Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
International
Advanced Level

Centre Number | | | | | |

Candidate Number | | | | |

Monday 7 January 2019

Afternoon (Time: 1 hour 35 minutes) | Paper Reference **WPH04/01**

Physics

Advanced

Unit 4: Physics on the Move

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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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 Which of the following units is equivalent to the farad?

☒ **A** C J^{-1}

☒ **B** C V^{-1}

☒ **C** J C^{-1}

☒ **D** V C^{-1}

(Total for Question 1 = 1 mark)

---

2 A potential difference V is applied across two identical capacitors of capacitance C connected in series.

Which of the following expressions is the total energy stored on the capacitors?

☒ **A** $\frac{1}{4}CV^2$

☒ **B** $\frac{1}{2}CV^2$

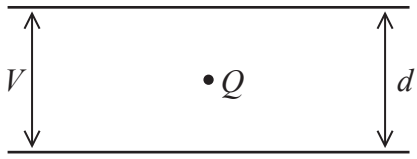
☒ **C** CV^2

☒ **D** $2CV^2$

(Total for Question 2 = 1 mark)

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3 Two parallel conducting plates are separated by a distance d. A potential difference V is applied between the plates and a charge Q is placed halfway between them, as shown.



Which of the following gives the magnitude of the force acting on the charge?

☒ **A** VQd

☒ **B** $\frac{VQ}{2d}$

☒ **C** $\frac{Vd}{Q}$

☒ **D** $\frac{VQ}{d}$

(Total for Question 3 = 1 mark)

4 A current-carrying wire is placed perpendicular to a magnetic field of magnetic flux density 0.05 T. The length of the wire in the field is 10 cm and the force on the wire is 2×10^{-3} N.

Which of the following is the current in the wire?

☒ **A** 1×10^{-5} A

☒ **B** 1×10^{-3} A

☒ **C** 4×10^{-3} A

☒ **D** 4×10^{-1} A

(Total for Question 4 = 1 mark)

5 Which row of the table shows the quark structures of a meson and its anti-meson?

	meson	anti-meson
☒ **A**	$\bar{u}\,d$	$u\,\bar{d}$
☒ **B**	$u\,\bar{d}$	$\bar{d}\,u$
☒ **C**	$u\,\bar{u}\,d$	$\bar{u}\,u\,\bar{d}$
☒ **D**	$u\,u\,d$	$\bar{u}\,\bar{u}\,\bar{d}$

(Total for Question 5 = 1 mark)

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6 A particle has mass 3.4 GeV/c^2.

Which of the following gives the mass of the particle in kg?

☒ **A** $3.4 \times 10^9 \times 1.6 \times 10^{-19} / 3 \times 10^8$

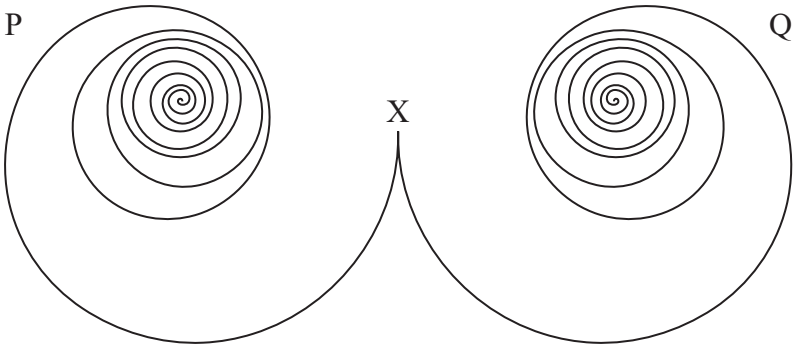
☒ **B** $3.4 \times 10^9 / 1.6 \times 10^{-19} \times (3 \times 10^8)^2$

☒ **C** $3.4 \times 10^9 \times 1.6 \times 10^{-19} \times (3 \times 10^8)^2$

☒ **D** $3.4 \times 10^9 \times 1.6 \times 10^{-19} / (3 \times 10^8)^2$

(Total for Question 6 = 1 mark)

7 The diagram shows the tracks of two particles, P and Q, created from an original particle at point X.



Which of the following can be concluded from this diagram?

☒ **A** P and Q have equal and opposite momentum.

☒ **B** The original particle had no charge.

☒ **C** The original particle was stationary.

☒ **D** There is a magnetic field acting into the page.

(Total for Question 7 = 1 mark)

8 The drum of a washing machine rotates at a rate of 1200 rotations per minute.

What is its angular velocity in radians per second?

☒ **A** 20

☒ **B** 63

☒ **C** 126

☒ **D** 191

(Total for Question 8 = 1 mark)

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9 A body of mass m has momentum p and kinetic energy E_K.

Which of the following is the kinetic energy of a body of mass $2m$ and momentum $2p$?

☒ **A** E_K

☒ **B** $2\,E_K$

☒ **C** $4\,E_K$

☒ **D** $8\,E_K$

(Total for Question 9 = 1 mark)

10 Electrons can be used to investigate atomic nuclei.

Which of the following is **not** a reason why electrons can be used for such an investigation?

☒ **A** Electrons can be accelerated to very high speeds.

☒ **B** Electrons can have wavelengths similar to the size of atomic nuclei.

☒ **C** Electrons have negative charge.

☒ **D** Electrons undergo diffraction.

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

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SECTION B

Answer ALL questions in the spaces provided.

11 The photograph shows an aeroplane which is powered by two engines.



When the aeroplane is cruising, air enters the engines at a speed of 252 m s^{-1} and is ejected at a higher speed, providing the thrust for the aeroplane. The mass of air ejected by one of the engines in 1 minute is 34 600 kg.

The total thrust provided by the engines is 138 kN.

Calculate the speed, relative to the aeroplane, at which the air is ejected by the engines.

(4)

Speed of air = ...

(Total for Question 11 = 4 marks)

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12 In a science fiction film, a spaceship has engines that use antimatter. Helium and anti-helium are collided in the engines.

(a) Describe the particles making up the helium atoms in terms of the standard quark-lepton model.

(3)

(b) Calculate the energy released when an atom of helium annihilates an atom of anti-helium.

mass of helium atom = 6.64×10^{-27} kg

(2)

Energy = ...

(Total for Question 12 = 5 marks)

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13 The Aurora Borealis (Northern Lights) are colourful visual displays seen above the North Pole of the Earth. They are created by interactions between air molecules in the upper atmosphere and charged particles from the solar wind captured by the Earth's magnetic field.

(a) The Aurora also produces radio waves. Charges following a circular path emit electromagnetic radiation at the frequency of their circular motion.

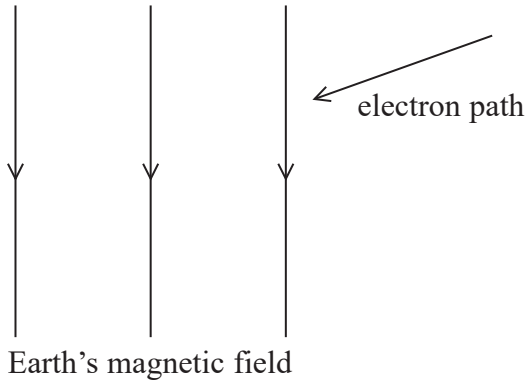
Show that an electron with a speed of $400\,\text{km}\,\text{s}^{-1}$ will emit radiation with a frequency of about 200 kHz if it is moving perpendicular to a magnetic field with magnetic flux density $6.8\,\mu\text{T}$.

(4)

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(b) Cosmic ray particles entering the Earth's magnetic field follow spiral paths through the atmosphere.

In the region of the North Pole, the magnetic field is vertically downwards.
The diagram shows an electron entering a section of uniform magnetic field.



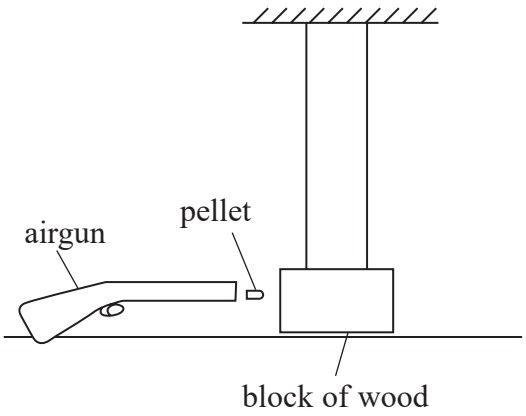
Explain why the electron follows a clockwise spiral path downwards, as seen from above.

(3)

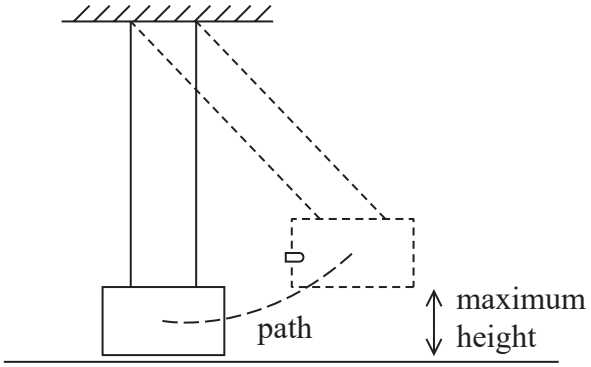
(Total for Question 13 = 7 marks)

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14 In the UK, the maximum legal speed for a pellet fired from an airgun is 184 m s^{-1}.
The diagram shows a suspended block of wood used in a school laboratory to determine the speed of an airgun pellet.



A pellet is fired from the airgun into the block of wood, as shown above.



The pellet stays in the block of wood. The block of wood and pellet together then move along the path shown. The maximum height reached is measured.

In a particular experiment, the maximum height reached is 6.0 cm.

mass of pellet = 0.93 g

mass of pellet and block of wood together = 150 g

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(a) Show that the speed of the block of wood immediately after it is struck by the pellet is about $1\,m\,s^{-1}$.

(3)

(b) Determine whether the pellet is fired at a speed below the maximum legal speed of $184\,m\,s^{-1}$.

(3)

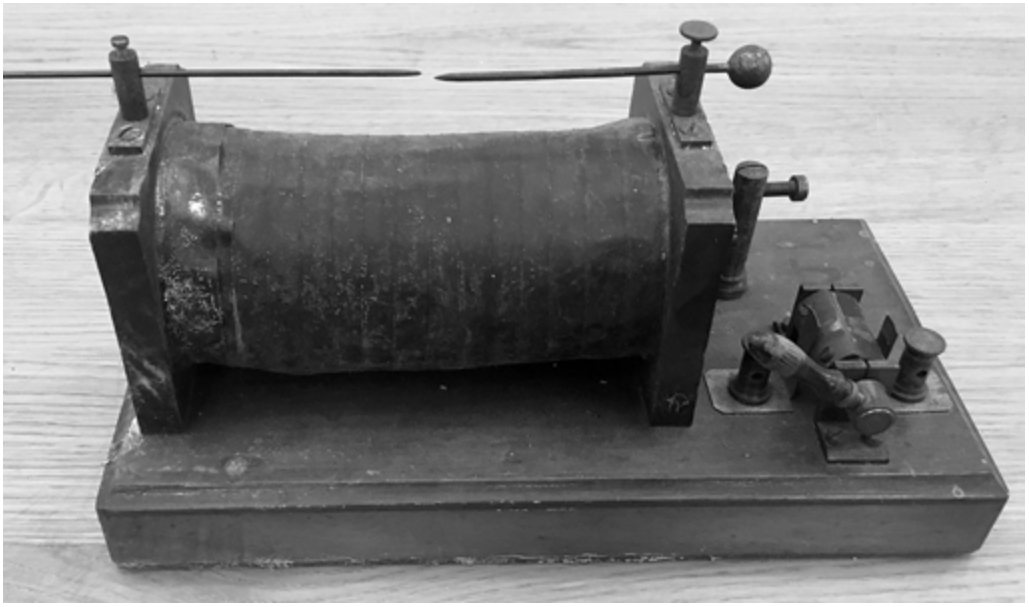
(c) Determine whether the interaction between the pellet and the block of wood is an elastic collision. Your answer should include suitable calculations.

(2)

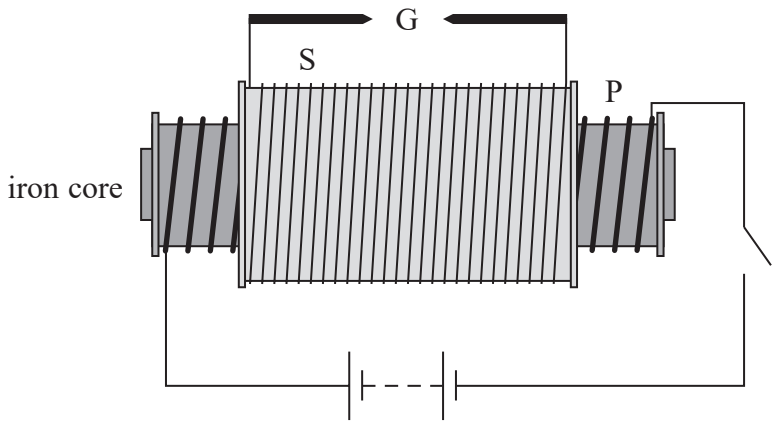
(Total for Question 14 = 8 marks)

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15 The photograph shows a spark coil, a device used in early experiments on electricity.



The diagram shows the parts of the spark coil.



A coil of wire P is wound around an iron core. A second coil S is wound around P. The ends of S are connected to two thin metal rods with a gap G between them, known as the spark gap.

With the switch closed there is a current in P. When the switch is opened, a large potential difference is produced across S and a spark is observed across G.

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*(a) Explain how a potential difference is produced across the ends of S.

(3)

(b) The potential difference across G is 110 kV.

Calculate the time taken for the magnetic flux in the core to decrease to zero when the switch is opened.

number of turns in S = 42 000
cross sectional area of iron core = 1.4×10^{-3} m^2
maximum magnetic flux density = 7.4 T

(3)

Time taken = ...

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(c) Sparks form when the electric field strength in the gap exceeds $3 \times 10^6\,V\,m^{-1}$ so the air becomes conducting for a short time.

Different spark coils produce different potential differences.

The maximum sizes of gap for which a spark is formed for different potential differences are shown in the table.

Potential difference / kV	Maximum gap for which a spark is formed / cm
110	10
150	20
190	30
230	40

(i) Explain how the data in the table show that the field in the gap is non-uniform.

(2)

(ii) Sketch the electric field in the gap.

(2)

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(Total for Question 15 = 10 marks)

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16 The structure of the atom was investigated in the early 1900s by directing alpha particles at thin metal foil and measuring the angles through which the particles were deflected.

(a) Explain why these experiments were carried out in a vacuum.

(2)

(b) In one series of experiments, about 1 in 8000 alpha particles directed at thin gold foil were deflected through angles greater than 90°.

Explain how this provided evidence for atoms having a concentration of charge in a central nucleus.

(2)

*(c) The angle at which the greatest number of alpha particles was detected for gold was 2.1°.

The experiment was repeated for other metal foils. The results are shown in the table.

Metal	Proton number	Angle / °
Gold	79	2.1
Silver	47	1.5
Copper	29	1.1
Aluminium	13	0.6

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Explain the pattern of results in the table.

(3)

(d) These experiments provided evidence for a nuclear atom. Bohr suggested that electrons can only orbit the nucleus at specific distances from the nucleus.
De Broglie developed this idea by stating that the lowest possible orbit is where the circumference of the orbit is equal to the de Broglie wavelength for the electron.

Show, by considering the force keeping the electron in orbit around a hydrogen nucleus, that this statement is true.

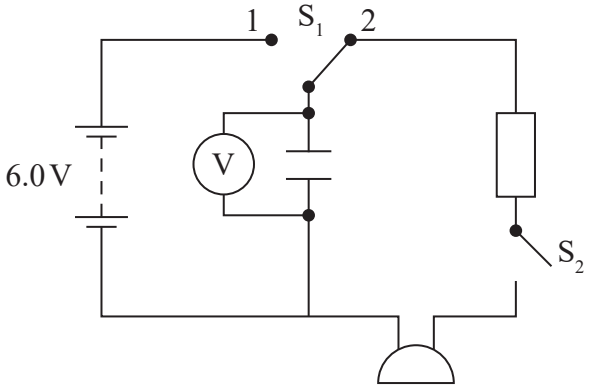
radius of orbit = 5.29×10^{-11} m

(5)

(Total for Question 16 = 12 marks)

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17 The circuit shown is designed to test reaction time.



The following instructions will test the reaction time of a student.

- Hide switch S_1 from the student.
- Move S_1 to position 1 and wait until the voltmeter reads 6.0 V.
- Close switch S_2.
- At a random time, move S_1 to position 2 so the buzzer sounds.
- As soon as the buzzer sounds, the student should open S_2.
- Use the new voltmeter reading to calculate the student's reaction time.

*(a) Explain how the circuit works to test reaction time.

(3)

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(b) When the circuit is used with a particular student, the final voltmeter reading is 0.70 V.

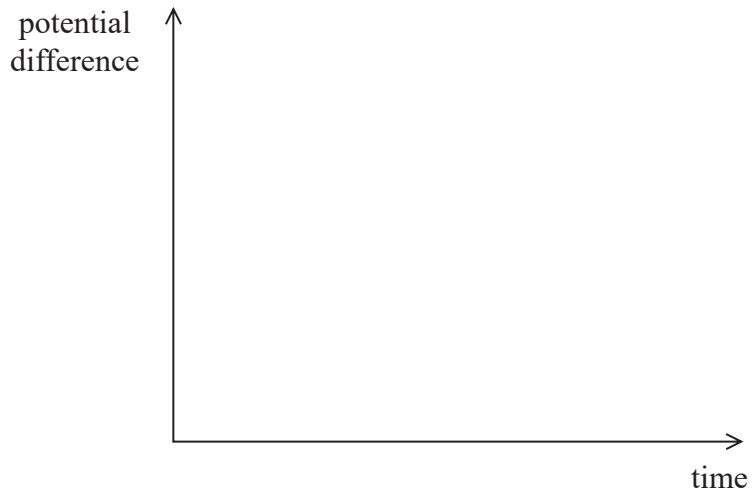
(i) Show that the student's reaction time is about 0.2 s.

capacitance of capacitor = 270 μF
resistance of resistor = 332 Ω
resistance of buzzer = 38 Ω

(2)

(ii) Sketch the graph of potential difference across the capacitor against time when S_1 is moved to position 2 and S_2 is closed.

(2)



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(iii) Explain how to make the circuit more sensitive for a reaction time of 0.2 s.
You should refer to the shape of your graph in (ii).

(4)

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(Total for Question 17 = 11 marks)

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18 The Moscow Meson Factory linear accelerator (linac) is used in the production of particular isotopes for medical use.

(a) Strontium-82 is created by bombarding rubidium-85 with protons.

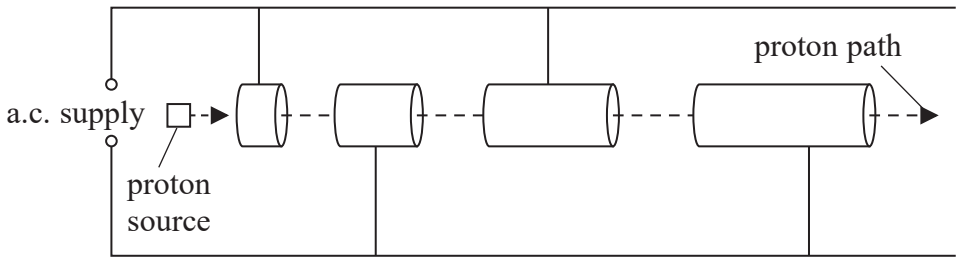
Complete the nuclear equation to show this process.

(2)

$$\ldots\ldots p + {}^{85}_{37}Rb \rightarrow {}^{82}Sr + \ldots\ldots \times \ldots\ldots n$$

(b) The Moscow Meson Factory accelerates protons up to energies of 160 MeV before colliding them into rubidium.

The first 100 MeV is supplied using a linac with drift tubes, as shown.

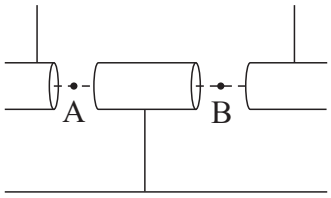


(i) Explain how the linac accelerates the protons.

(4)

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(ii) The diagram shows part of the path of a proton in the linac. Point A and point B are at the centres of two successive gaps between drift tubes.



The a.c. supply has a frequency of 198 MHz. The average kinetic energy of the proton as it moves from A to B is 2.0 MeV.

Calculate the distance from A to B. You may assume that the proton speed is non-relativistic.

(5)

Distance = ...

(iii) When the first linacs were made, the maximum frequency for the a.c. supply was about 7 MHz.

Suggest why it is an advantage to use a much higher frequency than this.

(2)

(Total for Question 18 = 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 $E_{el} = \frac{1}{2}F\Delta x$

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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	$hf = \phi + \frac{1}{2}mv^2_{max}$

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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	$Q = Q_0e^{-t/RC}$
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	$\lambda = h/p$

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