi\sqrt{\dfrac{m}{k}}$

Waves

two-source interference	$\lambda = \dfrac{ay}{d}$
diffraction grating	$d\sin\theta = n\lambda$

Thermal physics

average kinetic energy of a molecule	$\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$
kinetic theory	$pV = \frac{1}{3} Nm \langle c^2 \rangle$
thermal energy	$Q = mc\Delta\theta$

Capacitors

capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
capacitors in parallel	$C = C_1 + C_2 + C_3$
time constant	$\tau = RC$
capacitor discharge	$Q = Q_0 e^{\frac{-t}{CR}}$
	or $V = V_0 e^{\frac{-t}{CR}}$
	or $I = I_0 e^{\frac{-t}{CR}}$

Light

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

Electricity

terminal potential difference	$V = E - Ir$
	(e.m.f., E; Internal Resistance, r)
potential divider	$V_{out} = \frac{R_1 V_{in}}{R_1 + R_2}$
a.c. generator	$E = BAN\omega \sin\omega t$

Nuclear Physics

nuclear radius $r = r_0 A^{\frac{1}{3}}$

radioactive decay $A = -\lambda N, \quad A = A_0 e^{-\lambda t}$

half-life $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

Particles and photons

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

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

Astronomy

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

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

Hubble's law $v = H_0 d$