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

Thursday 22 May 2008 – Afternoon

Time: 30 minutes

Examiner's use only

Team Leader's use only

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

Materials required for examination
Nil

Items included with question papers
Nil

Instructions to Candidates

In the boxes above, write your centre number, candidate number, your surname, initial(s) 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) Classify each of the following stars by ticking **all** the appropriate boxes in the table. $M_\odot$ = one solar mass.

Star	Core remnant	$<1.4\ M_\odot$	$>2.5\ M_\odot$	Main sequence
Neutron star				
Black hole				
White dwarf				

(3)

(b) State two advantages and one disadvantage that a charge-coupled device (CCD) has compared to a photographic emulsion.

Advantage 1 ....

....

Advantage 2 ....

....

Disadvantage ....

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(3)

(c) (i) For most of its life (11 billion years) the Sun will burn hydrogen in its core. A chemistry student might use the word **burn** to describe a chemical reaction involving oxygen.

Explain fully the meaning of the word **burn** when used in astrophysics to describe what happens in the core of a star. You may be awarded a mark for the clarity of your answer.

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(4)

Leave blank

(ii) When the Sun nears the end of its life it will burn helium in its core for a further 100 million years and become a red giant star. When it has depleted the helium in its core it is estimated that its surface temperature will fall from its present value of 5780 K to 3160 K and its radius will increase from 6.96×10^8 m to 1.26×10^{11} m.

Show that the luminosity of the Sun will increase by a factor of about 3000 due to these changes.

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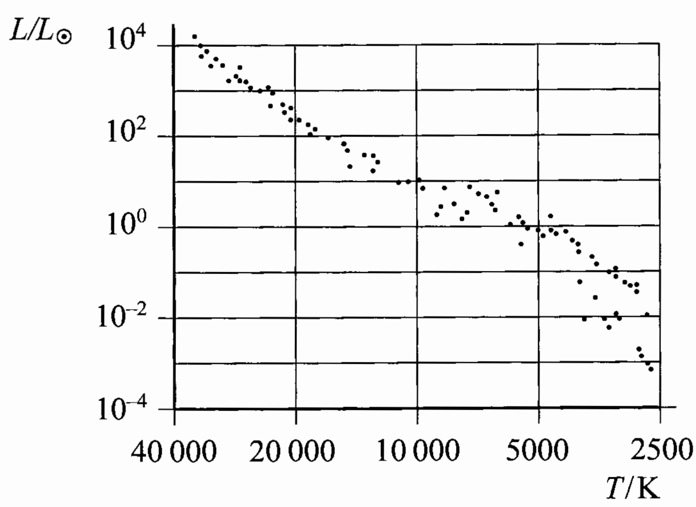
(4)

(iii) A Hertzsprung-Russell diagram is shown below.



Mark with an X the position of the Sun today.

Use the information given in (ii) to mark with a Y the position of the Sun when it has depleted its helium core.

(4)

N 3 0 6 1 8 A 0 3 2 0

Turn over

Leave blank

(d) (i) Near the end of its life the Sun will decrease in size and become a white dwarf.

State two other ways in which this type of star differs from the Sun as it is today.

1 ....

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2 ....

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(2)

(ii) Describe what will eventually become of a white dwarf star.

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(2)

(e) (i) Sirius A is the brightest star in the night sky. It is 8.6 light years from Earth. Show that this distance is approximately 8×10^{16} m.

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(2)

(ii) Hence determine the intensity of Sirius A as seen from Earth.

The luminosity of Sirius A is 1.0×10^{28} W.

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(3)

Leave blank

(iii) Calculate the mass being converted into energy in the core of Sirius A every second.

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(3)

(iv) Sirius A has a surface temperature of 9900 K.

Calculate the peak wavelength of the radiation spectrum emitted by Sirius A.

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(2)

Q1

(Total 32 marks)

Leave blank

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

Topic B – Solid Materials

2. (a) Classify each of the following treatments of metals by ticking **all** the appropriate boxes in the table.

Treatment	Involves heating	Involves repeated beating	Involves rapid cooling	Involves slow cooling
Annealing				
Work hardening				
Quench hardening				

(3)

(b) (i) A wire fence is made of steel wire of diameter 2.5 mm.

Show that this wire has a cross-sectional area of approximately 5×10^{-6} m^2.

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(2)

(ii) A force of 1500 N is applied to tension a single length of this wire.

Calculate the stress produced in the wire.

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(2)

(iii) Hence calculate the extension, in mm, produced in a 33 m length of this wire when it is tensioned. The Young modulus of steel is 210 GPa.

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(4)

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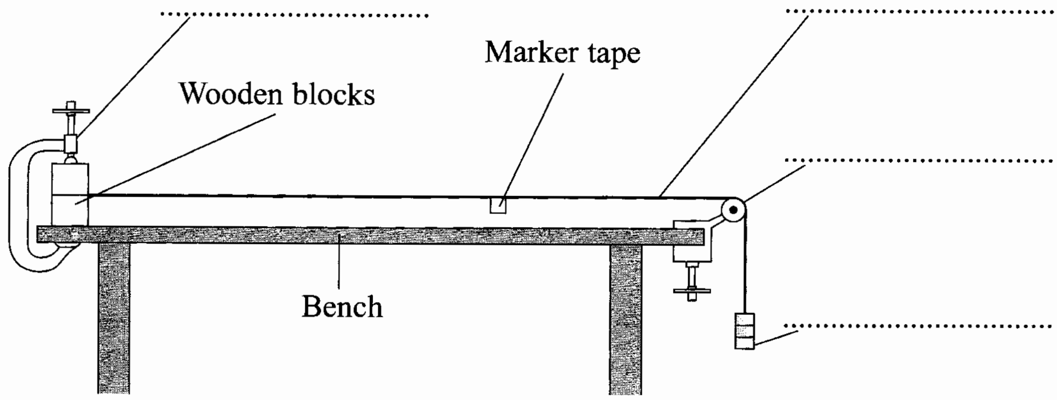
(c) A student uses the following apparatus to determine the Young modulus of copper.



(i) The diagram above has four labels missing. Add these labels to the diagram.
(2)

(ii) On the diagram show accurately the length l of the copper wire that should be considered.

Suggest an appropriate length for l.

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(2)

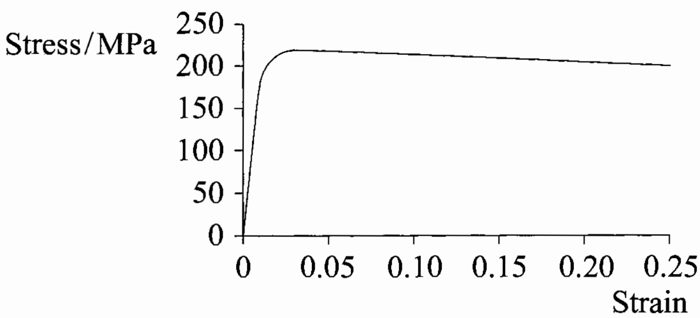
(iii) The student wishes to plot a stress-strain graph for the copper wire.

What two additional pieces of apparatus would be required to determine values for stress and strain?

1 ....

2 ....
(2)

(iv) The student plots a stress-strain graph which is shown below.



Estimate the energy density of the wire when it has a strain of 0.25.

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(3)

N 3 0 6 1 8 A 0 7 2 0

Turn over

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(d) When a crack exists in a sheet of metal, drilling a small hole in the crack will stop it from spreading.

State where the hole should be drilled and explain why this process works. You may be awarded a mark for the clarity of your answer.

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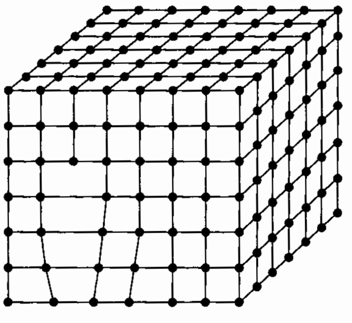
(4)

(e) The diagram shows a dislocation in the molecular arrangement of part of a crystal lattice.



(i) State what sort of dislocation this is.

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(1)

(ii) Add a line to the diagram to indicate the location of the slip plane.
(1)

N 3 0 6 1 8 A 0 8 2 0

Leave blank

(iii) Explain, in terms of bonds, why the presence of a half-row of atoms makes plastic deformation easier.

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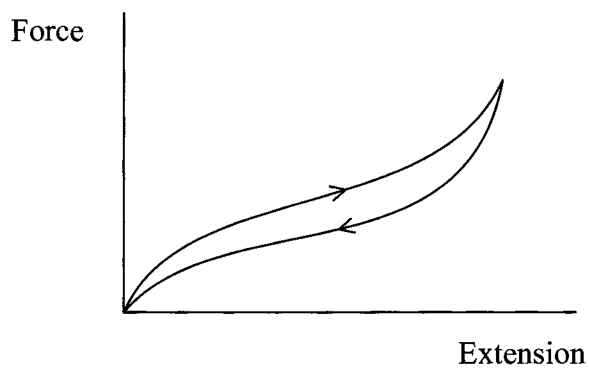
(3)

(f) An elastomer such as rubber is a material that can deform elastically to a large strain. A force-extension graph for the rubber used to make a squash ball is shown.



(i) State the name of the characteristic behaviour shown in the graph.

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(1)

(ii) By referring to the areas under the graph explain why a cold squash ball heats up when it is struck repeatedly against a wall.

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(2)

Q2

(Total 32 marks)

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

Topic C – Nuclear and Particle Physics

3. (a) Classify each of the following particles by ticking **all** the appropriate boxes in the table.

Particle	Lepton	Baryon	Hadron	Meson
Neutron, n				
Neutrino, υ				
Muon, μ				

(3)

(b) Uranium $^{238}_{92}U$ undergoes a series of alpha and beta decays until it becomes a stable isotope of lead $^{206}_{82}Pb$.

(i) State how many alpha particles will be emitted by a nucleus during this decay series. Justify your answer.

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(2)

(ii) As part of this decay series thorium $^{234}_{90}Th$ decays to protactinium $^{234}_{91}Pa$. Write a nuclear equation for this decay.

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(3)

(iii) State what change occurs in the $^{234}_{90}Th$ nucleus during this process.

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(1)

(iv) The $^{234}_{91}Pa$ nucleus will subsequently decay to nucleus X by emitting both beta-minus and gamma radiation. Determine the full name of nucleus X.

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(2)

Leave blank

(c) (i) Define the term binding energy.

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(1)

(ii) Use the following data to show that the binding energy of carbon-14 is approximately 100 MeV.

Masses: $^{14}_{6}\text{C}$ nucleus = 14.003 24 u

$^{1}_{1}\text{p}$ = 1.007 28 u

$^{1}_{0}\text{n}$ = 1.008 67 u

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(4)

(iii) The binding energy of carbon-12 is 89 MeV. Hence determine which of these two carbon isotopes is more stable.

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(3)

N 3 0 6 1 8 A 0 1 1 2 0

Turn over

Leave blank

(d) (i) Describe the composition of a nucleus of deuterium ^2_1H in terms of fundamental particles.

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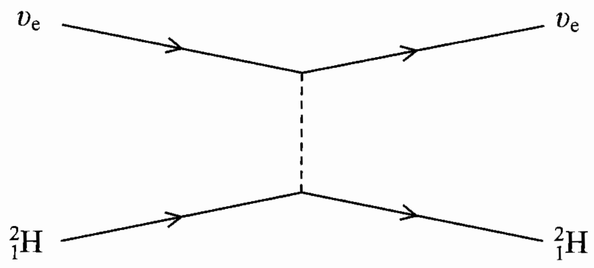
(2)

(ii) The Sudbury Neutrino Observatory in Canada detects neutrinos by their interaction with deuterium atoms (^2_1H) in heavy water. This is shown in the Feynman diagram below, in which the dotted line represents an exchange particle.



Of the four fundamental forces that could be responsible for this interaction, the gravitational force is far too weak for a particle interaction at this scale.

By describing the other fundamental forces and what they act upon, state which force(s) might be responsible for this interaction. You may be awarded a mark for the clarity of your answer.

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(5)

N 3 0 6 1 8 A 0 1 2 2 0

Leave blank

(iii) Hence name the exchange particle that must be involved in this interaction.

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(1)

(e) (i) Two particle reactions are shown. Use appropriate conservation laws to show whether these reactions are possible.

Δ^0	+	K^0	→	K^+	+	Σ^+		Ω^-	→	Ξ^-	+	$\overline{K}^0$
(udd)		($d\bar{s}$)		($u\bar{s}$)		(uus)		(sss)		(ssd)		($s\bar{d}$)

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(3)

(ii) Using **only** the information given above deduce the charges on each of the strange, up and down quarks. Justify your answers.

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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) Classify each of the following imaging techniques by ticking **all** the appropriate boxes in the table.

Imaging technique	Ionising radiation	Produced by a transducer	Good at soft tissue imaging	May be injected into patient
X-ray				
Nuclear medicine				
Ultrasound				

(3)

(b) (i) X-rays can be used to provide treatment for cancer patients using a process known as radiotherapy. State a typical photon energy for an X-ray used for radiotherapy.

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(1)

(ii) X-rays are used to destroy cancer cells in a process known as rotational arc therapy. Draw a labelled diagram to show how this is done and explain the benefit of using a rotating beam.

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(3)

Leave blank

(iii) Give two reasons why X-rays of relatively high energy must be used for radiotherapy.

1 ....

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2 ....

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(2)

(iv) Careful treatment planning is essential for successful radiotherapy. Explain why the criticality of dose is important.

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(2)

(c) (i) An ultrasound investigation is carried out on a liver, which is at a depth of 12 cm below the skin of a patient. Show that the time taken between transmitting a pulse into the body and receiving the reflected pulse from the surface of the liver is approximately 0.2 ms. Assume that the speed of sound in the human body is 1500 m s^{-1}.

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(2)

(ii) Hence calculate the maximum rate at which the pulses should be produced by the ultrasonic transducer.

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(2)

(iii) This investigation uses ultrasound of frequency 3 MHz. Show that the wavelength of this ultrasound in the body is 0.5 mm.

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(1)

Leave blank

(iv) A higher frequency of ultrasound is used when imaging an eye compared to when imaging a liver. Explain why higher frequencies are preferred for imaging structures near the surface of the body but would be unsuitable for imaging structures deeper within the body. You may be awarded a mark for the clarity of your answer.

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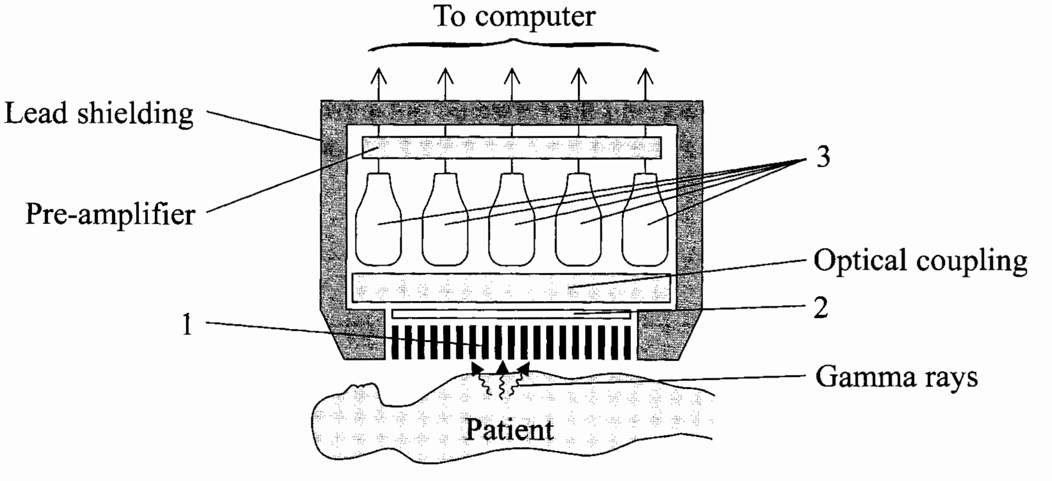
(4)

(d) The diagram shows part of a gamma camera.



Name and explain the function of the numbered parts of the gamma camera.

	Name	Function
1		
2		
3		

(6)

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(e) (i) An isotope of iodine ^{131}I is produced when unstable tellurium $^{131}_{52}Te$ undergoes beta-minus decay. Write a nuclear equation for this decay.

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(2)

(ii) The unstable tellurium is produced in a nuclear reactor from stable $^{130}_{52}Te$. Write a nuclear equation to show this process.

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(1)

(iii) State the meaning of biological half-life.

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(1)

(iv) ^{131}I has an effective half-life of 5.8 days and a biological half-life of 21 days. Calculate the radioactive half-life of ^{131}I.

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(2)

Q4

(Total 32 marks)

TOTAL FOR PAPER: 32 MARKS

END

List of data, formulae and relationships

Data

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

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 × (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	$P = I^2R$	

Electrical circuits

Terminal potential difference	$V = \mathcal{E} - Ir$	(E.m.f. $\mathcal{E}$; Internal resistance r)
Circuit e.m.f.	$\Sigma\mathcal{E} = \Sigma IR$	
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	$\theta/°\text{C} = T/\text{K} - 273$	

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	$1\ \text{u} = 930\ \text{MeV}$	
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)
	$\cos\theta \approx 1$	