Write your name here

Surname	Other names

Centre Number | Candidate Number

Edexcel GCE

Physics

Advanced

Unit 4: Physics on the Move

Monday 11 June 2012 – Afternoon
Time: 1 hour 35 minutes

Paper Reference
6PH04/01

You must have:
Protractor
Ruler

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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1/1/1/1/1/1/C2

P 3 9 8 5 5 A 0 1 2 8

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 ☒.

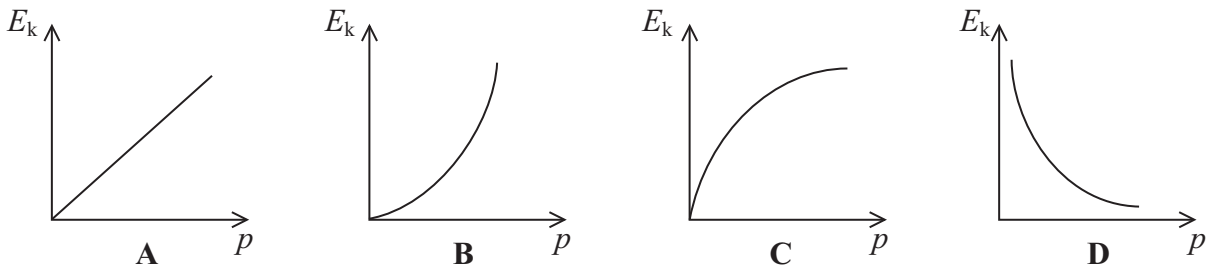
1 $^{208}_{82}Pb$ is the symbol for the heaviest, stable nucleus. The table shows possible numbers of neutrons and protons.

Which line of the table correctly shows the numbers of neutrons and protons for this nucleus?

	Number of neutrons	Number of protons
☒ **A**	82	208
☒ **B**	82	126
☒ **C**	126	82
☒ **D**	208	82

(Total for Question 1 = 1 mark)

2 A car is accelerated from rest. Which graph correctly shows how the kinetic energy E_k varies with momentum p?



☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 2 = 1 mark)

3 An inelastic collision is one in which

- ☒ **A** momentum is not conserved.
- ☒ **B** momentum and kinetic energy are not conserved.
- ☒ **C** momentum and kinetic energy are conserved.
- ☒ **D** kinetic energy is not conserved.

(Total for Question 3 = 1 mark)

4 A unit of electric field strength is

- ☒ **A** $J\ C^{-2}$
- ☒ **B** $N\ m^2\ C^{-2}$
- ☒ **C** $N\ m\ C^{-1}$
- ☒ **D** $N\ C^{-1}$

(Total for Question 4 = 1 mark)

5 A capacitor is discharging through a resistor and the time constant is 5.0 s. The time taken for the capacitor to lose half its charge is

- ☒ **A** 0.14 s
- ☒ **B** 0.81 s
- ☒ **C** 3.2 s
- ☒ **D** 3.5 s

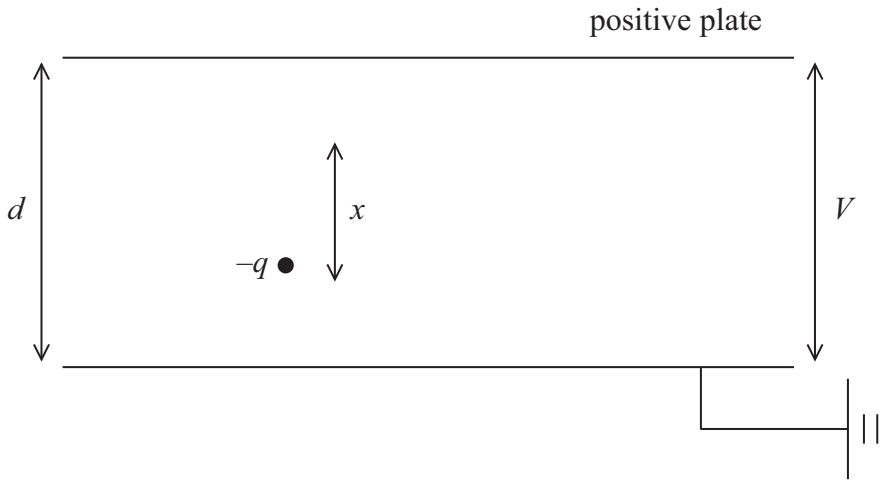
(Total for Question 5 = 1 mark)

6 Which one of the following statements does **not** help to explain why electrons can be used to probe the nuclei of atoms.

- ☒ **A** Electrons are negatively charged.
- ☒ **B** Electrons can have wavelengths similar in size to nuclear diameters.
- ☒ **C** Electrons can be accelerated to high energies.
- ☒ **D** Electrons can exhibit diffraction effects.

(Total for Question 6 = 1 mark)

7 The diagram shows two parallel plates a distance d apart. There is a potential difference V across the two plates. A particle, charge $-q$, is placed between the plates as shown. The particle is attracted to the positive plate and moves through a distance x.



Which of the following expressions gives the work done on the particle as it moves through the distance x?

☒ **A** $\frac{qV}{xd}$

☒ **B** $\frac{qVx}{d}$

☒ **C** $\frac{V}{xdq}$

☒ **D** $\frac{xV}{qd}$

(Total for Question 7 = 1 mark)

8 A coil of N turns and cross-sectional area A lies perpendicular to a magnetic field of flux density B. The magnetic flux linkage is X.

A second coil with twice the number of turns but half the cross-sectional area lies perpendicular to a magnetic field of flux density $2B$. The magnetic flux linkage with the second coil is

☒ **A** $\frac{X}{2}$

☒ **B** X

☒ **C** $2X$

☒ **D** $4X$

(Total for Question 8 = 1 mark)

9 A pion can decay to produce two leptons. Which one of the following is possible?

☒ **A** $\pi^+ \rightarrow e^+ + \nu_e$

☒ **B** $\pi^0 \rightarrow e^- + \nu_e$

☒ **C** $\pi^+ \rightarrow e^+ + e^-$

☒ **D** $\pi^0 \rightarrow \pi^+ + e^-$

(Total for Question 9 = 1 mark)

10 As a particle accelerates in a linac, it passes through drift tubes of increasing lengths. This is so that

☒ **A** the particle can be given more energy within each tube.

☒ **B** the frequency of the accelerating voltage can be constant.

☒ **C** the accelerating voltage can be as high as possible.

☒ **D** the time spent in the tube by the particle is longer.

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 The positively charged particles in the solar wind are accelerating away from the Sun. Some scientists have therefore concluded that the Sun is positively charged.

(a) Explain this conclusion.

(2)

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.....

(b) The circle below represents the Sun.

Complete the diagram to show the electric field produced by a positively-charged Sun.

(2)



(Total for Question 11 = 4 marks)

12 A spacecraft called Deep Space 1, mass 486 kg, uses an "ion-drive" engine. This type of engine is designed to be used in deep space.

The following statement appeared in a web site.

> The ion propulsion system on Deep Space 1 expels 0.13 kg of xenon propellant each day. The xenon ions are expelled from the spacecraft at a speed of 30 km s^{-1}. The speed of the spacecraft is predicted to initially increase by about 8 m s^{-1} each day.

Use a calculation to comment on the prediction made in this statement.

(4)

(Total for Question 12 = 4 marks)

13 An electron and a positron annihilate with the emission of two photons of equal energy.

Calculate the wavelength of the photons.

(5)

Wavelength = ...

(Total for Question 13 = 5 marks)

***14** A bubble chamber is a particle detector which makes use of electric and magnetic fields.

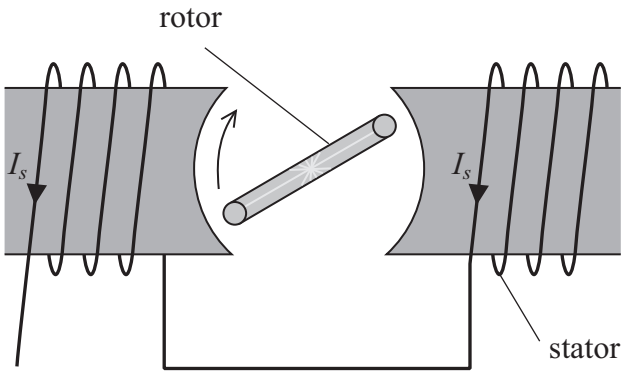
Explain the role of electric and magnetic fields in a particle detector.

(5)

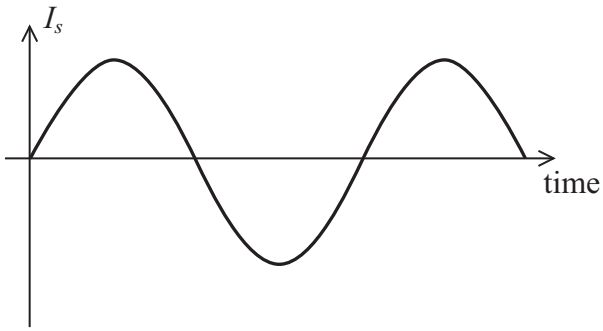
(Total for Question 14 = 5 marks)

15 The diagram represents a simple induction motor. An alternating current I_s is supplied to a stationary coil (stator). This coil is wrapped around an iron core.

A rotating coil (rotor) is shown end on in the diagram.



(a) The graph shows the variation of the alternating current I_s with time.



*(i) Explain how current is induced in the rotor coil.

(4)

(ii) Explain why the rotor turns.

(2)

(iii) State **two** ways of making the rotor turn faster.

(2)

1 .....

.....

2 .....

.....

(b) An induction motor is used to rotate the turntable in a record deck. Long-play records require the turntable to rotate at 33 revolutions per minute.

(i) Calculate the angular velocity of the turntable.

(3)

.....

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Angular velocity = ...

(ii) Calculate the acceleration of a speck of dust at the outside edge of a rotating record.

radius of record = 12.5 cm

(2)

.....

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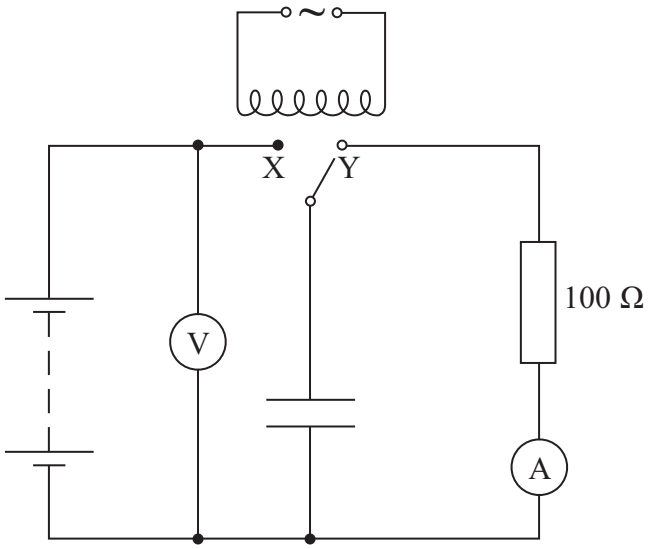
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Acceleration = ...

(Total for Question 15 = 13 marks)

16 A student is investigating capacitors. She uses the circuit below to check the capacitance of a capacitor labelled 2.2 μF which has a tolerance of ±30%.



The switch flicks between contacts, X and Y, so that the capacitor charges and discharges *f* times per second.

(a) The capacitor must discharge fully through the 100 Ω resistor.

(i) Explain why 400 Hz is a suitable value for *f*.

(3)

(ii) Show that the capacitance C can be given by

$$C = \frac{I}{fV}$$

where I is the reading on the ammeter and V is the reading on the voltmeter.

(3)

(iii) The student records I as 5.4 mA and V as 5.0 V.

Calculate the capacitance C.

(2)

$C =$ .....

(iv) Explain whether you think this value is consistent with the tolerance given for this capacitor.

(2)

(b) Calculate the energy stored on the capacitor when it is charged to a potential difference of 5.0 V.

(2)

.....

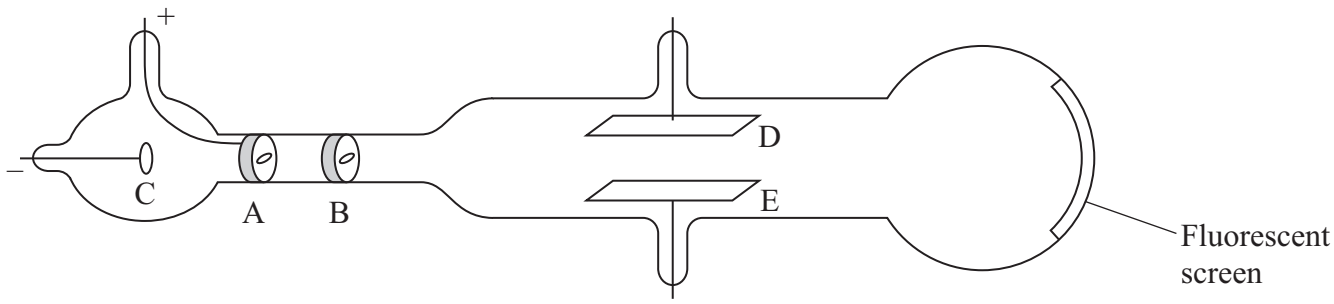
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Energy = ...

(Total for Question 16 = 12 marks)

17 J J Thomson is credited with the discovery of the electron. He measured the 'charge to mass ratio' *e/m* for the electron, using the apparatus shown.



A metal disc at C emits electrons. A positively-charged disc at A accelerates the electrons along the tube. Slits in A and B produce a narrow horizontal beam of electrons. An electric field is produced between plates D and E, which can be used to deflect the beam vertically. The final position of the beam is shown on a fluorescent screen at the end of the tube.

(a) Describe how a metal disc can be made to emit electrons.

(2)

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(b) The length of plates D and E is l. Thomson deduced that the vertical component v_v of velocity gained by the electrons as they leave the plates is given by

$$v_v = \frac{Ee}{m} \times \frac{l}{v}$$

where E is the electric field strength between the plates and v is the velocity with which the electrons entered the field.

Show that this expression is correct.

(3)

(c) Thomson determined the angle θ at which the beam was deflected.

Suggest how this angle could be determined.

(3)

(d) The angle θ is also given by

$$\tan\theta = \frac{Ee}{m} \times \frac{l}{v^2}$$

Show that this equation is correct.

(2)

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(e) Thomson replaced the electric field with a uniform magnetic field which acted over the same length as the plates. He adjusted the flux density B to obtain the same deflection on the screen.

For this arrangement he assumed that the vertical component of velocity gained by the electrons as they leave the plates is given by

$$v_V = \frac{Bev}{m} \times \frac{l}{v}$$

(i) Thomson just replaced the term eE in the equation in part (b) with Bev.

Suggest why he did this.

(1)

.....

.....

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.....

(ii) Give **two** reasons why the equation $v_V = \frac{Bev}{m} \times \frac{l}{v}$ is **not** correct.

(2)

1 .....

.....

2 .....

.....

(Total for Question 17 = 13 marks)

18 (a) Physicists were able to confidently predict the existence of a sixth quark. State why.

(1)

(b) The mass of the top quark was determined by an experiment. Collisions between protons and anti-protons occasionally produce two top quarks.

(i) How do the properties of a proton and an anti-proton compare?

(2)

(ii) After the collision the two top quarks move in opposite directions with the same speed.

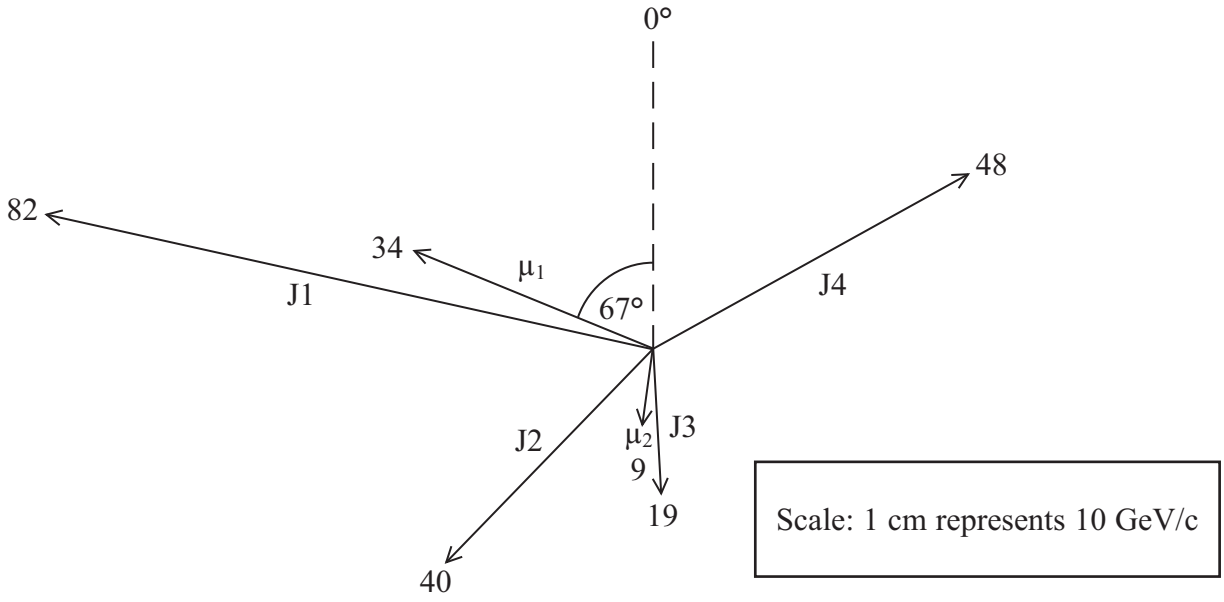
Explain why.

(2)

(c) The two top quarks decay rapidly into two muons and four jets of particles. These can be detected and their momenta measured.

The diagram shows an end-on view of the directions of the four jets (J1 to J4) of particles. The two muons are shown as μ_1 and μ_2. A muon neutrino is also produced but cannot be detected, so is **not** shown. Each momentum is measured in GeV/c.

The magnitude of the momentum for each particle or 'jet' is shown by the number printed at the end of each arrow.

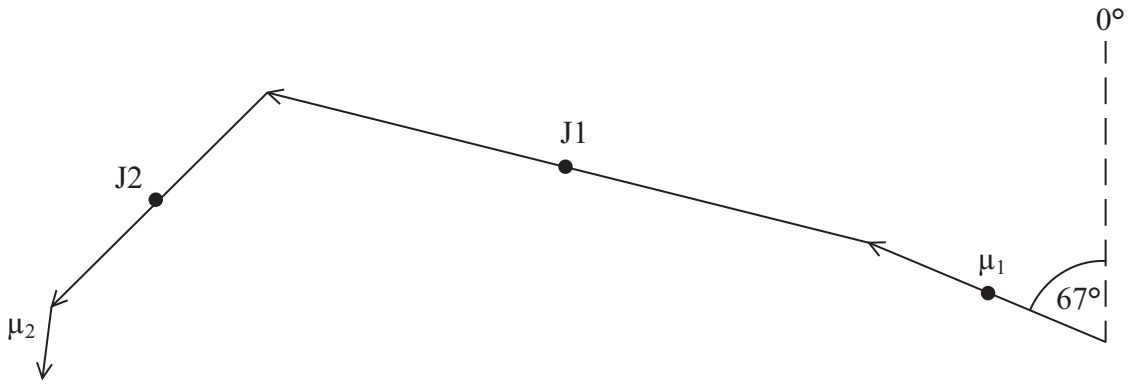


(i) Explain why GeV/c is a valid unit for momentum.

(2)

(ii) The vector diagram shown below is **not** complete. Add to the diagram arrows to represent the momenta of J3 and J4.

(2)



Scale: 1 cm represents 10 GeV/c

(iii) Complete the diagram to determine the magnitude of the momentum of the muon neutrino.

(1)

Momentum = ... GeV/c.

(iv) Show that the total energy of all the products of this event is about 300 GeV.

(1)

.....

.....

(v) Deduce the mass of a top quark in GeV/c^2.

(1)

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(vi) Suggest why it took a long time to find experimental evidence for the top quark.

(2)

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(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	$g = 9.81 \text{ m s}^{-2}$	(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	$Q = Q_0e^{-t/RC}$
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	$\lambda = h/p$