Centre No.						Paper Reference	Surname	Initial(s)
Candidate No.						6 7 3 3 / 0 1	Signature	

Paper Reference(s)

6733/01

Edexcel GCE

Physics

Advanced Subsidiary

Unit Test PHY3: Topics

Friday 9 June 2006 – Morning

Time: 30 minutes

ND0029648891

Materials required for examination	**Items included with question papers**
Nil	Nil

Examiner's use only

Team Leader's use only

Question Number	Leave Blank
1A	
2B	
3C	
4D	
Total	

Instructions to Candidates

In the boxes above, write your centre number, candidate number, your surname, initials and signature.
Answer ONE question only.
Indicate which Topic you are answering by putting a cross in the box (☒) at the start of the Topic.
If you change your mind, put a line through the box (☒) and then indicate your new question with a cross (☒).
In calculations you should show all the steps in your working, giving your answer at each stage.
Calculators may be used.
Include diagrams in your answers where these are helpful.

Information for Candidates

The marks for individual questions and the parts of questions are shown in round brackets.
The total mark for this paper is 32.
The list of data, formulae and relationships is printed at the end of this booklet.

Advice to Candidates

You will be assessed on your ability to organise and present information, ideas, descriptions and arguments clearly and logically, taking account of your use of grammar, punctuation and spelling.

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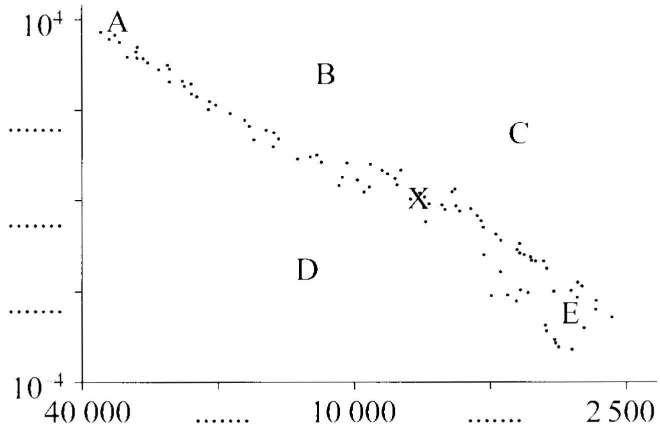
If you answer this Topic put a cross in this box ☐

Topic A – Astrophysics

1. (a) On the Hertzsprung-Russell diagram shown below X indicates the position of the Sun.



(i) Add labels and units to each axis.

(2)

(ii) Complete the scale on the y-axis by adding three further values where indicated.

(2)

(iii) Complete the scale on the x-axis by adding two further values where indicated.

(1)

(iv) Letters A, B, C, D and E represent different stars. Identify all stars which could be:

a red giant	
a low mass star on the main sequence	

(2)

(v) Use the data below to show that the luminosity of the star ζ Tau (Zeta Tauri) is approximately 4×10^{30} W.

Intensity = 1.9×10^{-8} W m^{-2}

Distance from Earth = 4.0×10^{18} m

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(3)

Leave blank

(vi) One of the labelled stars on the Hertzsprung-Russell diagram is ζ Tau. Calculate the luminosity of ζ Tau in terms of solar luminosities and thus deduce which letter must represent this star. Luminosity of the Sun $L_{\odot} = 3.9 \times 10^{26}$ W.

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Luminosity = ...

Star = ...

(3)

(b) When stars undergo nuclear fusion, hydrogen is fused to form helium. As part of this process two ${}^{3}_{2}He$ nuclei react to form ${}^{4}_{2}He$.

$${}^{3}_{2}He + {}^{3}_{2}He \longrightarrow {}^{4}_{2}He + {}^{1}_{1}H + {}^{1}_{1}H$$

(i) Calculate the change in mass in one such fusion reaction.

Nucleus	Mass / 10^{-27} kg
${}^{3}_{2}He$	5.0055
${}^{4}_{2}He$	6.6447
${}^{1}_{1}H$	1.6726

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Change in mass = ...

(2)

Leave blank

(ii) Hence calculate the energy released by this fusion reaction.

....

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....

....

Energy = ...

(2)

(c) In 2004 astronomers discovered a double pulsar: a system of two pulsars orbiting each other.

(i) Underline the four options that can be used to correctly describe pulsars.

A pulsar is a {neutron star / red giant / white dwarf / core remnant}.

A pulsar was previously a {white dwarf / black hole / supernova}.

A pulsar has a mass of at least {0.4 / 1.4 / 2.5 / 8} solar masses.

(4)

(ii) Explain how astronomers detect pulsars and suggest how a double pulsar might be recognised. You may be awarded a mark for the clarity of your answer.

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(4)

(iii) It is suggested that these two stars will spiral in towards each other and coalesce into a single mass after 85 million years. Suggest what might be formed by such an event.

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(1)

(d) (i) Write an equation for the density of a star in terms of its mass and radius.

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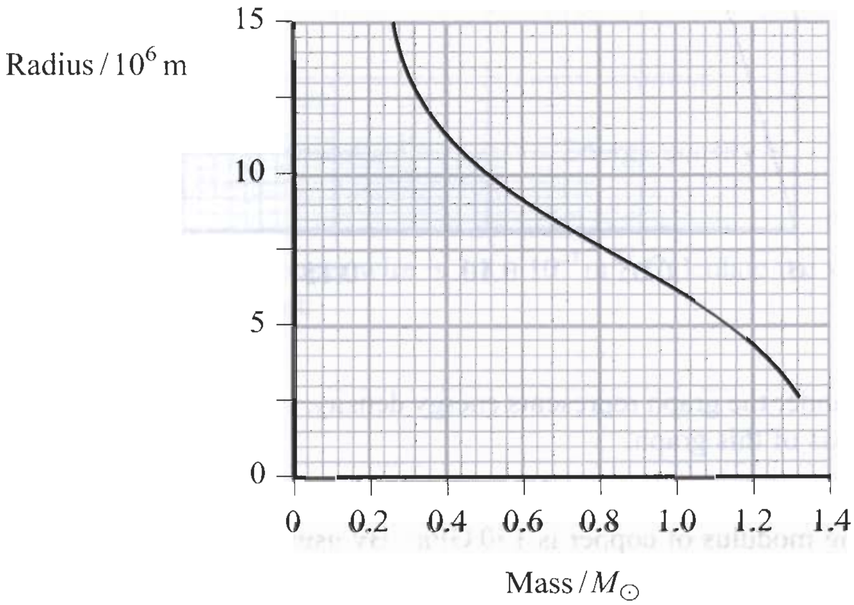
(1)

(ii) The graph shows the mass-radius relationship for white dwarf stars. The mass of the Sun $M_{\odot} = 2.0 \times 10^{30}$ kg.



Using the graph, calculate the density of two white dwarf stars and hence show that the density of a white dwarf increases as its mass increases.

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(3)

(iii) Describe what eventually happens to a white dwarf star.

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(2)

(Total 32 marks)

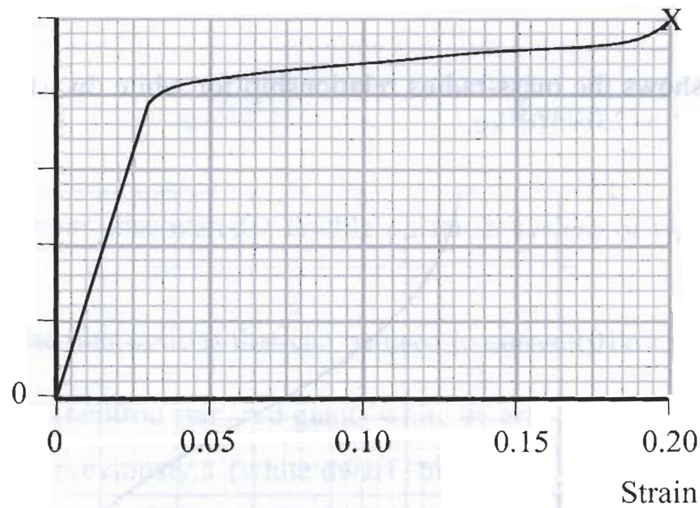
Q1

Leave blank

If you answer this Topic put a cross in this box ☒

Topic B – Solid Materials

2. (a) A copper wire is stretched in an experiment. The graph shows the behaviour of the copper until it breaks at point X.



(i) The area under the graph represents energy density. Add a suitable label and unit to the *y*-axis of this graph.

(2)

(ii) The Young modulus of copper is 130 GPa. By using an appropriate calculation add a suitable scale to the *y*-axis.

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(3)

(iii) From the graph determine the ultimate tensile stress of the copper.

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(1)

(iv) State what is meant by the term yield stress.

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....

(1)

(v) Label the yield point with a Y on the graph.

(1)

Leave blank

(vi) A second material is less stiff than copper and follows Hooke's Law to a strain beyond 0.20. Add a second line to the graph to indicate its behaviour.

(2)

(vii) Use the graph to estimate the energy density of the copper when it is stretched until it breaks.

....

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Energy density = ...

(3)

(viii) The volume of the copper wire is $3.8 \times 10^{-7}\,m^3$. Calculate the work done on this wire in the experiment.

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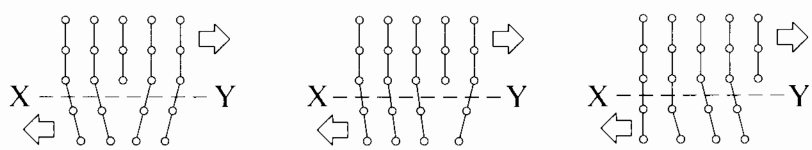
Work done = ...

(2)

(b) The series of diagrams shows the molecular arrangement of part of a crystal lattice. The arrows indicate forces applied to the crystal.



A B C

(i) Name the feature XY.

....

(1)

Leave blank

(ii) With reference to the diagrams explain how the presence of a dislocation makes plastic deformation easier. You may be awarded a mark for the clarity of your answer.

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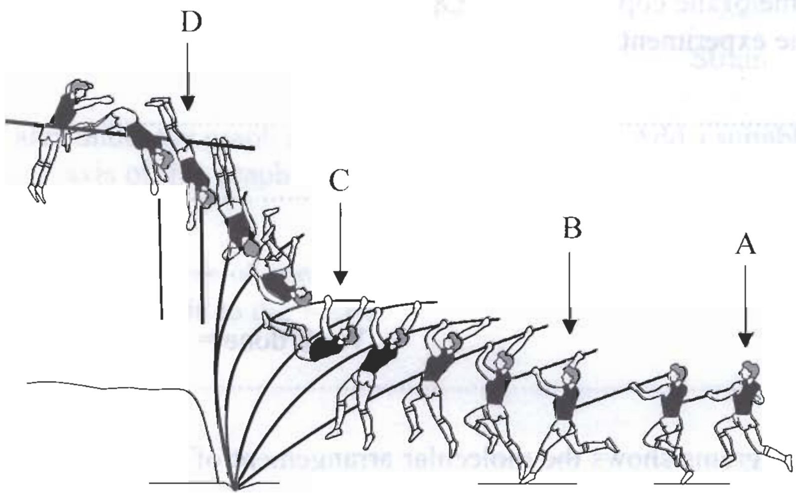
(4)

(c) The pole vault is an athletic event that requires high levels of sprinting, jumping and gymnastic ability. The diagram shows the sequence of actions involved in a jump. The pole is off the ground at A and B.



(i) State the energy changes that occur during the stages

A→B ....

B→C ....

C→D ....

(3)

(ii) Calculate the speed of a pole vaulter of mass 65 kg who has 2.1 kJ of kinetic energy on take off.

....

....

Speed = ...

(1)

N 2 2 3 6 9 A 0 8 2 0

Leave blank

(iii) Assuming no energy losses, and using the data below, show that the theoretical maximum height that could be reached by this athlete is over 5 m.

Initial height of centre of mass of pole vaulter from ground = 0.9 m
Additional height gained from technique during jump = 1.2 m

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(2)

(d) Modern vaulting poles are made of a carbon fibre composite material.

(i) State what is meant by a composite material.

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....

(1)

(ii) What is the benefit of using a composite material?

....

(1)

(iii) Circle the words that describe the properties of this composite material.

elastic flexible plastic stiff strong tough

(3)

(iv) Before carbon fibre poles were developed, fibreglass poles were used. These had the disadvantage of being brittle. State what is meant by brittle.

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....

(1)

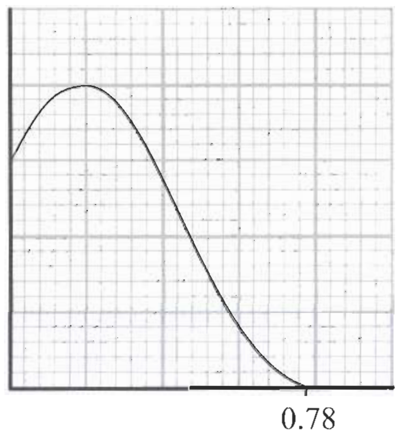
Q2

(Total 32 marks)

If you answer this Topic put a cross in this box ☐

Topic C – Nuclear and Particle Physics

3. (a) During an experiment into the energy spectrum of β^- particles, the following graph was produced.



(i) Add suitable labels, with units where appropriate, to each axis.

(3)

(ii) State the significance of the figure 0.78. Explain how the results of this experiment led to the prediction of the existence of an antineutrino. You may be awarded a mark for the clarity of your answer.

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(4)

Leave blank

(b) The equation for β^- decay can be written as:

$$n \longrightarrow p + \beta^- + \bar{\nu}$$

(i) For each particle, either give its quark composition or state that it is a fundamental particle.

n ....

p ....

β^- ....

$\bar{\nu}$ ....

(2)

(ii) Write a similar equation for β^+ decay.

(2)

(iii) Explain fully why these reactions can only be mediated by the weak interaction.

....

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....

....

(3)

(iv) Name the exchange particle for each of these decays.

β^- .... β^+ ....

(2)

Leave blank

(c) (i) The density of a nucleus of strontium Sr is 2.29×10^{17} kg m^{-3}. Calculate the mass of a nucleus of radius 5.34×10^{-15} m.

....

....

....

Mass = ...

(3)

(ii) Show that the nucleon number of this isotope is 88. (u = 1.66×10^{-27} kg)

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(2)

(iii) Hence calculate the radius r_0 of a single nucleon.

....

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....

Radius = ...

(3)

Leave blank

(d) A hydrogen atom consists of one proton and one electron. For each particle underline **all** the words that could be used to make a correct statement.

A proton is a {baryon / meson / lepton / hadron}

An electron is a {baryon / meson / lepton / hadron}

(2)

(e) In 1995 scientists at CERN created atoms of antihydrogen.

(i) Name the particles that make up antihydrogen.

....

....

(1)

(ii) Describe these particles in terms of charge and quark structure where relevant.

....

....

(2)

(iii) State the charge of an atom of antihydrogen.

....

(1)

(iv) Explain why it is not possible to store atoms of antihydrogen.

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(2)

Q3

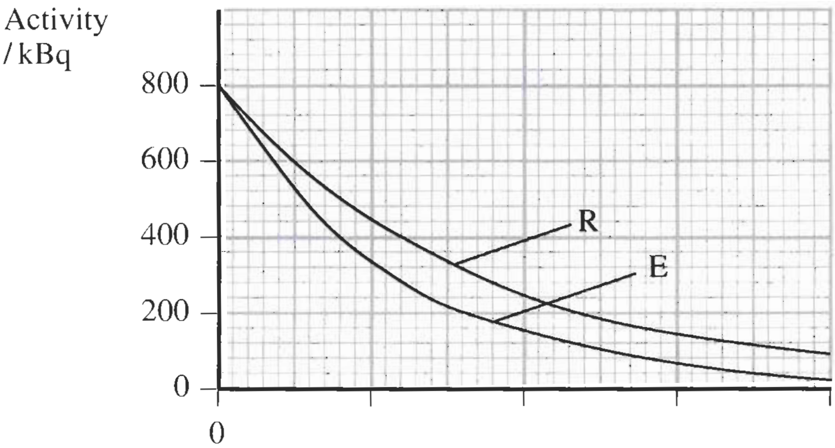
(Total 32 marks)

Leave blank

If you answer this Topic put a cross in this box ☐

Topic D – Medical Physics

4. (a) Graph R shows the radioactive decay of technetium ^{99m}Tc which has a radioactive half-life of 6 hours. Graph E shows the observed decay of the same isotope when it is used in a tracer investigation in a patient.



(i) Label the x-axis.

(1)

(ii) Use graph R to add a scale and units to the x-axis. Show how you did this on the graph.

(2)

(iii) Use graph E to calculate the biological half-life of the isotope in this investigation.

....

....

....

Biological half-life = ...

(3)

(b) (i) Molybdenum $^{99}_{42}Mo$ decays to ^{99m}Tc by beta-minus emission. Write a balanced nuclear equation for this decay.

....

(1)

(ii) In what is radioactive molybdenum produced?

....

(1)

Leave blank

(iii) Describe and explain the process of elution that is used to extract the ^{99m}Tc from an elution cell. You may be awarded a mark for the clarity of your answer.

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(4)

(iv) Technetium ^{99m}Tc decays by gamma emission. Write a balanced nuclear equation for this decay.

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(1)

(v) The product of this decay has a half-life of 210 000 years. Explain the importance of this long half-life when ^{99m}Tc is used as a tracer.

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(2)

Leave blank

(c) In X-ray diagnosis the absorption of keV X-rays is highly dependent on Z.

(i) State what Z represents in this context.

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(1)

(ii) Explain the relevance of the value of Z in the production of radiographic images.

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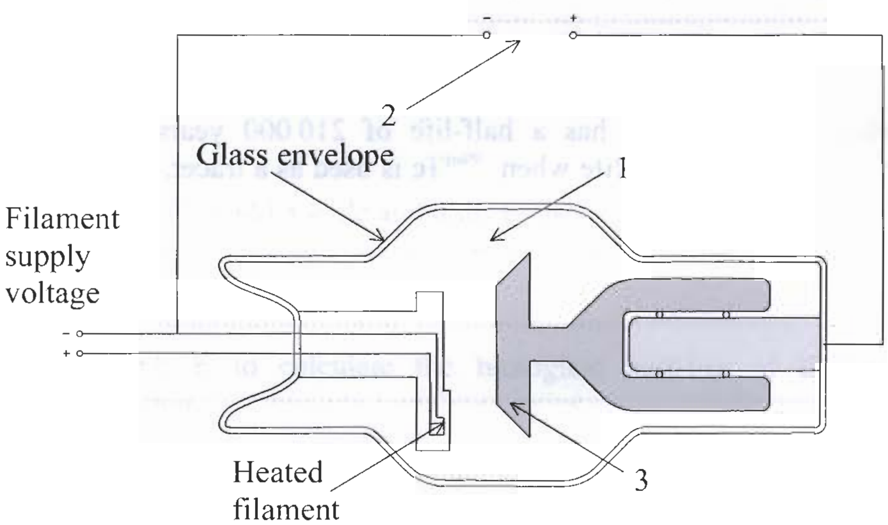
(2)

The diagram shows a rotating anode X-ray tube.



(iii) Name and explain the function of the numbered parts of the X-ray tube.

	Name	Function
1		
2		
3		

(6)

N 2 2 3 6 9 A 0 1 6 2 0

Leave blank

(d) In ultrasonic diagnosis the reflection coefficient α can be written as

$$\alpha = \left(\frac{Z_1 - Z_2}{Z_1 + Z_2}\right)^2$$

(i) State what is represented by Z_1 and Z_2 in this equation.

....

....

(2)

(ii) Show that the units of Z are $\mathrm{kg\,m^{-2}\,s^{-1}}$.

....

....

(2)

(iii) Calculate the reflection coefficient using the data given below.

Medium	$Z/\mathrm{kg\,m^{-2}\,s^{-1}}$
Blood	1.59×10^6
Muscle	1.70×10^6

....

....

....

....

α = ...

(2)

(iv) Hence find the percentage of the incident ultrasound that will be transmitted through a muscle-blood boundary.

....

....

(2)

Q4

(Total 32 marks)

TOTAL FOR PAPER: 32 MARKS

END

List of data, formulae and relationships

Data

Speed of light in vacuum	$c = 3.00 \times 10^{8}\ \mathrm{m\ s^{-1}}$	
Acceleration of free fall	$g = 9.81\ \mathrm{m\ s^{-2}}$	(close to the Earth)
Gravitational field strength	$g = 9.81\ \mathrm{N\ kg^{-1}}$	(close to the Earth)
Elementary (proton) charge	$e = 1.60 \times 10^{-19}\ \mathrm{C}$	
Electronic mass	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$	
Electronvolt	$1\ \mathrm{eV} = 1.60 \times 10^{-19}\ \mathrm{J}$	
Unified atomic mass unit	$1\ \mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$	
Molar gas constant	$R = 8.31\ \mathrm{J\ K^{-1}\ mol^{-1}}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \mathrm{W\ m^{-2}\ K^{-4}}$	

Rectilinear motion

For uniformly accelerated motion:

$$v = u + at$$

$$x = ut + \tfrac{1}{2}at^2$$

$$v^2 = u^2 + 2ax$$

Forces and moments

Moment of F about O $= F \times$ (Perpendicular distance from F to O)

Sum of clockwise moments about any point in a plane = Sum of anticlockwise moments about that point

Dynamics

Force $\quad F = m\dfrac{\Delta v}{\Delta t} = \dfrac{\Delta p}{\Delta t}$

Impulse $\quad F\Delta t = \Delta p$

Mechanical energy

Power $\quad P = Fv$

Radioactive decay and the nuclear atom

Activity $\quad A = \lambda N \quad$ (Decay constant λ)

Half-life $\quad \lambda t_{\frac{1}{2}} = 0.69$

Electrical current and potential difference

Electric current	$I = nAQv$	
Electric power	$P = I^2 R$	

Electrical circuits

Terminal potential difference	$V = \varepsilon - Ir$	(E.m.f. ε; Internal resistance r)
Circuit e.m.f.	$\Sigma\varepsilon = \Sigma IR$	
Resistors in series	$R = R_1 + R_2 + R_3$	
Resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	

Heating matter

Change of state	energy transfer $= l\Delta m$	(Specific latent heat or specific enthalpy change l)
Heating and cooling	energy transfer $= mc\Delta T$	(Specific heat capacity c; Temperature change ΔT)
Celsius temperature	$\theta/°C = T/K - 273$	

Kinetic theory of matter

Temperature and energy	$T \propto$ Average kinetic energy of molecules	
Kinetic theory	$p = \frac{1}{3}\rho\langle c^2\rangle$	

Conservation of energy

Change of internal energy	$\Delta U = \Delta Q + \Delta W$	(Energy transferred thermally ΔQ; Work done on body ΔW)
Efficiency of energy transfer	$= \frac{\text{Useful output}}{\text{Input}}$	
Heat engine	maximum efficiency $= \frac{T_1 - T_2}{T_1}$	

Astrophysics

Stefan-Boltzmann law	$L = \sigma T^4 \times$ surface area	(Luminosity L; Stefan constant σ)
Wien's law	$\lambda_{max} T = 2.898 \times 10^{-3}$ m K	
Estimating distance	intensity $= L/4\pi D^2$	
Mass-energy	$\Delta E = c^2 \Delta m$	(Speed of light in vacuum c)

Solid materials

Hooke's law	$F = k\Delta x$	
Stress	$\sigma = \frac{F}{A}$	
Strain	$\varepsilon = \frac{\Delta l}{l}$	
Young modulus	$E = \frac{\text{Stress}}{\text{Strain}}$	
Work done in stretching	$\Delta W = \frac{1}{2}F\Delta x$	(provided Hooke's law holds)
Energy density	= Energy/Volume	

Nuclear and particle physics

Nuclear radius	$r = r_0 A^{1/3}$	(Nucleon number A)
Mass-energy	$1\ \mathrm{u} = 930\ \mathrm{MeV}$	
Quark charge/e	up $= +\frac{2}{3}$; down $= -\frac{1}{3}$	

Medical physics

Effective half-life	$\frac{1}{t_e} = \frac{1}{t_r} + \frac{1}{t_b}$	(Radioactive half-life t_r; Biological half-life t_b)
Inverse square law	$I = P/4\pi r^2$	(Intensity I; Power P of a point source; Distance r from point source)
Acoustic impedance	$Z = c\rho$	(Speed of sound in medium c; Density of medium ρ)
Reflection coefficient	$= (Z_1 - Z_2)^2/(Z_1 + Z_2)^2$	

Experimental physics

$$\text{Percentage uncertainty} = \frac{\text{Estimated uncertainty} \times 100\%}{\text{Average value}}$$

Mathematics

$$\sin(90° - \theta) = \cos\theta$$

Equation of a straight line	$y = mx + c$	
Surface area	cylinder $= 2\pi rh + 2\pi r^2$	
	sphere $= 4\pi r^2$	
Volume	cylinder $= \pi r^2 h$	
	sphere $= \frac{4}{3}\pi r^3$	
For small angles:	$\sin\theta \approx \tan\theta \approx \theta$	(in radians)
	$\cos\theta \approx 1$	