Write your name here

Surname	Other names

Edexcel GCE

Centre Number	Candidate Number

Physics

Advanced
Unit 5: Physics from Creation to Collapse

Tuesday 29 June 2010 – Afternoon
Time: 1 hour 35 minutes

Paper Reference
6PH05/01

You do not need any other materials.

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- The list of data, formulae and relationships is printed at the end of this booklet.
- Candidates may use a scientific calculator.

Advice

- Read each question carefully before you start to answer it.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Protactinium has a half-life of 70 s. A sample of protactinium is prepared and monitored over a period of time. Which of the following statements is correct?

☐ **A** The activity of the protactinium will be zero after 140 s.

☐ **B** The activity of the protactinium will be 25% of its initial value after 140 s.

☐ **C** The activity of the protactinium will be 12.5% of its initial value after 280 s.

☐ **D** The activity of the protactinium will never become zero.

(Total for Question 1 = 1 mark)

2 A mass is hung from a spring and set into vertical oscillation. Which row in the table correctly shows the kinetic energy E_k of the mass at maximum displacement and the potential energy E_p of the mass at the equilibrium position.

		Maximum displacement position	Equilibrium position
☐	**A**	E_k is a maximum	E_p is minimum
☐	**B**	E_k is a maximum	E_p is a maximum
☐	**C**	E_k is zero	E_p is a maximum
☐	**D**	E_k is zero	E_p is minimum

(Total for Question 2 = 1 mark)

3 Scientists believe that our universe began with a big bang, and is presently expanding. The ultimate fate of the universe depends upon the total amount of matter in the universe. One possibility is a big crunch where the universe eventually contracts back into a point of infinite density. A universe with such a future would be described as being

☐ **A** closed.

☐ **B** critical.

☐ **C** flat.

☐ **D** open.

(Total for Question 3 = 1 mark)

4 The relative masses of oxygen and hydrogen molecules are 32 and 2 respectively. For any given temperature, the ratio

$$\frac{\text{root mean square speed of oxygen molecules}}{\text{root mean square speed of hydrogen molecules}} \text{ is given by}$$

☒ **A** $\frac{1}{16}$

☒ **B** $\frac{1}{4}$

☒ **C** 4

☒ **D** 16

(Total for Question 4 = 1 mark)

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5 On a Hertzsprung-Russell diagram our Sun is located on the main sequence. Which of the following statements is correct?

☒ **A** All giant stars are larger and cooler than our Sun.

☒ **B** All giant stars are larger and hotter than our Sun.

☒ **C** All white dwarf stars are smaller and hotter than our Sun.

☒ **D** All white dwarf stars are hotter and brighter than our Sun.

(Total for Question 5 = 1 mark)

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6 In which of the following situations would a blue shift be observed?

☒ **A** Source and observer moving with the same velocity.

☒ **B** Source moving along a circular path around an observer.

☒ **C** Source moving away from a stationary observer.

☒ **D** Source moving towards a stationary observer.

(Total for Question 6 = 1 mark)

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7 The average kinetic energy of the molecules in a gas is proportional to

☒ **A** the number of molecules in the gas.

☒ **B** the specific heat capacity of the gas.

☒ **C** the temperature of the gas.

☒ **D** the total mass of the gas.

(Total for Question 7 = 1 mark)

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8 X and Y are identical stars. When viewed from Earth the flux from star X is 4 times the flux from star Y. Which of the following explanations is possible?

☒ **A** X is twice as far away as Y.

☒ **B** X is four times as far away as Y.

☒ **C** Y is twice as far away as X.

☒ **D** Y is four times as far away as X.

(Total for Question 8 = 1 mark)

9 For a black-body radiator, the frequency at which maximum radiation of energy occurs is proportional to

☒ **A** T^{-4}

☒ **B** T^{-1}

☒ **C** T

☒ **D** T^{4}

(Total for Question 9 = 1 mark)

10 Newton’s law of gravitation can be applied to the Earth-Moon system. Which of the following statements is **not** correct?

☒ **A** The value of G at the surface of the Moon is the same as that at the surface of the Earth.

☒ **B** The gravitational force between the Earth and the Moon is proportional to the square of the separation of the Earth and the Moon.

☒ **C** The gravitational force between the Earth and the Moon is proportional to the mass of the Moon.

☒ **D** The orbital time of the Moon about the Earth is independent of the mass of the Moon.

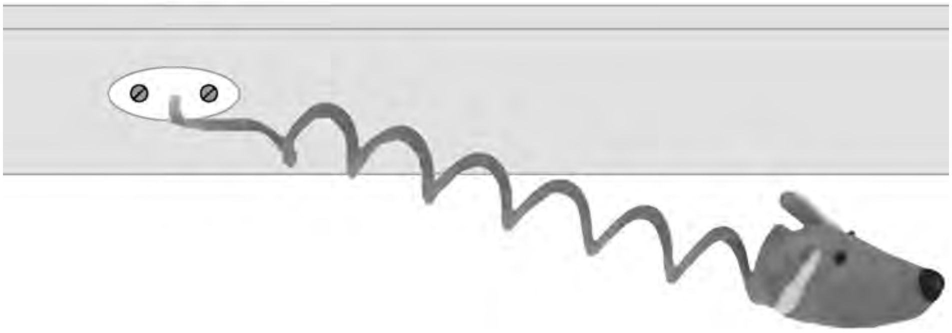
(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 A toy for cats consists of a plastic mouse of mass *m* attached to a spring. When the mouse is on a low-friction horizontal surface, with the spring attached to a rigid support as shown, it performs simple harmonic motion when given a small displacement *x* from its equilibrium position and released.



(a) Show that the acceleration of the mouse, *a*, is given by $a = -\left(\frac{k}{m}\right)x$, where *k* is the stiffness of the spring.

(2)

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(b) The mouse has a mass $m = 0.15$ kg and the spring extends by 20 cm when the mouse is supported vertically by the spring.

Calculate the frequency of oscillation of the mouse if it is set into oscillation on a low friction horizontal surface.

(5)

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Frequency = ...

(Total for Question 11 = 7 marks)

12 Radioisotopes are often used for medical applications. ^{131}I is a β^--emitter, and can be used to treat an overactive thyroid gland. When a small dose of ^{131}I is swallowed, it is absorbed into the bloodstream. It is then concentrated in the thyroid gland, where it begins destroying the gland's cells.

(a) Patients are advised that radiation detection devices used at airports may detect increased radiation levels up to 3 months after the treatment. Explain how it is possible for the activity of the ^{131}I to be detected outside the body.

(2)

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(b) (i) The half-life of ^{131}I is 8 days. What fraction of the original number of iodine atoms will have decayed after a period of 24 days?

(2)

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Fraction = ...

(ii) Doctors wish to prescribe a sample of ^{131}I of activity 1.5 MBq. The sample is prepared exactly 24 hours before it is due to be swallowed by the patient. Calculate the activity that the sample should have when it is prepared.

(3)

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Activity = ... MBq

(Total for Question 12 = 7 marks)

13 When nearby stars are observed over a period of a year, their positions are seen to move in tiny ellipses relative to the background of more distant stars.

(a) Explain why relative movement of these nearby stars is observed.

(3)

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(b) By means of a labelled diagram, outline the steps necessary for this effect to be used to find the distance to nearby stars.

(3)

(c) The effect is too small for the distances to more distant stars to be determined. Outline a method which can be used for more distant stars.

(1)

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(Total for Question 13 = 7 marks)

14 Ionisation smoke detectors contain a small amount of the radioactive isotope americium. ^{241}Am is an α-emitter. It has a half-life of 432 years, and the activity from the source in a new smoke detector is about 3.5×10^4 Bq.

(a) Explain why the radiation produced by a smoke detector does not pose a health hazard.

(1)

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(b) (i) Complete the nuclear equation for the decay of americium.

(2)

$$^{241}_{\dots}\text{Am} \rightarrow {}^{\dots}_{93}\text{Np} + {}^{\dots}_{\dots}\alpha$$

(ii) Using data from the table, calculate the energy, in MeV, of α-particles released when a nucleus of americium-241 undergoes alpha decay.

(3)

Nuclide	**Mass/u**
Am	241.056 822
Np	237.048 166
α-particle	4.002 603

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Energy = ... MeV

(c) An ionisation smoke detector is sold with the guarantee that it "lasts a lifetime". Comment on the appropriateness of this guarantee, based on its use of americium-241.

(1)

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(Total for Question 14 = 7 marks)

*15 The Sun behaves as an approximate black-body radiator with peak energy radiation occurring at a wavelength of 5.2×10^{-7} m.

(a) (i) Show that the Sun has a surface temperature of about 6000 K.

(2)

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(ii) The radiation received from the Sun at the top of the atmosphere is 1.37 kW m^{-2}. Show the Sun's luminosity is about 4×10^{26} W.

Distance from the Sun to the Earth = 1.49×10^{11} m

(2)

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(iii) Hence calculate the radius of the Sun.

(2)

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Radius = ...

(b) The huge power output of the Sun is due to nuclear fusion reactions taking place within its core. State and explain the conditions necessary for fusion to occur.

(3)

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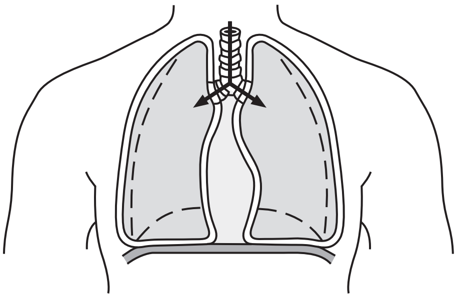
(Total for Question 15 = 9 marks)

16 When your diaphragm contracts, the pressure in the chest cavity is lowered below atmospheric pressure and air is forced into your lungs.



(a) The diaphragm contracts and the lung capacity increases by 20%. State **two** assumptions you would need to make to calculate the new pressure in the lungs if the initial pressure is known.

(2)

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(b) (i) The volume of air inhaled in a typical breath is 2.5×10^{-4} m^3 and an adult takes about 25 breaths per minute. Show that the mass of air taken into the lungs each second is about 1×10^{-4} kg.

Density of air = 1.2 kg m^{-3}

(2)

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(ii) If body temperature is 37.6 °C and the temperature outside the body is 20.0 °C, calculate the rate at which energy is used to warm air up to body temperature.

Specific heat capacity of air = 1000 J kg^{-1} K^{-1}

(2)

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Rate = ...

(Total for Question 16 = 6 marks)

*17 The Hubble Space Telescope (HST) was launched in 1990 into an orbit of radius 6940 km. The satellite makes 15 complete orbits of the Earth every 24 hours and its position high above the Earth's atmosphere has allowed high quality images of extremely distant objects to be produced.

(a) (i) Show that the HST has a centripetal acceleration of about 8 m s^{-2}.

(4)

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(ii) The HST is kept in orbit by the gravitational pull of the Earth. Use your answer to (a)(i) to calculate a value for the mass of the Earth.

(3)

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Mass = ...

(b) The telescope was named in honour of Edwin Hubble who measured the red shift of light from a number of galaxies and related it to their distance from the Earth.

Explain what is meant by the term *red shift* in this context and state the inference that Hubble made from his measurements.

(2)

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(c) The song "Nine Million Bicycles" by Katie Melua includes the lines, "We are 12 billion light years from the edge, that's a guess, no one can ever say it's true".

(i) Explain how the line "12 billion light years from the edge" implies an age of 12 billion years for the universe.

(2)

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(ii) Calculate the value of the Hubble constant consistent with an age of 12 billion years for the universe.

1 billion years = 3.15×10^{16} s

(2)

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Hubble constant = ...

(iii) These lyrics were famously contested by Dr Simon Singh in the Guardian newspaper. He argued that the correct age was 13.7 billion years, and disputed that scientists had guessed the age of the universe. As a result Katie performed the song with revised lyrics.

Discuss the suggestion in the song that values for the age of the universe are only guesses.

(3)

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(Total for Question 17 = 16 marks)

*__18__ Read this passage and answer the questions that follow.

The Millennium Bridge opened on 10 June 2000 as London's first new Thames crossing in more than 100 years. The bridge uses "lateral suspension" – an engineering innovation that allows suspension bridges to be built without tall supporting columns. Tens of thousands of people crossed the bridge on its opening day. The structure was designed to take the weight, but suddenly the bridge began to sway and twist in regular oscillations. The worst of the movement occurred on the central span where the edge of the bridge oscillated through a total distance of 70 mm.

To solve the problem the engineers decided to use damping mechanisms – giant shock absorbers to limit the bridge's response to external forces. They decided to use two systems: viscous dampers, similar to car shock absorbers, and tuned mass dampers. A tuned mass damper is a large mass stiffened by springs.

(a) Name the effect that results in a system being driven into large amplitude oscillations, and state the condition necessary for this to happen.

(2)

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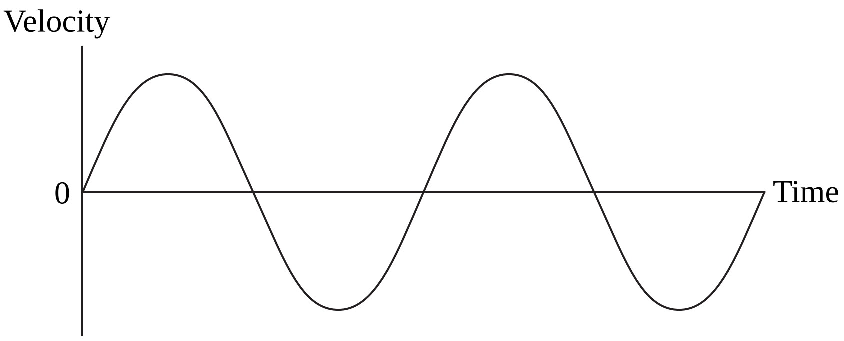
(b) The graph shows the variation of velocity with time at the edge of the central span of the bridge.



Mark on this graph:

(i) An instant X at which the displacement was a maximum.

(1)

(ii) An instant Y at which the acceleration was zero.

(1)

(c) Before modification the edge of the central span of the bridge oscillated with simple harmonic motion, and had a maximum acceleration of 0.89 m s^{-2}. Calculate the maximum velocity of the edge of the central span of the bridge.

(4)

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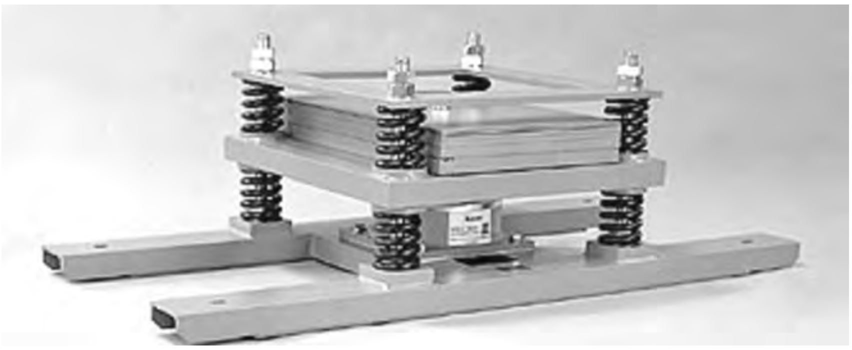
Maximum velocity = ...

(d) The photograph shows the tuned mass dampers which were fitted to the bridge. They are tuned to the natural frequency of oscillation of the bridge.



Discuss how the tuned mass dampers reduce the amplitude of the oscillations of the bridge and explain why they must be very heavily damped.

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(Total for Question 18 = 11 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

List of data, formulae and relationships

Acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$	
Coulomb's law constant	$k = 1/4\pi\varepsilon_0$	
	$= 8.99 \times 10^{9}\ \text{N m}^{2}\ \text{C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19}\ \text{C}$	
Electron mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	
Electronvolt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$	
Gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^{-2}\ \text{kg}^{-2}$	
Gravitational field strength	$g = 9.81\ \text{N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27}\ \text{kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27}\ \text{kg}$	

Unit 1

Mechanics

Kinematic equations of motion	$v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
Forces	$\Sigma F = ma$ $g = F/m$ $W = mg$
Work and energy	$\Delta W = F\Delta s$ $E_k = \frac{1}{2}mv^2$ $\Delta E_{grav} = mg\Delta h$

Materials

Stokes' law	$F = 6\pi\eta rv$
Hooke's law	$F = k\Delta x$
Density	$\rho = m/V$
Pressure	$p = F/A$
Young's modulus	$E = \sigma/\varepsilon$ where Stress $\sigma = F/A$ Strain $\varepsilon = \Delta x/x$
Elastic strain energy	$E_{el} = \frac{1}{2}F\Delta x$

Unit 2

Waves

Wave speed	$v = f\lambda$
Refractive index	${}_1\mu_2 = \sin i/\sin r = v_1/v_2$

Electricity

Potential difference	$V = W/Q$
Resistance	$R = V/I$
Electrical power, energy and efficiency	$P = VI$ $P = I^2R$ $P = V^2/R$ $W = VIt$

$$\%\ \text{efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100$$

$$\%\ \text{efficiency} = \frac{\text{useful power output}}{\text{power input}} \times 100$$

Resistivity	$R = \rho l/A$
Current	$I = \Delta Q/\Delta t$ $I = nqvA$
Resistors in series	$R = R_1 + R_2 + R_3$
Resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Quantum physics

Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \frac{1}{2}mv^2_{max}$

Unit 4

Mechanics

Momentum	$p = mv$
Kinetic energy of a non-relativistic particle	$E_k = p^2/2m$
Motion in a circle	$v = \omega r$ $T = 2\pi/\omega$ $F = ma = mv^2/r$ $a = v^2/r$ $a = r\omega^2$

Fields

Coulomb's law	$F = kQ_1Q_2/r^2$ where $k = 1/4\pi\varepsilon_0$
Electric field	$E = F/Q$ $E = kQ/r^2$ $E = V/d$
Capacitance	$C = Q/V$
Energy stored in capacitor	$W = \frac{1}{2}QV$
Capacitor discharge	$Q = Q_0 e^{-t/RC}$
In a magnetic field	$F = BIl \sin\theta$ $F = Bqv \sin\theta$ $r = p/BQ$
Faraday's and Lenz's Laws	$\varepsilon = -d(N\phi)/dt$

Particle physics

Mass-energy	$\Delta E = c^2 \Delta m$
de Broglie wavelength	$\lambda = h/p$

Unit 5

Energy and matter

Heating	$\Delta E = mc\Delta\theta$
Molecular kinetic theory	$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$
Ideal gas equation	$pV = NkT$

Nuclear Physics

Radioactive decay	$\mathrm{d}N/\mathrm{d}t = -\lambda N$
	$\lambda = \ln 2/t_{\frac{1}{2}}$
	$N = N_0 \mathrm{e}^{-\lambda t}$

Mechanics

Simple harmonic motion	$a = -\omega^2 x$ $a = -A\omega^2 \cos \omega t$ $v = -A\omega \sin \omega t$ $x = A \cos \omega t$ $T = 1/f = 2\pi/\omega$
Gravitational force	$F = Gm_1m_2/r^2$

Observing the universe

Radiant energy flux	$F = L/4\pi d^2$
Stefan-Boltzmann law	$L = \sigma T^4 A$ $L = 4\pi r^2 \sigma T^4$
Wien's Law	$\lambda_{max}T = 2.898 \times 10^{-3}$ m K
Redshift of electromagnetic radiation	$z = \Delta\lambda/\lambda \approx \Delta f/f \approx v/c$
Cosmological expansion	$v = H_0 d$