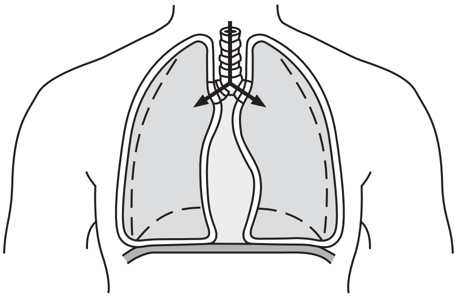
Edexcel Physics Unit 5

Topic Questions from Papers

Thermal Energy

16 When your diaphragm contracts, the pressure in the chest cavity is lowered below atmospheric pressure and air is forced into your lungs.



(a) The diaphragm contracts and the lung capacity increases by 20%. State **two** assumptions you would need to make to calculate the new pressure in the lungs if the initial pressure is known.

(2)

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(b) (i) The volume of air inhaled in a typical breath is 2.5×10^{-4} m^3 and an adult takes about 25 breaths per minute. Show that the mass of air taken into the lungs each second is about 1×10^{-4} kg.

Density of air = 1.2 kg m^{-3}

(2)

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(ii) If body temperature is 37.6 °C and the temperature outside the body is 20.0 °C, calculate the rate at which energy is used to warm air up to body temperature.

Specific heat capacity of air = 1000 J kg^{-1} K^{-1}

(2)

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Rate = ...

(Total for Question 16 = 6 marks)

SECTION B

Answer ALL questions in the spaces provided.

11 (a) A typical aerosol can is able to withstand pressures up to 12 atmospheres before exploding. A 3.0×10^{-4} m^3 aerosol contains 3.0×10^{22} molecules of gas as a propellant. Show that the pressure would reach 12 atmospheres at a temperature of about 900 K.

1 atmosphere = 1.0×10^5 Pa

(2)

*(b) Some such aerosol cans contain a liquid propellant. The propellant exists inside the can as a liquid and a vapour. Explain what happens when such an aerosol can is heated to about 900 K.

(3)

(Total for Question 11 = 5 marks)

14 A copper wire, diameter 1.63 mm and length 105 km, is to be melted down to sell for scrap.

(a) (i) Show that the mass of the wire is about 2000 kg.

density of copper = 8960 kg m^{-3}

(3)

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(ii) The wire is initially at a temperature of 25 °C and its melting point is 1085 °C. Calculate the energy required to raise the temperature of the wire to its melting point.

specific heat capacity of copper = 385 J kg^{-1} K^{-1}

(2)

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Energy = ...

(b) Once the melting point is reached, there is no further increase in temperature until all of the copper has melted. Discuss what happens to the energy of the copper atoms before and during the melting process.

(2)

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(Total for Question 14 = 7 marks)

18 Records of people walking on fire have existed for thousands of years. Walking across hot coals without getting burned does seem impossible, especially when the coals are at a temperature of 1500 K. However, as long as they do not take too long to walk across the coals, firewalkers won't get burned.

The explanation may have something to do with the relatively small amount of thermal energy involved. Although the coals are hot, the total amount of thermal energy transferred to the soles of the walker's feet is small. This is a little like quenching a red hot metal bar in a trough of cold water. The metal bar cools rapidly, transferring thermal energy to the water, but the rise in temperature of the water is quite small because of the relatively large value for the specific heat capacity of the water.

(a) Describe an experiment you could carry out to measure the specific heat capacity of a metal, assuming that you have a number of metal washers which can be heated to a known temperature in a Bunsen flame and plunged into a container of water. State the measurements that you would need to make and give the theoretical basis of the calculation that you would carry out.

What assumption would you make in calculating the specific heat capacity of the metal?

(4)

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

(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)

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

(1)

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(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 washing machine uses 15 litres of water in a hot-wash cycle in which the machine is set to wash at 60 °C.

1.0 litre of water has a mass of 1.0 kg

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(a) On a particular day the inlet temperature of the water is 15 °C. Show that the energy that must be supplied in order to bring the water to the correct temperature is about 3 MJ.

(2)

(b) (i) The power of the heater is 2.5 kW. Calculate the minimum time it takes for the water to be brought to the correct temperature.

(2)

Minimum time = ...

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

(1)

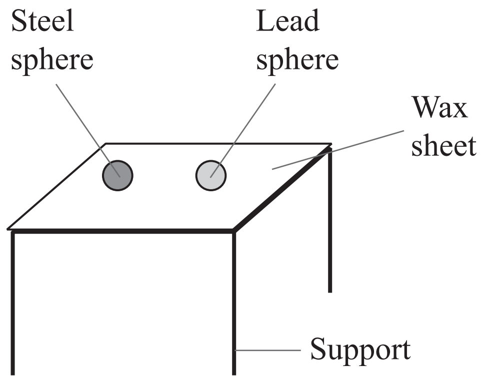
(c) The washing machine is connected to a 230 V supply. What current is drawn from the supply by the heater?

(2)

Current = ...

(Total for Question 15 = 7 marks)

12 Two metal spheres of the same size are heated to a temperature of 100 °C in a water bath. One of the spheres is made of lead and the other of steel. The spheres are then placed onto a sheet of paraffin wax as shown. Paraffin wax melts at 55 °C.



	Mass / g	**Specific heat capacity /J kg^{-1} K^{-1}**
Lead sphere	50	130
Steel sphere	34	490

(a) The steel sphere melts through the wax sheet and drops to the floor. The temperature of the steel sphere when it reaches the floor is 53 °C.

Calculate the thermal energy lost by the steel sphere from the time when it was removed from the water bath.

(2)

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Thermal energy lost = ...

(b) The lead sphere is only able to partially melt the wax, so does not drop to the floor.

Explain this observation.

(2)

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(Total for Question 12 = 4 marks)

14 A magazine article states that an inflated balloon contains about two hundred billion trillion (2×10^{23}) air molecules.

(a) Taking the balloon to be a sphere of volume 8.2×10^{-3} m^3 in a room at a temperature of 22 °C, show that this figure for the number of molecules is correct.

pressure of air in balloon = 1.1×10^5 Pa

(2)

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*(b) The article also states that the internal energy of the air in the balloon could become zero if the temperature of the gas became low enough.

Explain what is meant by the internal energy of the air and discuss whether the statement is correct.

(4)

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(Total for Question 14 = 6 marks)

SECTION B

Answer ALL questions in the spaces provided.

11 A student carries out an experiment to investigate how the volume occupied by a gas depends upon the temperature.

(a) What variables must the student control in this investigation?

(2)

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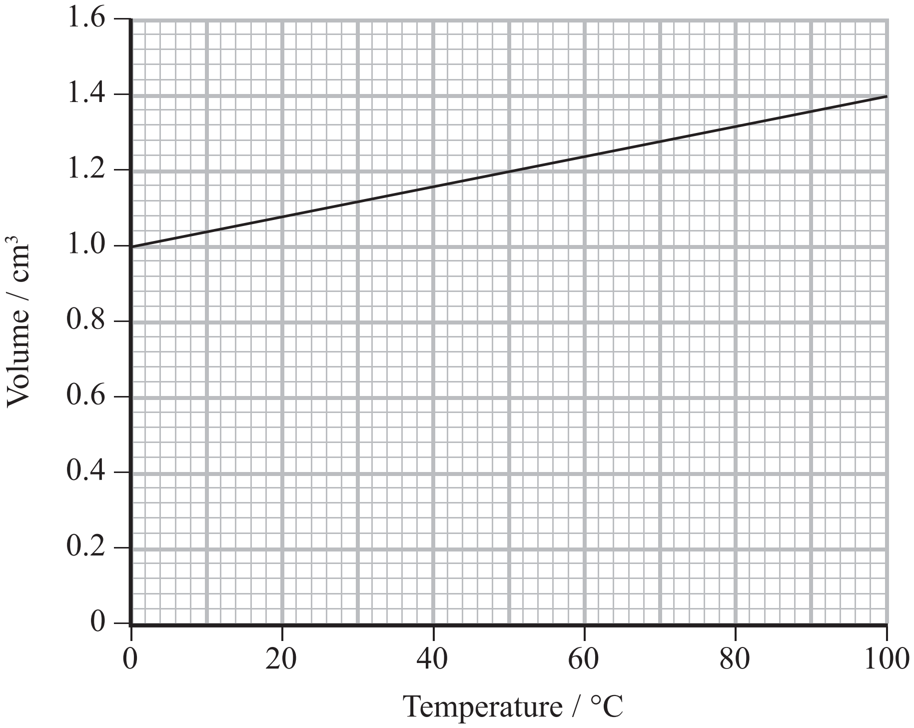
(b) The following graph is obtained.



Explain how graphs such as this provide evidence for an absolute zero of temperature.

(2)

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(Total for Question 11 = 4 marks)

(ii) The rotor has a diameter of 30 cm and spins at a rate of 60,000 revolutions per minute.

Calculate the centripetal acceleration at the rim of the rotor.

(2)

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Centripetal acceleration = ...

(iii) The rotor is subjected to huge forces because of the high spin rate.

Give **two** mechanical properties essential for the material from which the rotor is made.

(2)

Property 1 ....

Property 2 ....

(d) The waste heat from some power stations is transferred to water.

The San Onofre Nuclear Generating Station in California has reactors with a total output power of 2200 MW. These reactors circulate sea water at an average mass flow rate of 7.0×10^4 kg s^{-1}. The water is heated to approximately 11 K above the input temperature as it flows through condensers, before being discharged back into the ocean.

Show that the rate at which energy is removed from the reactors is about 3000 MW, and hence estimate a value for the efficiency of the electrical power generation process.

specific heat capacity of the sea water = 3990 J kg^{-1} K^{-1}

(4)

Efficiency = ...

(Total for Question 18 = 16 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

12 The heating element of an electric shower has a power of 6.0 kW.

(a) The shower is operated from a 230 V mains supply.

Calculate the resistance of the heating element.

(2)

Resistance = ...

(b) Water enters the shower at a temperature of 7.5 °C.

Calculate the water flow rate required to give an output temperature of 37.5 °C.

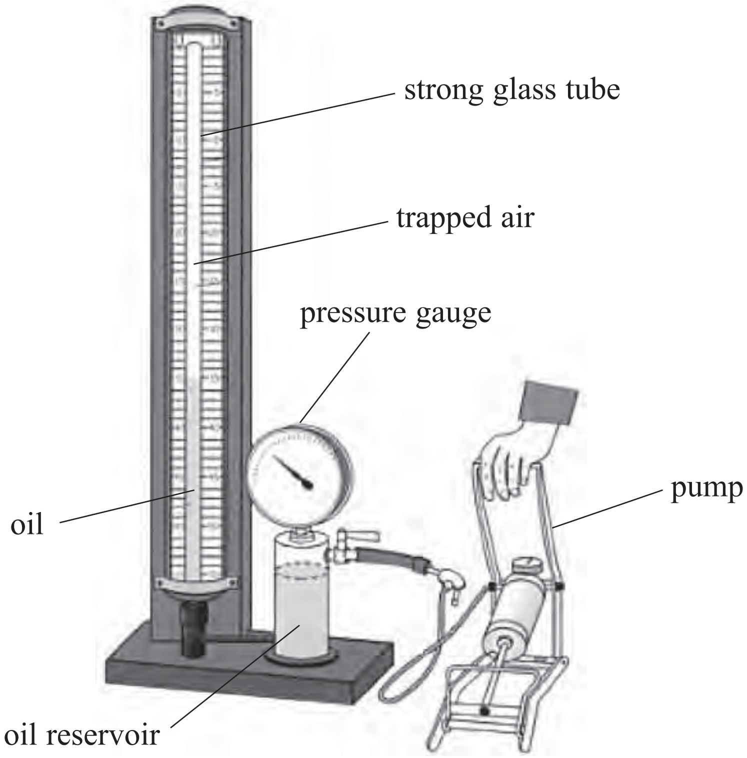
specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(3)

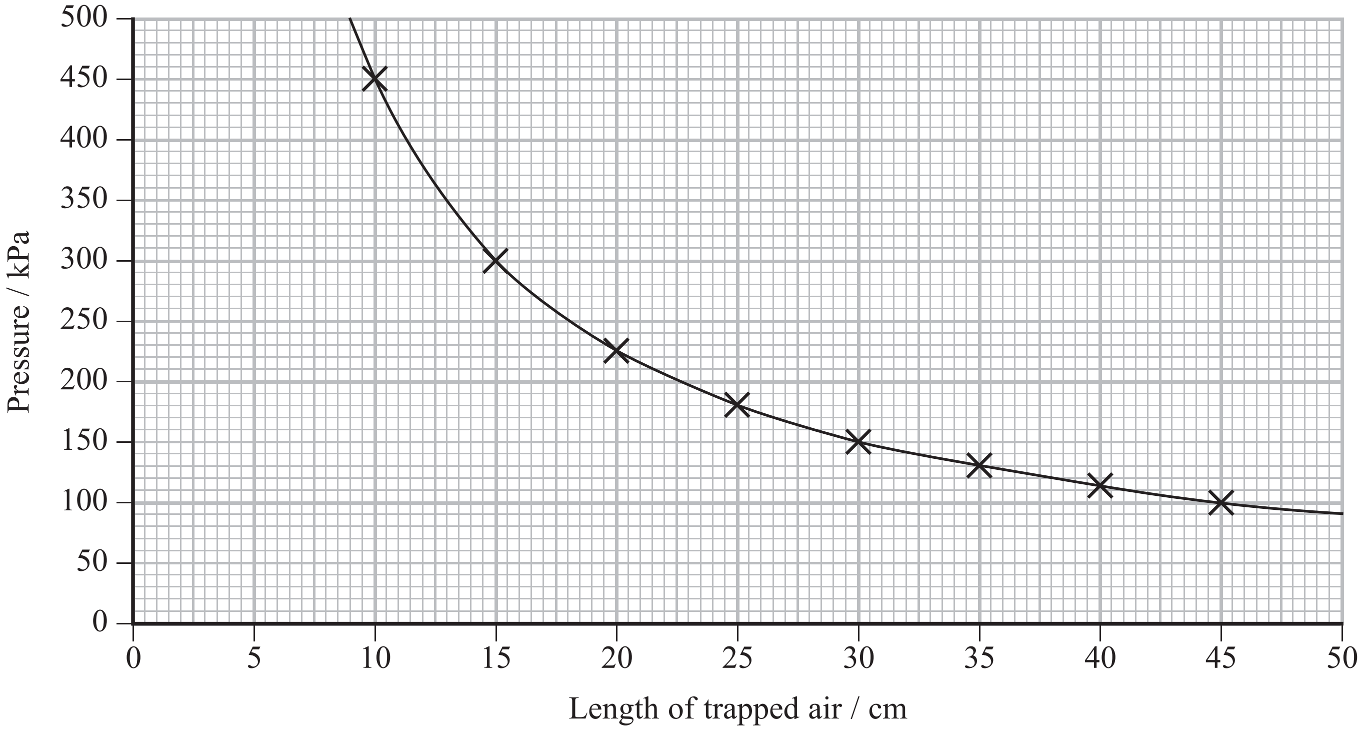
Flow rate = ...

(Total for Question 12 = 5 marks)

16 A student uses the apparatus shown to investigate the relationship between pressure and volume of a gas.



Air is trapped in a glass tube of uniform cross-sectional area. As the pressure of the trapped air is increased, the length of trapped air decreases. The student collects data and plots the following graph.



(a) State the variables that should be controlled in this investigation.

(2)

(b) Theory suggests that, for the air trapped in the tube, the pressure p is inversely proportional to the volume V.

Use the graph to show that this relationship is correct. State an assumption that you are making.

(4)

(c) On the day that the investigation was carried out, the temperature in the laboratory was 20 °C.

Calculate the number of air molecules trapped in the tube.

cross-sectional area of tube = 7.5×10^{-5} m^2

(3)

Number of air molecules = ...

(d) State how the graph would change if

(i) the air molecules in the tube were replaced by the same number of molecules of hydrogen gas.

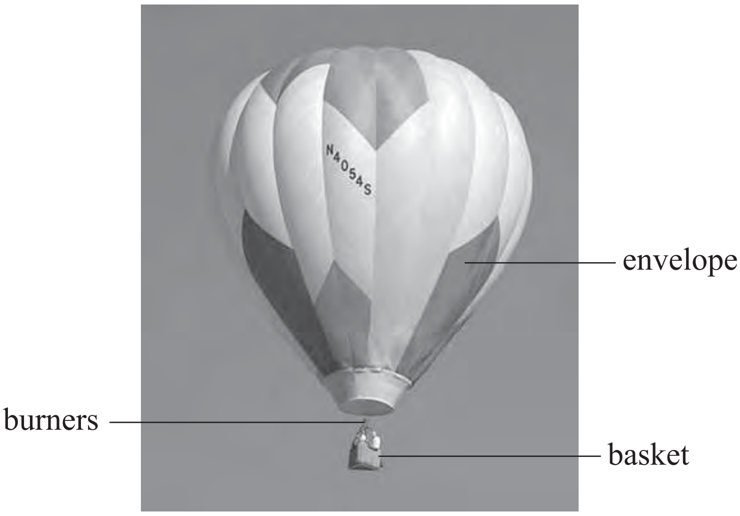
(1)

(ii) the temperature of the laboratory was substantially higher.

(2)

(Total for Question 16 = 12 marks)

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)

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	$P = VI$ $P = I^2R$ $P = V^2/R$ $W = VIt$ $\%\text{ efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100$ $\%\text{ efficiency} = \dfrac{\text{useful power output}}{\text{total power input}} \times 100$
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	$hf = \phi + \tfrac{1}{2}mv^2_{\text{max}}$

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

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	$v = H_0 d$