Write your name here

Surname	Other names

Pearson Edexcel
International
Advanced Level

Centre Number

Candidate Number

Physics

Advanced
Unit 5: Physics from Creation to Collapse

Monday 6 November 2017 – Morning
Time: 1 hour 35 minutes

Paper Reference
WPH05/01

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.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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P 5 0 7 9 6 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 A Geiger counter is used to determine the count rate from a radioactive source. The count rate is unchanged when a 5 mm thickness of aluminium is placed between the counter and the source. The count rate reduces significantly when a thin sheet of lead is placed between the counter and the source.

Which of the following is the radiation emitted by the source?

☐ **A** α-particles

☐ **B** β-particles

☐ **C** β-particles and γ-radiation

☐ **D** γ-radiation

(Total for Question 1 = 1 mark)

2 Protactinium has a half-life of 70 s.

Which of the following is the time taken for 75% of a sample of protactinium to decay?

☐ **A** 35 s

☐ **B** 70 s

☐ **C** 140 s

☐ **D** 210 s

(Total for Question 2 = 1 mark)

3 Two containers are filled with two gases, A and B. The gases have the same temperature, but the mean squared speed of the molecules in A is twice the mean squared speed of the molecules in B.

Which of the following is the ratio of the mass of a molecule in A to the mass of a molecule in B?

☐ **A** 0.25

☐ **B** 0.5

☐ **C** 2

☐ **D** 4

(Total for Question 3 = 1 mark)

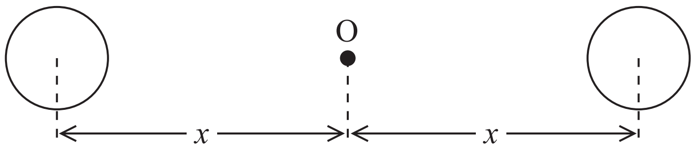
4 The temperature of a sample of helium gas is increased.

Which row of the table shows changes that could maintain the pressure of the sample at a constant value?

	Volume of the container	Number of helium molecules
☒ **A**	decrease	remain constant
☒ **B**	decrease	increase
☒ **C**	increase	decrease
☒ **D**	remain constant	increase

(Total for Question 4 = 1 mark)

5 Two identical stars each of mass M are orbiting about point O in a binary system, as shown.



Which of the following is the gravitational field strength at O?

☒ **A** 0

☒ **B** $\dfrac{GM}{2x^2}$

☒ **C** $\dfrac{GM}{x^2}$

☒ **D** $\dfrac{2GM}{x^2}$

(Total for Question 5 = 1 mark)

6 A guitar string is set into vibration by plucking it at its centre.

Which of the following quantities, if altered, would change the wavelength of the vibration of the string?

☒ **A** density of the string

☒ **B** diameter of the string

☒ **C** length of the string

☒ **D** tension of the string

(Total for Question 6 = 1 mark)

P 5 0 7 9 6 A 0 3 2 4

7 Electromagnetic radiation of frequency 1.42 GHz is emitted by a stellar source.
The radiation is received by an observer on Earth who measures the frequency as 1.44 GHz.

The difference in the two frequency values is because

☒ **A** the source is approaching the Earth.

☒ **B** the source is receding from the Earth.

☒ **C** the Earth is receding from the source.

☒ **D** the Earth is rotating about its axis.

(Total for Question 7 = 1 mark)

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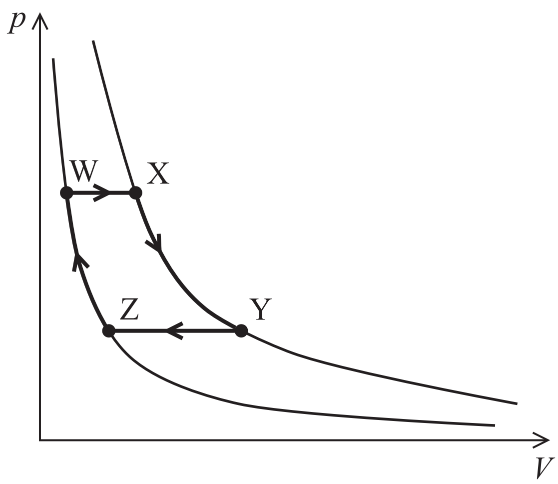
8 The graphs show how the pressure p exerted by a fixed mass of gas varies with the volume V of the gas, for two different temperatures.
The gas is made to expand and then contract in the cycle WXYZW, as shown.



Select the stage of the cycle during which the temperature of the gas increases.

☒ **A** W → X

☒ **B** X → Y

☒ **C** Y → Z

☒ **D** Z → W

(Total for Question 8 = 1 mark)

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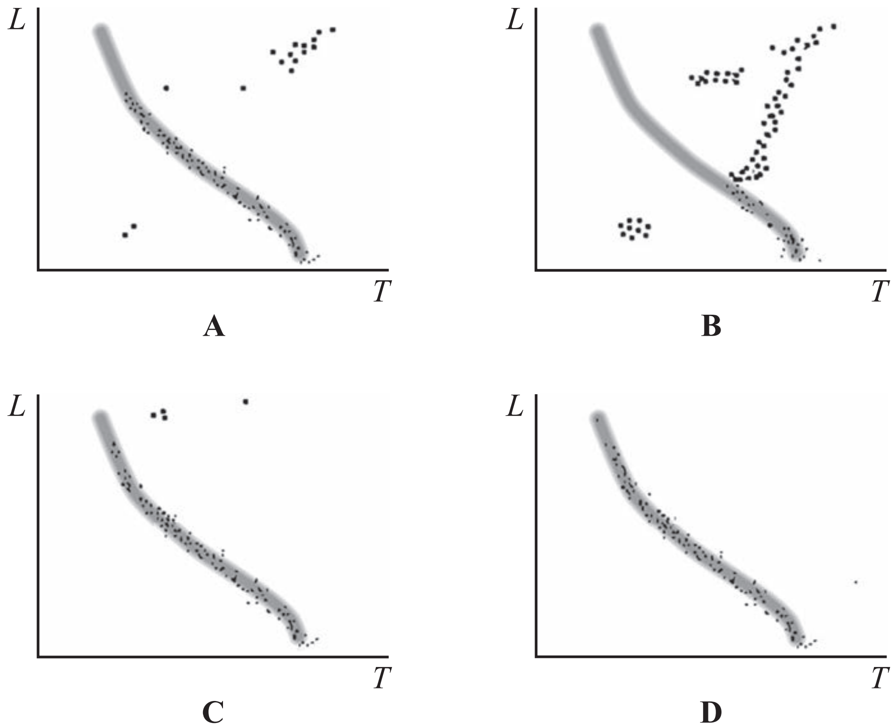
Questions 9 and 10 relate to the Hertzsprung-Russell diagrams below.

A star cluster is a group of stars which were all formed at about the same time.
The diagrams are drawn for a star cluster at different stages of its evolution.



9 Select the diagram for the star cluster when it is closest to the beginning of its evolution.

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 9 = 1 mark)

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10 Select the diagram for the star cluster when its first red giants have run out of fuel and collapsed.

☒ **A**

☒ **B**

☒ **C**

☒ **D**

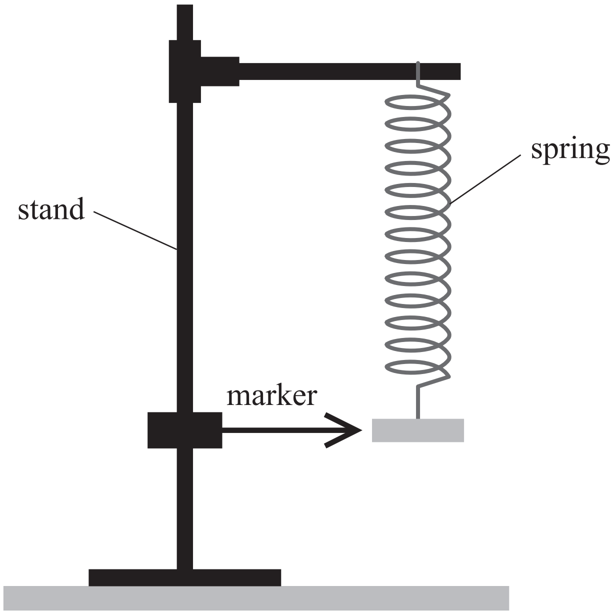
(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 A student is carrying out an experiment to determine the time period of vertical oscillations of a mass attached to a spring.



The student places a marker at the centre of the oscillation.

Explain why the centre of the oscillation is the best place to use as a reference point.

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(Total for Question 11 = 3 marks)

12 The Ancient Greeks believed that all stars were the same distance from the Earth.

(a) Describe how astronomers today are able to determine the distance to nearby stars.

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(b) Explain how two stars which appear to be equally bright might not be the same distance from the observer.

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(Total for Question 12 = 6 marks)

13 A hot drinks dispenser fills a cup with 0.25 kg of water at a temperature of 85 °C in 9.4 s.

(a) The water enters the dispenser at a temperature of 22 °C.

Calculate the electrical power of the heater in the dispenser.

(3)

specific heat capacity of water = $4200\,\mathrm{J\,kg^{-1}\,K^{-1}}$

Electrical power of heater = ...

(b) Suggest why the actual power of the heater may differ from the value calculated in (a).

(2)

(Total for Question 13 = 5 marks)

***14** A partially inflated balloon is placed under a bell jar, as shown in Diagram 1.
An airtight seal is made at the base of the bell jar and a vacuum pump is turned on.
After several minutes, the volume of the balloon has increased, as shown in Diagram 2.

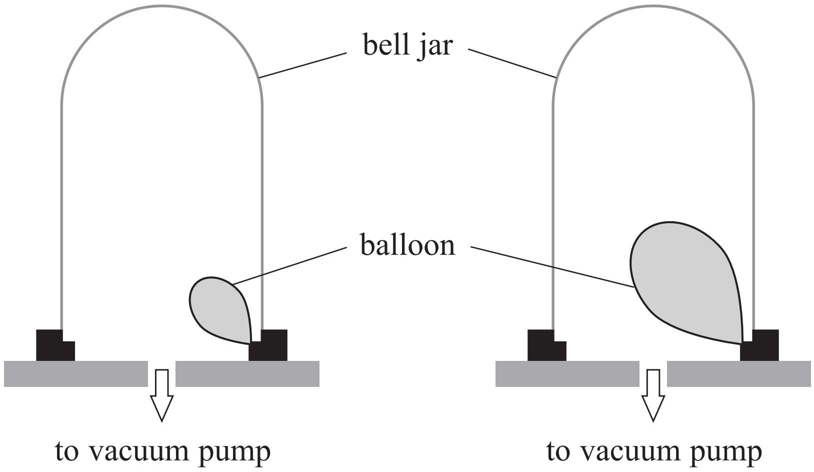

Diagram 1 **Diagram 2**

Explain, using ideas of molecular momentum, why the volume occupied by the balloon increases.

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(Total for Question 14 = 5 marks)

15 The binding energy per nucleon varies over the range of known nuclei.

(a) The table shows the masses of a nucleus of hydrogen-3 and its nucleons.

	mass / 10^{-27} kg
hydrogen-3	5.008 75
neutron	1.675 40
proton	1.673 09

(i) Show that the binding energy of a nucleus of hydrogen-3 is about 8.5 MeV.

(4)

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(ii) The binding energy of a nucleus of helium-3 is 7.7 MeV.

Explain whether the hydrogen-3 nucleus or the helium-3 nucleus should be more stable.

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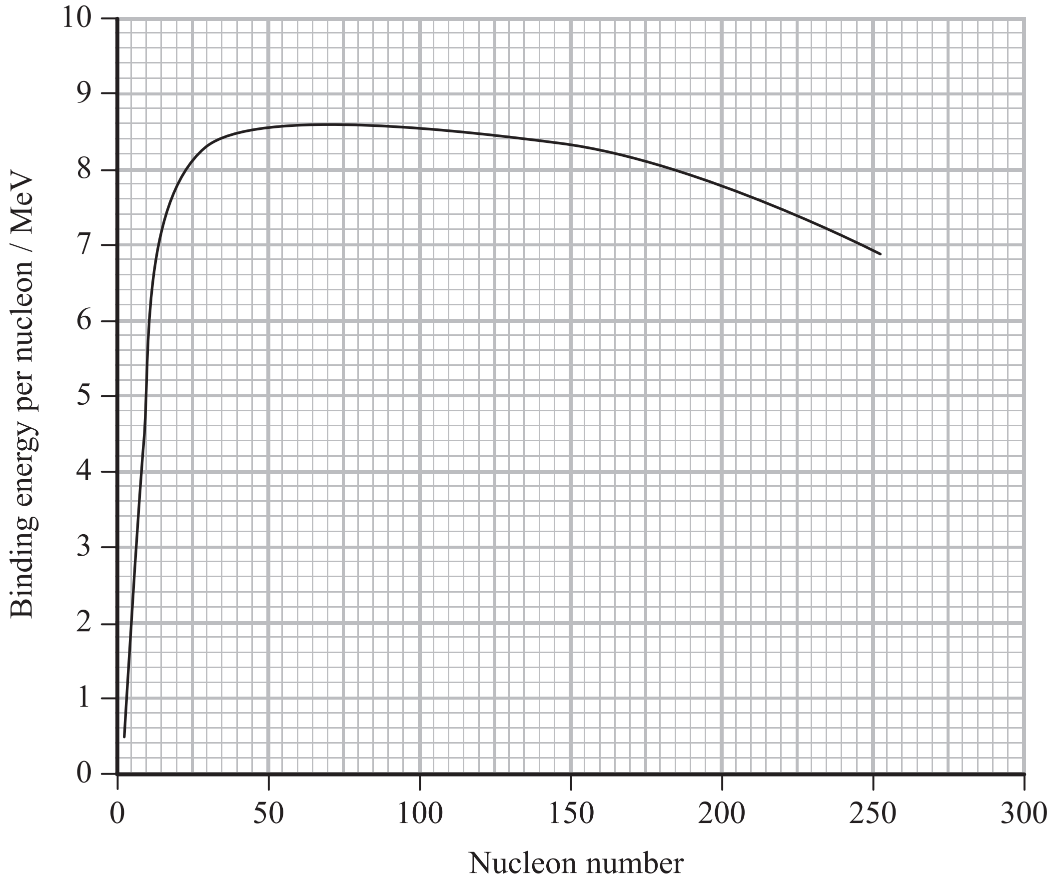
(b) The graph of binding energy per nucleon for a range of nuclei is shown.



Explain, with reference to the graph, how the fission of uranium-235 nuclei can lead to a large output of energy.

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(Total for Question 15 = 9 marks)

16 The Sun is a typical star which emits electromagnetic radiation in a spectrum with a peak at a wavelength of 0.50×10^{-6} m.

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

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(b) A textbook states "the extreme conditions in its core enable the Sun to fuse hydrogen".

State the extreme conditions necessary for fusion in the core of the Sun.

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(c) When the Sun nears the end of its life it will become a red giant star. When it has depleted the hydrogen in its core its surface temperature will decrease and its radius will increase. Its luminosity L_1 will change to a new value L_2.

Calculate the ratio $\frac{L_2}{L_1}$.

(3)

initial surface temperature = 5700 °C
final surface temperature = 2700 °C

initial radius = 6.96×10^{8} m
final radius = 1.26×10^{11} m

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$\frac{L_2}{L_1}$ = ...

P 5 0 7 9 6 A 0 1 2 2 4

*(d) The Sun is a relatively low-mass main sequence star. Some main sequence giant stars are much more massive.

A student states "A star with fifty times the mass of the Sun contains much more hydrogen than the Sun. Such a star should therefore spend longer than the Sun on the main sequence."

Discuss the validity of this statement.

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(Total for Question 16 = 11 marks)

17 A fuel rod in a nuclear reactor contains uranium-238. When a nucleus of uranium-238 absorbs a neutron, the nucleus decays to neptunium-239 which then decays to plutonium.

(a) Complete the nuclear equation for the decay of the neptunium.

(2)

$$^{239}_{93}\text{Np} \rightarrow \,^{\dots\dots}_{\dots\dots}\text{Pu} + \,^{\dots\dots}_{\dots\dots}\beta^{-}$$

(b) Neptunium-239 nuclei are produced at a constant rate in the fuel rod. Eventually, the number of neptunium-239 nuclei in the fuel rod will reach a maximum.

(i) Explain how the rate of decay of neptunium-239 initially varies with time.

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(ii) Give a reason why the number of neptunium-239 nuclei in the fuel rod will eventually reach a maximum.

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(iii) The rate at which neptunium-239 nuclei are produced in the fuel rod is $1.85 \times 10^7\ s^{-1}$.

Calculate the maximum number of neptunium-239 nuclei in the fuel rod.

(3)

half-life of neptunium-239 = 2.04×10^5 s

Maximum number of neptunium-239 nuclei = ...

(c) Explain why the core of a nuclear reactor is surrounded by up to six metres of concrete.

(2)

(Total for Question 17 = 10 marks)

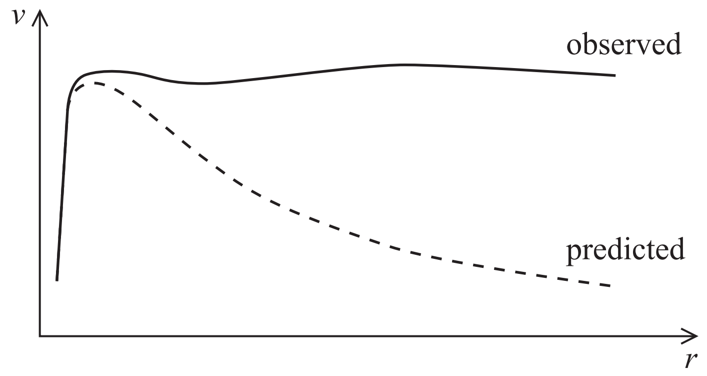
18 Almost fifty years ago, a physicist found evidence for the existence of dark matter from her observations of the Andromeda Galaxy. The rotation of this spiral galaxy seemed to contradict Newton's laws.

(a) Show that the velocity v of a star of mass m, in an orbit of radius r about a larger mass M, is given by

$$v = \sqrt{\frac{GM}{r}}$$

(2)

(b) The stars in the Andromeda Galaxy are in orbit about the centre of the galaxy. Most of the visible mass of the galaxy is concentrated at its centre. The graph shows how the velocity v of stars varies with distance r from the centre of the galaxy.



Explain how dark matter may account for the difference between the observed velocity and the predicted velocity of stars far away from the centre of the galaxy. You may assume that, for a star orbiting at radius *r*, all the matter inside the sphere of radius *r* acts like a point mass at the centre.

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(c) The exact amount of dark matter in the Universe is unknown.

Explain how the amount of dark matter might be expected to determine the ultimate fate of the Universe.

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(Total for Question 18 = 8 marks)

19 A loudspeaker is designed to produce the low frequency notes in a music system. The loudspeaker contains a cone that oscillates when it is supplied with an electrical signal. A signal of frequency 120 Hz is supplied to the loudspeaker and the cone moves with simple harmonic motion.

(a) State what is meant by simple harmonic motion.

(2)

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(b) When it is producing the loudest sound, the cone has a maximum displacement of 3.0 mm from the equilibrium position.

Calculate the maximum acceleration of the cone.

(3)

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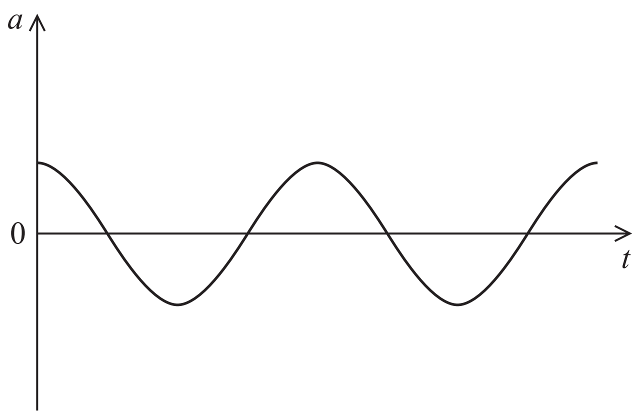
Maximum acceleration of cone = ...

(c) The graph shows how acceleration a varies with time t for two cycles of oscillation of the cone.

Draw a graph, on the same axes, to show how velocity varies with time for the same two cycles.

(2)



(d) The loudspeaker is inside a casing.

The casing is designed so that its natural frequency of oscillation is much greater than 120 Hz.

Explain an advantage of this.

(3)

(e) Loudspeaker casings often contain pieces of absorbent material at positions within the casing where the oscillations are greatest. This dampens the oscillations of the casing.

Explain why this damping is necessary.

(3)

(Total for Question 19 = 13 marks)

TOTAL FOR SECTION B = 70 MARKS
TOTAL FOR PAPER = 80 MARKS

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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	$P = VI$ $P = I^2R$ $P = V^2/R$ $W = VIt$

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

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

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	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

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

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	$v = H_0 d$