Write your name here

Surname	Other names

Centre Number | Candidate Number

Edexcel GCE

Physics

Advanced
Unit 5: Physics from Creation to Collapse

Thursday 20 June 2013 – Morning
Time: 1 hour 35 minutes

Paper Reference
6PH05/01R

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/C2

P 4 3 3 2 4 A 0 1 2 4

PEARSON

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 At night the Earth's surface cools down as energy is radiated away into space.

Most of the energy is radiated away as

☐ **A** infrared radiation.

☐ **B** microwaves.

☐ **C** ultraviolet radiation.

☐ **D** visible light.

(Total for Question 1 = 1 mark)

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2 In a famous thought experiment, Schrödinger imagined that a cat is locked in a box, along with a radioactive atom that is connected to a tube containing a deadly poison. If the atom decays, it causes the tube to smash and the cat to die.

The random nature of radioactive decay means that the radioactive atom will

☐ **A** decay after one half-life.

☐ **B** probably decay after one half-life.

☐ **C** have a fixed probability of decaying in a given time interval.

☐ **D** have a number of possible decay paths.

(Total for Question 2 = 1 mark)

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3 Mars has twice the mass of Mercury and is 4 times further away from the Sun.

The ratio of the gravitational force from the Sun on Mercury to the gravitational force from the Sun on Mars is

☐ **A** 0.5

☐ **B** 2.0

☐ **C** 8.0

☐ **D** 32

(Total for Question 3 = 1 mark)

P 4 3 3 2 4 A 0 2 2 4

4 A star is estimated to have approximately the same surface temperature as the Sun, but less than 1% of the Sun's luminosity.

The star is best classified as a

- ☒ **A** main sequence star.
- ☒ **B** red dwarf star.
- ☒ **C** red giant star.
- ☒ **D** white dwarf star.

(Total for Question 4 = 1 mark)

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5 A radioactive source is placed a few cm away from a detector. There is no change in the count rate when a thin aluminium foil is placed between the source and the detector, but the count rate is reduced to the background rate when a 0.5 cm aluminium plate is introduced.

These observations show that the source must be emitting

- ☒ **A** alpha and beta radiation.
- ☒ **B** beta and gamma radiation.
- ☒ **C** beta radiation only.
- ☒ **D** gamma radiation only.

(Total for Question 5 = 1 mark)

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6 Fission and fusion are both nuclear processes.

Which of the following statements is correct for both processes?

- ☒ **A** Neutrons are released.
- ☒ **B** No harmful radiation is produced.
- ☒ **C** The binding energy per nucleon increases.
- ☒ **D** The total mass increases.

(Total for Question 6 = 1 mark)

7 An object is hung from a vertical spring and undergoes undamped simple harmonic motion.

It is correct to say that there are **no** changes in the

☒ **A** elastic potential energy of the oscillating system.

☒ **B** gravitational potential energy of the oscillating system.

☒ **C** kinetic energy of the oscillating system.

☒ **D** total energy of the oscillating system.

(Total for Question 7 = 1 mark)

8 A car is travelling over a rough road surface. At low speed the ride is very bumpy with the car and its occupants suffering large amplitude vertical oscillations. However, when the car is driven at a higher speed the ride gets smoother.

This is because at the higher speed

☒ **A** the car leaves the ground and misses the bumps.

☒ **B** the car crushes the bumps and makes the road smoother.

☒ **C** there is a greater amount of damping in the car's suspension.

☒ **D** the car's suspension oscillates at a greater frequency than its natural frequency.

(Total for Question 8 = 1 mark)

9 The gravitational field strength at the surface of the Earth is 9.8 N kg^{-1}. A satellite is orbiting at a height above the ground equal to the radius of the Earth.

The gravitational field strength, in N kg^{-1}, at this height is

☒ **A** 0.0

☒ **B** 2.5

☒ **C** 4.9

☒ **D** 9.8

(Total for Question 9 = 1 mark)

10 The absolute temperature scale is a theoretical scale proposed by Lord Kelvin.

On this scale, zero is the temperature at which

- ☒ **A** all gases become liquids.
- ☒ **B** an ideal gas would exert no pressure.
- ☒ **C** the Celsius temperature is −373 °C.
- ☒ **D** water freezes.

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 Light from all distant galaxies is found to be shifted towards longer wavelengths. The more distant the galaxy, the greater the shift in wavelength.

State the conclusions that we can draw from this.

(3)

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(Total for Question 11 = 3 marks)

12 A student is constructing a spreadsheet to calculate the radius R of some stars. To obtain the radius, the surface temperature T of the star must first be calculated. She is given values for the stars' luminosities L and the wavelengths λ_{max} at which peak energy emission occurs. Part of the spreadsheet is shown, A is the surface area of the star.

	A	B	C	D	E
1	λ_{max} / 10^{-7} m	T / 10^3 K	L / 10^{27} W	A / 10^{19} m^2	R / 10^9 m
2	6.85	4.23	0.039		0.41
3	5.74	5.05	0.384	1.04	0.91
4	3.56	8.14	3.385	1.36	1.04
5					

(a) Write an equation to show how the value in B2 is calculated.

(1)

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(b) Show that the value in D2 is about 0.2

(2)

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(c) The student was given the luminosity values to enter into column C.

Describe how astronomers could determine the luminosity of a star.

(2)

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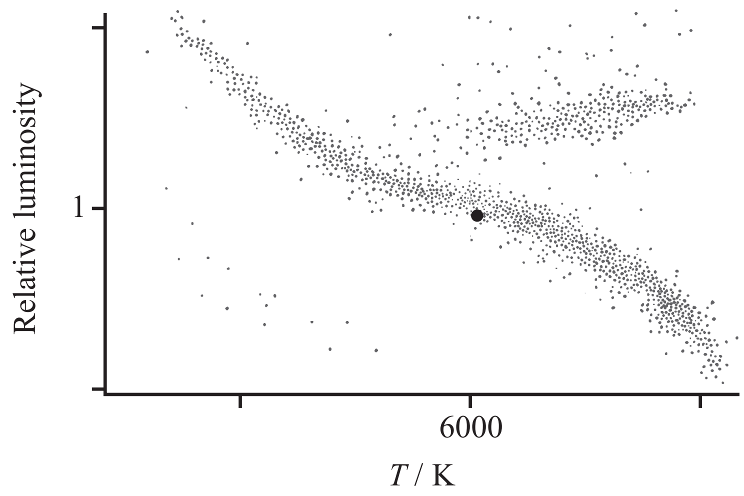
(Total for Question 12 = 5 marks)

13 This Hertzsprung-Russell diagram is a plot of relative luminosity against temperature for a large number of stars.



The position of the Sun, at a surface temperature of about 6000 K and a relative luminosity of 1, is marked on the diagram.

(a) Complete the temperature and relative luminosity scales by adding values at the positions shown.

(2)

(b) The Sun is an example of a main sequence star.

(i) State the fusion process taking place in the core of all main sequence stars.

(1)

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(ii) Draw a circle where the most massive main sequence stars are located on the diagram and explain why they are found in this position.

(3)

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(Total for Question 13 = 6 marks)

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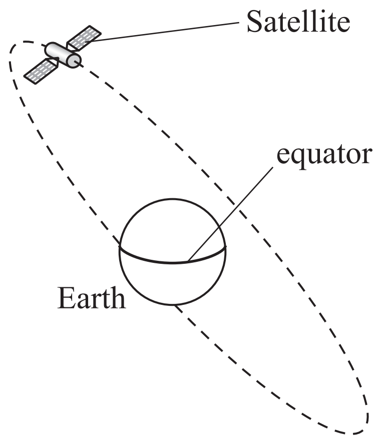
P 4 3 3 2 4 A 0 9 2 4

14 The Global Positioning System (GPS) is a network of satellites orbiting the Earth. The satellites are arranged in six different orbital planes at a height of 20 200 km above the Earth's surface. Wherever you are, at least four GPS satellites are 'visible' at any time. The diagram shows a single satellite.



(a) Show that the GPS satellites take about 40 000 s (12 hours) to complete one orbit about the Earth.

mass of the Earth $M_E = 6.0 \times 10^{24}$ kg

radius of the Earth $R_E = 6400$ km

(4)

(b) Communications satellites are placed in orbit with an orbital time of 24 hours.

Explain why it is essential for communications satellites to be in such an orbit.

(2)

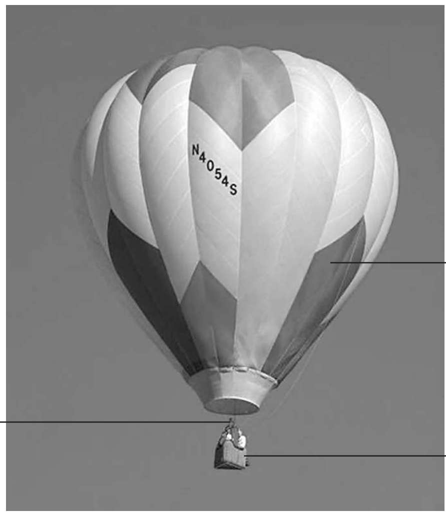
(c) State how the orbit of a GPS satellite differs from that of a communications satellite.

(2)

(Total for Question 14 = 8 marks)

P 4 3 3 2 4 A 0 1 1 2 4

15 Hot air ballooning is one way to explore the landscape. Air in a balloon is heated from underneath by a set of burners and the balloon starts to rise.



(a) Explain why heating the air causes the balloon to rise.

(2)

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(b) In 1991, Per Lindstrand and Richard Branson become the first people to cross the Pacific in a hot air balloon.

With a volume of 7.4×10^4 m^3 the balloon was, at the time, the largest ever built.

Calculate the energy supplied by the burners to heat the air from 20.0 °C to 35.0 °C.

average density of air in the balloon = 1.20 kg m^{-3}

specific heat capacity of air = 1010 J kg^{-1} K^{-1}

(3)

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Energy = ...

(c) The first balloons used were filled with hydrogen and sealed to keep the volume constant. As the balloon rose there would be changes in the pressure of the hydrogen due to the temperature changes of the atmosphere.

(i) Calculate the new pressure exerted by the hydrogen if the temperature changed from 20.0 °C to −5.0 °C, as the balloon rose from ground level.

pressure exerted by the hydrogen in the balloon at ground level = 1.01×10^5 Pa

(2)

New pressure = ...

(ii) State **two** assumptions that you must make to calculate this change.

(2)

*(iii) By considering the motion of molecules in the gas, explain why the pressure exerted by the gas decreases as it cools.

(3)

(Total for Question 15 = 12 marks)

16 According to astronomers in Denmark and Australia a common type of active galactic nucleus (AGN) could be used as an accurate “standard candle” for measuring cosmic distances. The technique has been used to measure distances corresponding to redshifts significantly larger than was previously possible.

(a) (i) State what is meant by a standard candle.

(1)

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(ii) Explain how a standard candle is used to measure cosmic distances.

(2)

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(b) (i) State what is meant by redshift.

(1)

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(ii) Calculate the distance to a galaxy with a redshift $z = 0.12$

$H_0 = 2.1 \times 10^{-18}\ \mathrm{s^{-1}}$

(2)

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Distance to galaxy = ...

*(c) Discuss how astronomers were led to propose the existence of dark matter and the consequences of its existence for the ultimate fate of the universe.

(3)

(d) Explain why the observable universe has a finite size.

(2)

(Total for Question 16 = 11 marks)

17 Positron emission tomography (PET) is a nuclear medicine imaging technique. Pairs of gamma rays, produced when positrons from a radioisotope annihilate with electrons, are detected to form the image.

Radioisotopes used in PET scanning are typically isotopes with short half-lives such as carbon-11. Carbon-11 has a half-life of 1220 s and decays by positron emission to stable boron-11. Positrons are the antiparticles to electrons.

(a) Explain what is meant by a radioactive atom.

(2)

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(b) Complete the equation for the decay of carbon-11.

$$^{11}_{6}\mathrm{C} \rightarrow {}^{\cdots}_{\cdots}\mathrm{B} + {}^{\cdots}_{\cdots}\mathrm{e}^{+} + {}^{0}_{0}\nu_{e}$$

(2)

(c) Calculate the energy in joules released in a positron decay of carbon-11.

	Mass / MeV/c^2
positron	0.511
carbon	10 253.6
boron	10 252.2

(3)

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Energy = ... J

(d) Explain why carbon-11 is a relatively safe radioisotope to use within the body.

(2)

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(e) A patient was injected intravenously with a radioactive compound containing carbon-11 with an activity of 1.58×10^6 Bq.

The sample was prepared 3600 s before it was administered to the patient.

Calculate the activity of the sample when it was prepared.

(4)

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Activity of the sample = ...

(Total for Question 17 = 13 marks)

18 A baby-bouncer is a light harness, into which a baby can be placed, suspended by a vertical spring.

The height of the baby-bouncer is adjusted so that the baby's feet are a few centimetres above the floor when the baby is in equilibrium in the harness. If the baby is then displaced downwards and released, the system oscillates vertically with simple harmonic motion.

It is stated in a textbook that "a mass-spring system that obeys Hooke's law will lead to simple harmonic motion when the mass is displaced."

*(a) Explain why a system consisting of a mass and a spring that obeys Hooke's law may be set into simple harmonic motion.

(3)

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(b) The acceleration experienced by a baby of mass 8.2 kg is 0.49 m s^{-2} when the displacement from the equilibrium position is 3.0 cm.

Show that the period of vertical oscillations for this baby is about 1.6 s.

(3)

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(c) The amplitude of the oscillations quickly decreases, so the baby has to keep kicking on the floor to maintain them.

(i) State the name given to oscillations that die away quickly.

(1)

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(ii) State the name that is given to oscillations such as those that are kept going by the baby kicking on the floor.

(1)

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(iii) If the baby kicks on the floor at a certain frequency, the amplitude of the bounces can be made to increase to a maximum.

Name this effect and calculate the frequency at which it occurs.

(2)

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Frequency = ...

(d) The baby is replaced by a baby of less mass. This baby also kicks to produce maximum amplitude of oscillation. Without further calculation, explain how the frequency at which the baby must kick compares to that for the larger mass baby.

(2)

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(Total for Question 18 = 12 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 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	$P = VI$ $P = I^2R$ $P = V^2/R$ $W = VIt$ $\% \text{ efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100$ $\% \text{ efficiency} = \dfrac{\text{useful power output}}{\text{total power input}} \times 100$
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	$\mathrm{d}N/\mathrm{d}t = -\lambda N$
	$\lambda = \ln 2/t_{\frac{1}{2}}$
	$N = N_0 e^{-\lambda t}$

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	$v = H_0 d$