Write your name here

Surname	Other names

Edexcel GCE

Centre Number	Candidate Number

Physics
Advanced
Unit 5: Physics from Creation to Collapse

Monday 27 June 2011 – Morning
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 ▶

1/1/1/1/1/

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 Samples of nitrogen gas and helium gas are at the same temperature. Compared with the helium molecules, the nitrogen molecules have

☒ **A** a lower mean square speed.

☒ **B** the same mean square speed.

☒ **C** a higher mean square speed.

☒ **D** a mean square speed dependent upon the amount of each gas.

(Total for Question 1 = 1 mark)

2 Which of the following descriptions **cannot** apply to the oscillations of a system undergoing resonance?

☒ **A** Damped

☒ **B** Driven

☒ **C** Forced

☒ **D** Free

(Total for Question 2 = 1 mark)

3 During an earthquake, steel-framed buildings absorb energy because steel is

☒ **A** ductile.

☒ **B** elastic.

☒ **C** stiff.

☒ **D** strong.

(Total for Question 3 = 1 mark)

4 On a Hertzsprung-Russell diagram, the main sequence shows

☒ **A** only the most luminous stars.

☒ **B** only the most massive stars.

☒ **C** stars near the end of their lives.

☒ **D** stars principally fusing hydrogen.

(Total for Question 4 = 1 mark)

5 Which one of the following does **not** contribute to background radiation?

☒ **A** Dead matter

☒ **B** Living matter

☒ **C** Mobile phones

☒ **D** Rocks

(Total for Question 5 = 1 mark)

6 When a forced oscillation is damped, the amplitude

☒ **A** builds up quite slowly.

☒ **B** constantly rises and falls.

☒ **C** is always small.

☒ **D** is reduced.

(Total for Question 6 = 1 mark)

7 The ultimate fate of the Universe is uncertain because

☒ **A** atmospheric absorption limits our observations.

☒ **B** our galaxy is not typical of other galaxies in the Universe.

☒ **C** the total average density of the Universe is uncertain.

☒ **D** we cannot observe very distant galaxies.

(Total for Question 7 = 1 mark)

8 A radioactive source is placed 2 cm from a detector. The count rate decreases slightly if a sheet of paper is placed between the source and the detector. It is reduced to background radiation level when the paper is replaced with a 1 cm thickness of aluminium.

The correct conclusion is that the source emits

☒ **A** alpha radiation only.

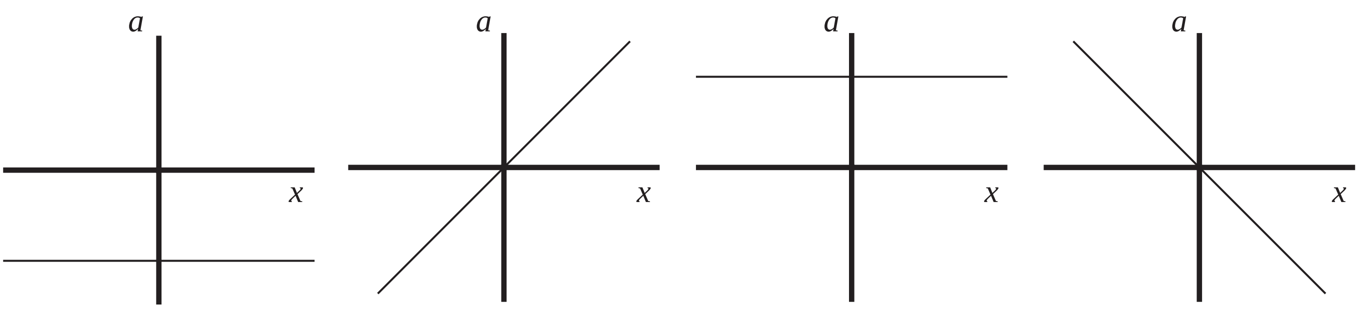
☒ **B** alpha and beta radiation.

☒ **C** beta and gamma radiation.

☒ **D** gamma radiation only.

(Total for Question 8 = 1 mark)

9 A mass-spring system is set into simple harmonic motion. Which graph shows the variation of the acceleration, a, of the mass with its displacement, x?



A **B** **C** **D**

☒ **A**

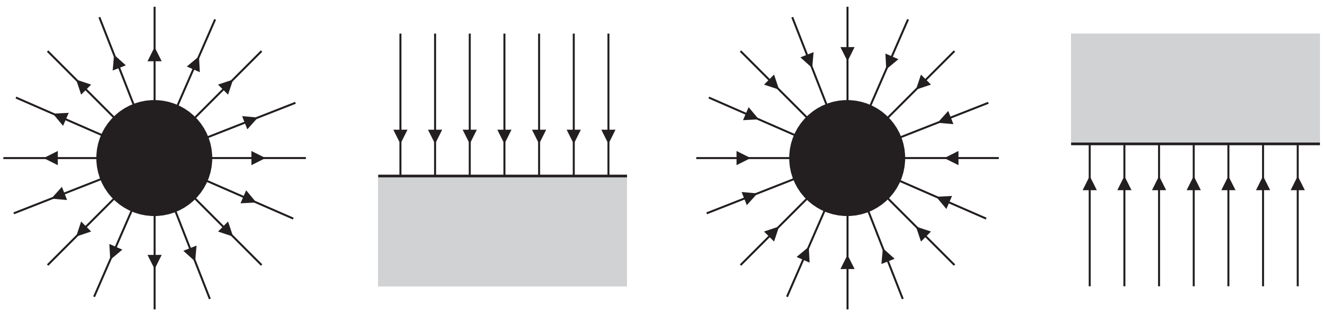
☒ **B**

☒ **C**

☒ **D**

(Total for Question 9 = 1 mark)

10 Electric and gravitational fields can be represented in similar ways. Which of the diagrams below **cannot** be used for a gravitational field?



A **B** **C** **D**

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 (a) State what astronomers mean by a standard candle.

(1)

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....

(b) The luminosity of Sirius is 8.94×10^{27} W and its distance from the Earth is 8.08×10^{16} m.

Calculate the radiant energy flux of Sirius at the Earth.

(2)

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....

Radiant energy flux = ...

(Total for Question 11 = 3 marks)

12 (a) Derive an expression for the gravitational field strength g at a distance r from the centre of a mass M. Use the list of equations at the end of this question paper.

(2)

....

....

....

(b) Use your expression to calculate g at the surface of the Earth.

mass of Earth $M_E = 5.97 \times 10^{24}$ kg
radius of Earth $r_E = 6.38 \times 10^{6}$ m

(1)

....

....

g = ...

(Total for Question 12 = 3 marks)

13 The heating element of a hair dryer supplies 2.1 kW to the air flowing past it.

(a) The hair dryer is connected to a 230 V supply.

Calculate the minimum current in the heating element.

(2)

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....

....

Current = ...

(b) (i) The fan in the hair dryer blows air at 20 °C across the heating element at a rate of 0.068 kg s^{-1}.

Calculate the temperature of the air emerging from the hair dryer.

specific heat capacity of air = 1.01×10^3 J kg^{-1} K^{-1}

(2)

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....

Exit temperature = ...

(ii) Describe the energy changes that occur as air is blown past the heating element.

(2)

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....

....

(Total for Question 13 = 6 marks)

14 A football has a diameter of 22.5 cm. It contains air at a temperature of 20 °C and a pressure of 1.65×10^5 Pa. When the football is left in direct sunlight, the temperature of the air in the football increases to 40 °C.

In the following calculations, assume that the volume of the football remains constant.

(a) (i) Show that the new pressure exerted by the air in the football is about 2×10^5 Pa.

(2)

....

....

....

....

(ii) State another assumption you made in your calculation.

(1)

....

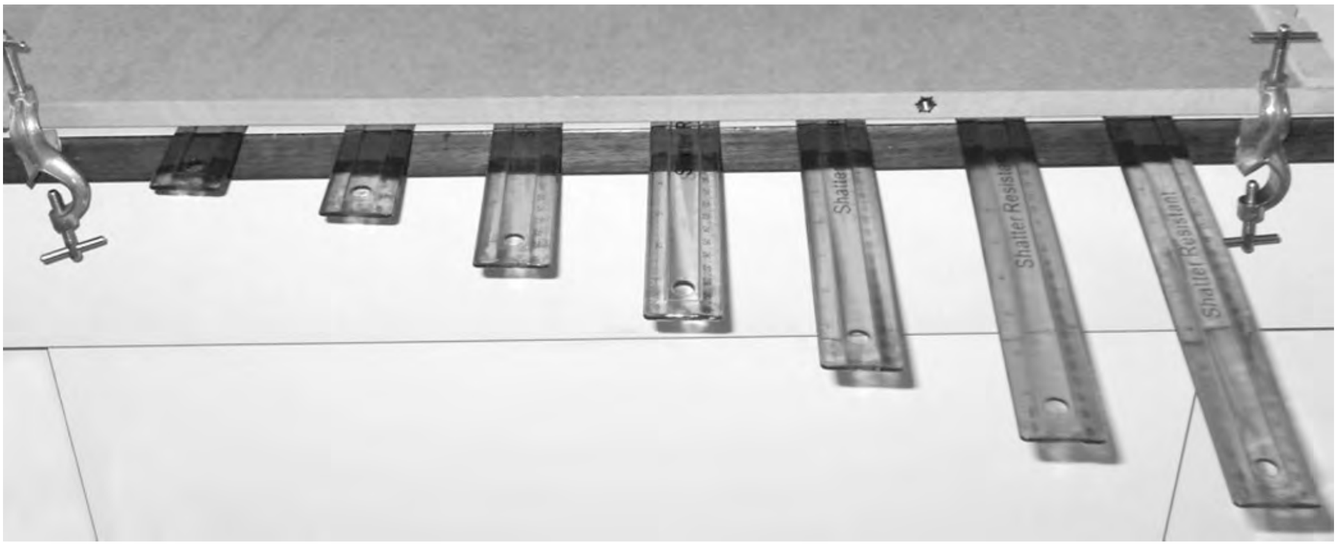
(b) Air is then released from the football until the pressure returns to its original value. Assuming that the temperature remains at 40 °C, calculate the number of molecules that escape.

(3)

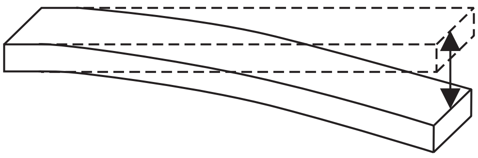
Number of molecules escaping = ...

(Total for Question 14 = 6 marks)

15 A student makes the "ruler piano" shown in the photograph.



One end of each ruler is held flat on the desk whilst the other end is set into oscillation. Each ruler oscillates at a different frequency. Some of the rulers produce an audible sound.



(a) State the condition for an oscillation to be simple harmonic.

(2)

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....

(b) The end of one ruler moves through 5.0 cm from one extreme position to the other, and makes 10 complete oscillations in 4.5 s.

Calculate the maximum velocity of this end.

(3)

Maximum velocity = ...

(c) A standing wave is set up on each oscillating ruler.

Explain why each length of ruler oscillates at a different frequency.

(3)

(Total for Question 15 = 8 marks)

16 Polonium-210 is an alpha-emitter with a half-life of 138 days. It emits alpha particles of energy 5.3 MeV as it decays to a stable isotope of lead.

One small pellet of polonium-210 contains 1.3×10^{21} atoms.

(a) (i) Show that the initial activity of this polonium pellet is about 8×10^{13} Bq.

(3)

(ii) Hence show that the rate of energy release by the pellet is more than 60 W.

(3)

(b) The radius of the pellet is 2.25 mm and its equilibrium temperature would be about 1000 K.

(i) Assuming that 5% of the energy released is radiated away, show that this approximate value of temperature is correct.

(3)

(ii) Calculate the wavelength at which peak energy radiation occurs.

(2)

....

....

....

....

Wavelength of peak energy radiation = ...

(iii) State the region of the electromagnetic spectrum in which this wavelength of radiation would be found.

(1)

....

(c) Explain why very small quantities of polonium-210 are a health hazard only if taken into the body.

(2)

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(Total for Question 16 = 14 marks)

17 Fission and fusion are both nuclear processes that release energy. About 20% of the UK's energy need is currently provided by the controlled fission of uranium. Intensive research continues to harness the energy released from the fusion of hydrogen.

(a) (i) Fission of uranium-235 takes place after the absorption of a thermal neutron. Assume such neutrons behave as an ideal gas at a temperature of 310 K.

Show that the square root of the mean square speed of the neutrons is about 3000 m s^{-1}.

mass of neutron = 1.0087u

(3)

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(ii) Complete the equation for the fission of uranium-235.

(2)

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{......}_{92}U \rightarrow ^{138}_{......}Cs + ^{96}_{37}Rb + ... ^{1}_{0}n$$

(iii) Calculate the energy released in a single fission. Hence determine the rate of fission necessary to maintain a power output of 2.5 GW.

Mass / u	
^{235}U	235.0439
^{138}Cs	137.9110
^{96}Rb	95.9343

(4)

Fission rate = ...

(b) *(i) State the conditions for fusion and hence explain why it has proved difficult to maintain a sustainable reaction in a practical fusion reactor.

(4)

(ii) The nuclear reaction below represents the fusion of two deuterium nuclei. Complete the equation and identify particle X.

(1)

$${}^{2}_{1}\mathrm{D} + {}^{2}_{1}\mathrm{D} \rightarrow {}^{3}_{1}\mathrm{H} + {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{X}$$

Particle X is a ....

(iii) Despite the difficulties, the quest for a practical fusion reactor continues.

State **two** advantages fusion power might have over fission power.

(2)

1 ....

....

2 ....

....

(Total for Question 17 = 16 marks)

18 Current theory predicts that there is a massive black hole at the centre of every galaxy. It is suggested that if galaxies approach, then their central black holes begin to orbit each other until the galaxies merge.

In 2009, astronomers found convincing evidence of two such black holes orbiting as a binary system. From data collected, they estimated that the separation of the black holes was 3.2×10^{15} m and that their masses were 1.6×10^{39} kg and 4.0×10^{37} kg.

(a) (i) State the origin of the force that maintains the black holes in an orbit.

(1)

....

(ii) Show that the magnitude of this force is about 4×10^{35} N.

(2)

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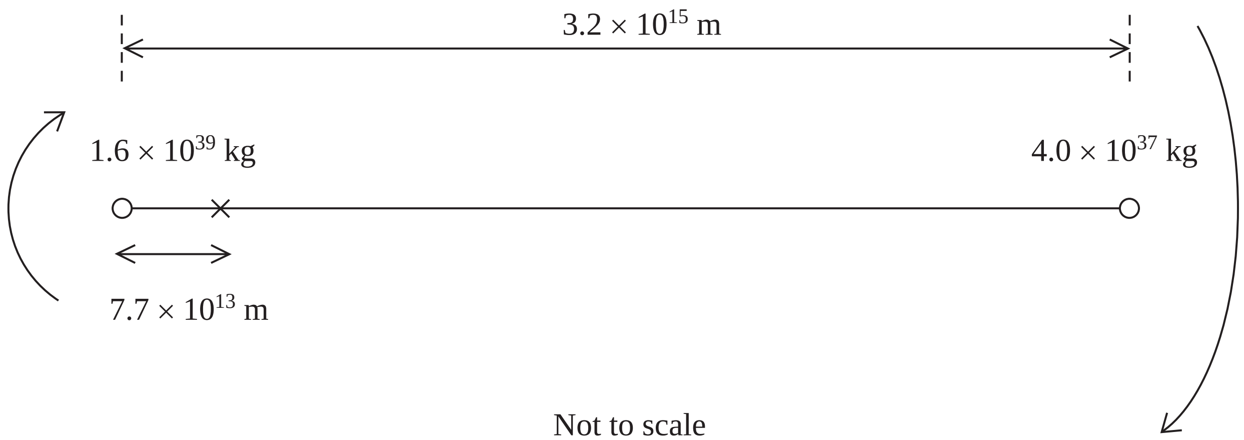
(iii) The black holes orbit about a point 7.7×10^{13} m from the larger mass black hole.



Not to scale

Show that the orbital time of the binary system is about 100 years.

(3)

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(b) As the black holes swallow up matter, radiation is emitted. To observers on Earth this radiation appears to be red shifted.

*(i) State what red shift means and discuss the conclusions that can be drawn from the observation that radiation from all distant galaxies is red shifted.

(3)

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(ii) Suggest why the light from both black holes is red shifted, even though the black holes are orbiting each other and hence moving in opposite directions.

(2)

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(iii) The observed red shift for the two black holes was 0.38.

Calculate the distance of the merging galaxies from the Earth.

$H_o = 1.6 \times 10^{-18}\ \text{s}^{-1}$

(3)

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Distance from the Earth = ...

(Total for Question 18 = 14 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

List of data, formulae and relationships

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

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 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	$P = VI$ $P = I^2R$ $P = V^2/R$ $W = VIt$
	$\% \text{ efficiency} = \dfrac{\text{useful energy output}}{\text{energy input}} \times 100$
	$\% \text{ efficiency} = \dfrac{\text{useful power output}}{\text{power input}} \times 100$
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	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

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	$\varepsilon = -\mathrm{d}(N\phi)/\mathrm{d}t$

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	$\tfrac{1}{2}m\langle c^2\rangle = \tfrac{3}{2}kT$
Ideal gas equation	$pV = NkT$

Nuclear Physics

Radioactive decay	$\mathrm{d}N/\mathrm{d}t = -\lambda N$
	$\lambda = \ln 2/t_{½}$
	$N = N_0\mathrm{e}^{-\lambda t}$

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	$v = H_0 d$