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 10 June 2005 – Morning

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	Items included with question papers
Nil	Nil

Instructions to Candidates

In the boxes above, write your centre number, candidate number, your surname and initials and your 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) (i) The equation $I = L / 4\pi D^2$ can be used to determine the luminosity L of a star of known distance D and intensity I. Use this equation to show that the base units of intensity are kg s^{-3}.

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(3)

(ii) Calculate the luminosity of a star which has a measured intensity of 1370 W m^{-2} and which is known to be 1.49×10^{11} m from Earth.

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(3)

(b) (i) Give three advantages that charge coupled devices (CCDs) have compared with photographic emulsions.

Advantage 1 ....

....

Advantage 2 ....

....

Advantage 3 ....

....

(ii) Give one disadvantage of CCDs compared with photographic emulsions.

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(4)

(c) In 1983 the Infrared Astronomical Satellite (IRAS) conducted a survey of the sky by observing stars. Explain why such a survey would give far better results than a similar one made from the Earth's surface. You may be awarded a mark for the clarity of your answer.

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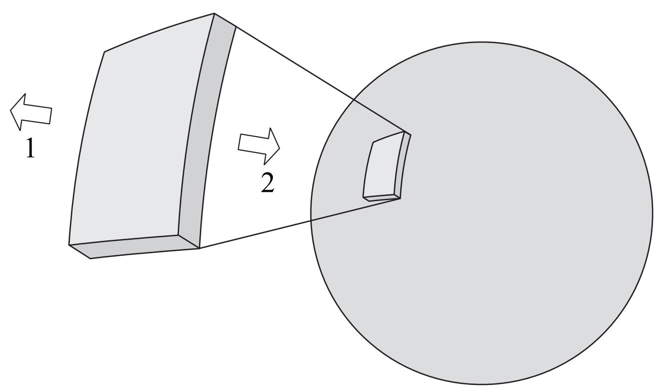
(3)

(d) The diagram shows a main-sequence star. The arrows on the enlarged section of star material represent the forces acting on it.



(i) State the origin of these forces.

1. ....

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2. ....

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(2)

(ii) How do these forces compare in size?

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(1)

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Turn over

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(iii) State three differences between white dwarf stars and red giant stars. One of your answers should be numerical.

1. ....

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2. ....

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3. ....

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(3)

(iv) What determines whether a neutron star will be formed from a supernova?

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(2)

(e) When the Sun was formed some 4.6×10^9 years ago, it was slightly smaller than it is today. Theoretical calculations show that it has become 40% more luminous and grown in radius by 6% (i.e. $L_\odot = 1.4\,L$ and $r_\odot = 1.06\,r$ where L and r represent the luminosity and radius of the Sun when it was formed).

Data for the Sun today:

Luminosity $L_\odot$ $= 3.9 \times 10^{26}$ W

Radius $r_\odot$ $= 7.0 \times 10^5$ km

Temperature $T_\odot = 5\,800$ K

(i) Calculate the luminosity of the Sun when it was formed.

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(2)

(ii) Calculate the surface area of the Sun when it was formed.

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(2)

Leave blank

(iii) Hence show that the surface temperature of the Sun has increased by approximately 300 K during its lifetime.

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(4)

(iv) The Sun has become slightly more yellow during its lifetime. It used to be more orange in colour. This is because the wavelength at which the peak intensity of its emitted radiation occurs has decreased. Use Wien's law to calculate the decrease in the wavelength of the peak intensity.

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(3)

Q1

(Total 32 marks)

Leave blank

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

Topic B – Solid Materials

2. (a) (i) When calculating the energy density of a material, the area under a stress-strain graph is calculated. Show that the base units of energy density are kg m^{-1} s^{-2}.

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(3)

(ii) A sample deforms elastically obeying Hooke's law. A stress of 200 MPa produces a strain of 9.5×10^{-4}. Show that the energy density is approximately 100 kJ m^{-3}.

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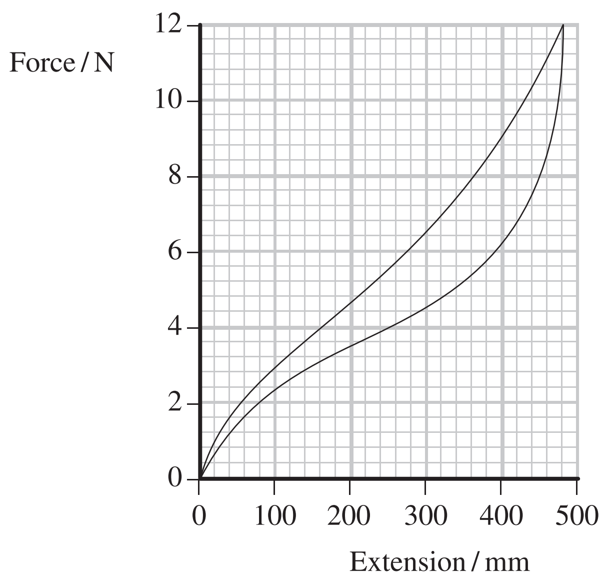
(3)

(b) In an experiment to measure the extension of a rubber band the following graph was obtained. The line represents the extension during loading and unloading.



(i) Label the two lines to indicate which represents loading and which represents unloading.

(1)

N 2 0 8 2 8 A 0 6 2 0

Leave blank

(ii) What is the name for the characteristic behaviour shown by the shape of this graph?

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(1)

(iii) If the rubber band has a cross-sectional area of $6.0 \times 10^{-6}\,\text{m}^2$ calculate the stress produced in the elastic band when it is fully loaded.

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(2)

(iv) Estimate how much work is done on the rubber band as it is fully loaded.

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(4)

(v) Hence show that the energy dissipated during the loading and unloading process is approximately 1 J.

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(2)

(vi) When the rubber band has a load placed on it a new reading is taken. Over the next minute this reading increases by a few millimetres. If a material deforms plastically in this way when stress is applied, what is the name of this mechanism?

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(1)

Leave blank

(vii) State Hooke's law.

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....
(1)

(viii) Draw a labelled diagram of the apparatus that could be used to produce a force-extension graph for a rubber band, for loads up to 12 N.

(4)

(c) (i) Glass objects are often referred to as being fragile. Circle any of the following words which could be used to describe the properties of glass at room temperature.

brittle tough flexible stiff plastic

(ii) A cylindrical glass rod has a diameter of 4.0 mm, a length of 30 cm and a Young modulus of 7.0×10^{10} Pa. If a load of 880 N is applied to the rod, calculate its extension.

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(6)

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(d) Modern canoes can be made of polyethylene (polythene). One canoe manufacturer describes how their canoes can withstand being dropped from the factory roof without being damaged because they are made from cross-linked polymers. Describe with the aid of a diagram the microscopic properties of such a polymer. You may be awarded a mark for the clarity of your answer.

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(4)

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) (i) Particle energies are often quoted in units of mega-electronvolts (MeV). Show that the base units of the electronvolt can be expressed as $kg\,m^2\,s^{-2}$.

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....
(3)

(ii) Calculate the theoretical energy released when a $^{238}_{92}U$ nucleus is formed from individual protons and neutrons. Give your answer in MeV.

Data (masses):

$^{238}_{92}U$ = 238.0003 u
proton = 1.0073 u
neutron = 1.0087 u

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(4)

(b) Name the two main forces acting in the nucleus of an atom. State what each of these forces acts upon in the nucleus and indicate their ranges.

Force 1: ....

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....

Force 2: ....

....

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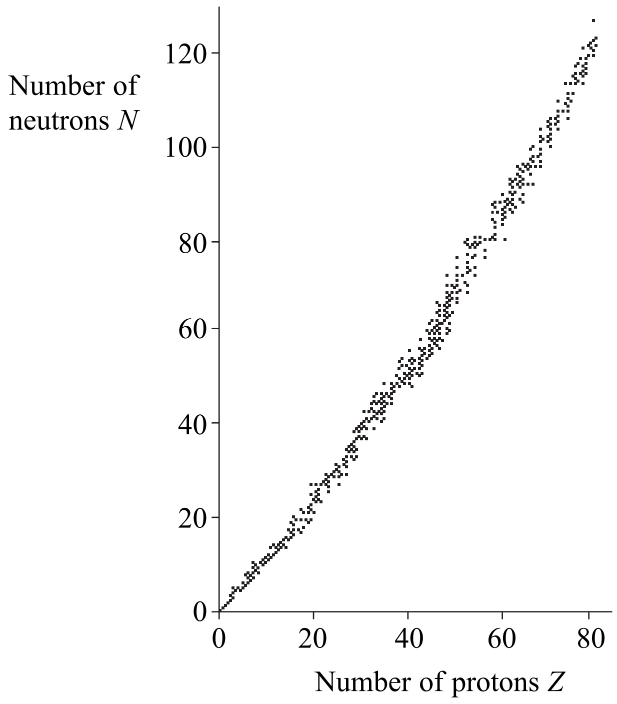
(4)

Leave blank

(c) (i) On the *N-Z* plot shown below, indicate the regions where nuclei that might undergo α, β^- and β^+ decay would occur.



(3)

(ii) Explain the significance of the region indicated by the dots in this plot. You may be awarded a mark for the clarity of your answer.

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(3)

(d) (i) In the Sun, fusion reactions convert hydrogen nuclei into helium nuclei. One step of this process involves a β^+ decay. Complete a full nuclear equation for this part of the reaction by adding nucleon and proton numbers to each particle.

$$p \longrightarrow n + \beta^+ + \nu$$

(2)

(ii) Tick the appropriate boxes to indicate which particles fit which classification.

	baryon	hadron	meson	lepton	antimatter
proton					
neutron					
β^+					
ν					

(4)

Leave blank

(e) A sigma-plus particle Σ^+ can decay to a particle X^+ and a π^0 particle. Quark flavours are shown for the Σ^+ and π^0 particles.

$$\underset{(usu)}{\Sigma^+} \longrightarrow \underset{(qqq)}{X^+} + \underset{(\bar{u}u)}{\pi^0}$$

(i) Show that this decay is permitted by using appropriate conservation laws.

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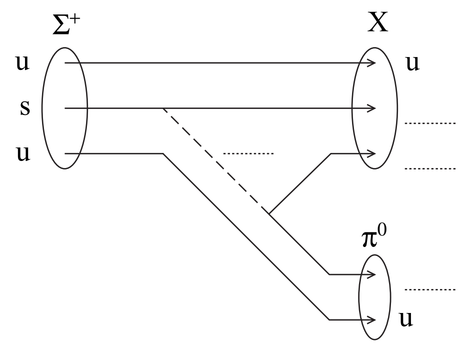
(2)

(ii) In this decay, the strange quark turns into an up quark by emitting a W^- particle, which in turn decays into down and anti-up quarks.

$$s \longrightarrow u + W^-$$

$$W^- \longrightarrow d + \bar{u}$$

Use this information to complete the diagram to show the W^- particle and the quarks by adding labels to each of the four dotted lines.



(2)

(iii) Identify particle X.

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(1)

(iv) What sort of particle is a W^-?

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(1)

(v) Give two reasons why a W^- particle must be responsible for the interaction.

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(2)

Leave blank

(vi) The Σ^+ can also decay to produce a neutron. Three decays are shown.

1. $\Sigma^+ \rightarrow n + \pi^-$

2. $\Sigma^+ \rightarrow n + \pi^0$

3. $\Sigma^+ \rightarrow n + \pi^+$

Which of these decays is possible? Explain your answer. Pions (π^-, π^0 and π^+) are mesons.

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(1)

Q3

(Total 32 marks)

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

Topic D – Medical Physics

4. (a) (i) The equation $I = P/4\pi r^2$ can be used in calculating intensity of X-rays from a source. Use this equation to show that the base units of intensity are kg s^{-3}.

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(3)

(ii) An X-ray beam has an intensity of 5.7 W mm^{-2} at a distance of 0.4 m from an X-ray tube. How far from the X-ray tube should a radiographer stand in order to reduce the intensity to 0.80 W mm^{-2}?

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(3)

(b) An X-ray tube works by accelerating electrons through a potential of 65 kV towards a target.

(i) Show that the energy of an electron arriving at the target is approximately 1×10^{-14} J.

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(2)

(ii) Assuming that the usual kinetic energy formula is valid, calculate the theoretical speed reached by an electron.

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(3)

(iii) What happens to the energy of the electrons when they strike the X-ray tube target?

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(2)

Leave blank

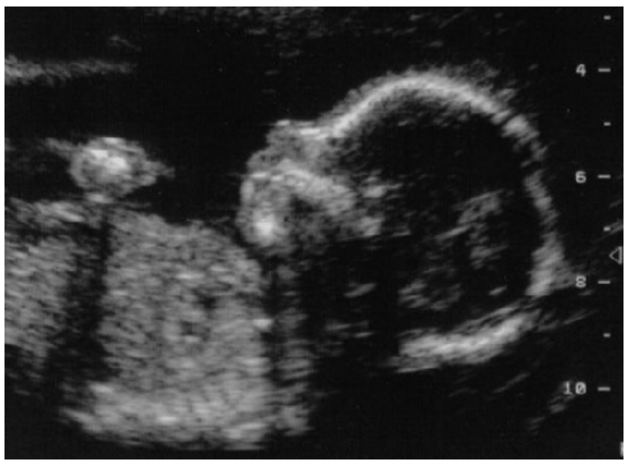
(iv) A typical X-ray tube has an efficiency of less than 1%. List two features of an X-ray tube target that enable it to cope with this low efficiency.

1. ....

2. ....

(2)

(c) An ultrasound image of a 19-week-old unborn baby is shown below.



(i) Is this an A-scan or a B-scan?

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(1)

(ii) Outline the principles for producing such a scan, with reference to the above image. You may be awarded a mark for the clarity of your answer.

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(5)

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(d) (i) Define each of the following in terms of a radioactive tracer which may be given to a patient.

Radioactive half-life ....

....

Biological half-life ....

....

Effective half-life ....

....

(3)

(ii) An isotope of iodine ^{125}I has an effective half-life of 16 days when it is used to label the human serum albumin. If it has a radioactive half-life of 60 days calculate its biological half-life.

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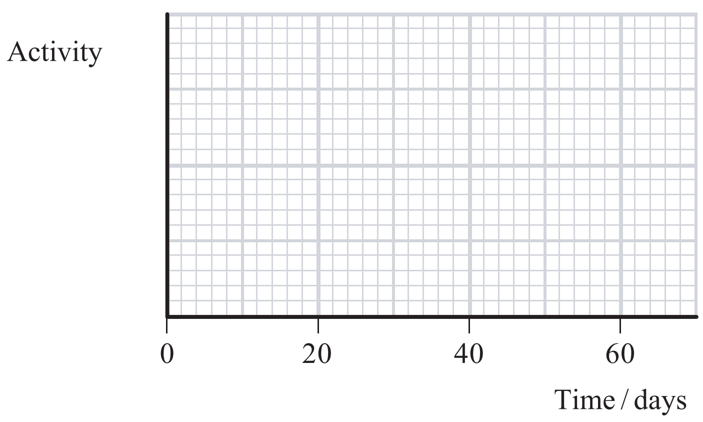
(3)

(iii) On the axes below sketch two curves, one showing the activity of the ^{125}I within a patient and the other showing the activity of an identical sample that was kept in a laboratory. Label your curves P (patient) and L (laboratory).



(3)

(iv) What type of radiation should ^{125}I emit in order to be used as a tracer? Justify your answer.

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(2)

Q4

(Total 32 marks)

TOTAL FOR PAPER: 32 MARKS

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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 $= F \times$ (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 $\quad \lambda t_{\frac{1}{2}} = 0.69$

N 2 0 8 2 8 A 0 1 8 2 0

Electrical current and potential difference

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

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	$\theta/°\mathrm{C} = T/\mathrm{K} - 273$	

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)

$\cos\theta \approx 1$