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

Wednesday 16 January 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	Items included with question papers
Nil	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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Turn over

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

Topic A – Astrophysics

1. (a) (i) When the Sun nears the end of its life it will become a red giant star. Give one similarity and one difference (apart from size, age and colour) between the Sun now and when it becomes a red giant.

Similarity. ....

....

Difference. ....

....

(2)

(ii) Complete the sentence below by circling the appropriate term within each pair of brackets.

A white dwarf star is a { cool, hot } star of { high, low } luminosity

and small { density, surface area } which has moved

{ higher up, lower down, off } the main sequence.

(2)

(b) Stars can vary in mass from 120 $M_\odot$ (where $M_\odot$ is the mass of the Sun) to 0.08 $M_\odot$. Below this lower limit a star cannot sustain itself by fusion reactions in its core, but objects known as brown dwarfs, which are below this lower limit, can form. Brown dwarfs do not stably burn hydrogen but give off radiation as they fuse their original supply of deuterium (hydrogen-2) to helium as shown:

$$^{2}_{1}\text{H} + {^{2}_{1}\text{H}} + \rightarrow {^{4}_{2}\text{He}}$$

(i) Calculate the energy released when two deuterium nuclei fuse to form one helium nucleus.

Masses: $^{2}_{1}\text{H} = 3.3436 \times 10^{-27}\,\text{kg}$
$^{4}_{2}\text{He} = 6.6447 \times 10^{-27}\,\text{kg}$

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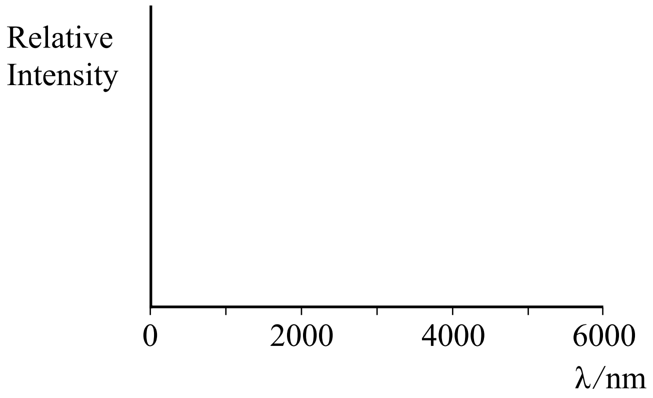
(3)

(ii) Only a small number of brown dwarfs have been discovered. One of these was identified by its relatively low surface temperature of about 1000 K. Show that the wavelength at which the intensity of radiation emitted by this brown dwarf is a maximum is approximately 3000 nm.

(3)

(iii) Sketch a graph to show how the relative intensity of radiation from this brown dwarf varies with wavelength.



Hence explain why radiation from this object cannot be observed by the naked eye.

(4)

(iv) Had the mass M_J of Jupiter been greater than $0.08\,M_\odot$ it could have become a star, forming a binary system with the Sun. Astronomers estimate that Jupiter has approximately 1% of the required mass for this.

Use the following data to confirm this estimate.

$$M_J = 1.9 \times 10^{27}\,\text{kg}$$
$$M_\odot = 2.0 \times 10^{30}\,\text{kg}$$

(2)

(c) (i) A star of mass 30 $M_{\odot}$ has a lot more fuel available than our Sun. A student suggests that this star should therefore spend longer than the Sun on the main sequence. Criticise this statement. You may be awarded a mark for the clarity of your answer.

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(4)

(ii) Another high mass star becomes a supernova. If the mass of the core remnant left after the supernova stage is 2.2$M_{\odot}$, circle the type of star that would be formed in the list below.

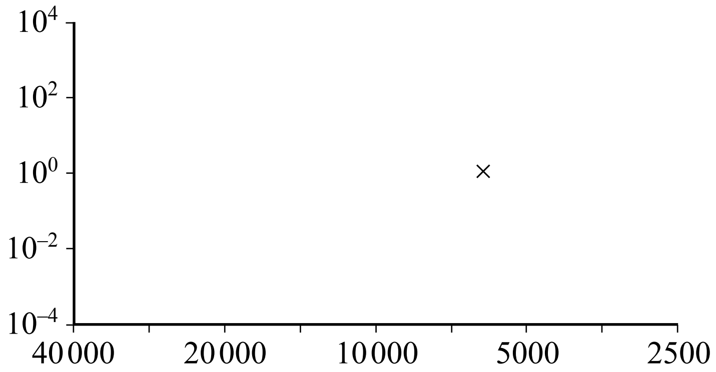
Red giant Black hole White dwarf Neutron star Black dwarf

(iii) The Sun will go through different evolutionary phases in the future. In the list below, circle all the types of star that the Sun will become at some stage in the future.

Red giant Black hole White dwarf Neutron star Black dwarf

(4)

(d) Astronomers can use a Hertzsprung-Russell diagram to classify stars.



(i) Fully label each axis.

(3)

(ii) The position of the Sun is marked with an ×. Add a line to the diagram to show where main sequence stars lie.

(2)

(iii) With reference to your diagram, describe how astronomers could use the temperature of a main sequence star to calculate its distance from Earth.

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(3)

Q1

(Total 32 marks)

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

Topic B – Solid Materials

2. (a) (i) Give one similarity and one difference between quench hardening and annealing.

Similarity. ....

....

Difference. ....

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(3)

(ii) While a sword is being made, it is work hardened. Describe how this is done and explain in terms of molecular behaviour how this process would make its surface harder. You may be awarded a mark for the clarity of your answer.

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(4)

(b) Show that the equation

Energy density = ½ × stress × strain

is homogenous with respect to units.

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(3)

(c) (i) Draw a line from each of the polymers on the left to its correct classification on the right.

Perspex

Nylon

Melamine

Polythene

Rigid Thermoset

Amorphous Thermoset

Semi-crystalline Thermoset

Rigid Thermoplastic

Amorphous Thermoplastic

Semi-crystalline Thermoplastic

(4)

(ii) State which of these polymers would be most suitable for use as a kitchen worktop.

....

(1)

(iii) State which of these polymers could be made into a supermarket carrier bag.

....

(1)

(iv) A nylon guitar string is tuned by tightening it. When a force of 40 N is applied to the string, it stretches by 2.0 cm. Calculate the original length of the string. The cross-sectional area of the string is 8.0×10^{-7} m^2 and the Young modulus of nylon is 2.0×10^{9} Pa.

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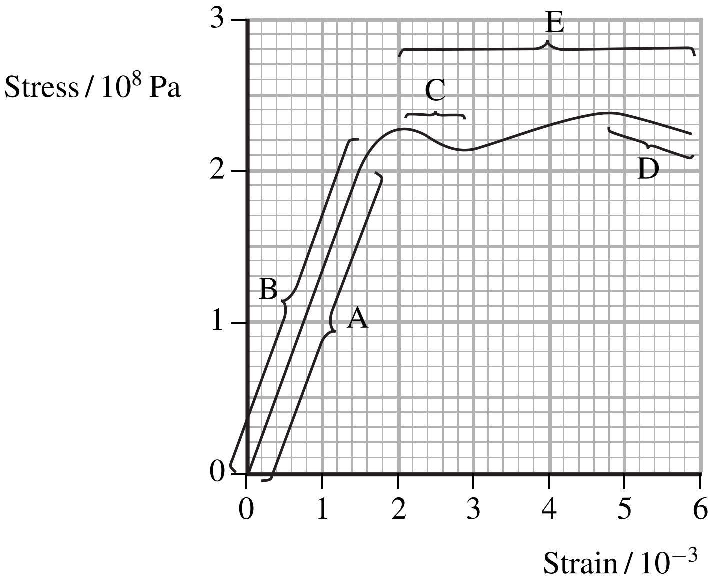
(3)

(d) The graph shows the behaviour of a copper alloy when it is stressed.



(i) Complete the table by using the letters from the graph (A, B, C, D or E) to indicate the correct regions.

Necking	
Elastic deformation	
Plastic flow	

(3)

(ii) Calculate the Young modulus of the copper alloy.

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(4)

(iii) Add a second graph to the axes above to show the behaviour of a brittle material with a Young modulus lower than that of the copper alloy and which fractures at a strain of 2.6×10^{-3}.

(3)

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

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(1)

(ii) A manufacturer describes a hockey stick as having a seven-ply wooden head with a carbon-composite handle.

State what type of composite the head is.

....

State what type of composite the handle is.

....
(2)

Q2

(Total 32 marks)

Leave blank

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

Topic C – Nuclear and Particle Physics

3. (a) State one similarity and two differences between alpha and beta radiations.

Similarity. ....

....

Difference 1. ....

....

Difference 2. ....

....

(3)

(b) (i) An alpha particle is fired at a beryllium (Be) nucleus, producing a carbon-12 nucleus and a neutral particle X. One beryllium nucleus contains four protons and five neutrons. Complete the equation for this reaction by adding proton and nucleon numbers to **all four** particles. Hence deduce the name of particle X.

$$\alpha \; + \; \mathrm{Be} \longrightarrow \mathrm{C} \; + \; \mathrm{X}$$

Name of particle X. ....

(3)

(ii) Show that a carbon-12 nucleus has a radius of approximately 3×10^{-15} m.
$r_0 = 1.2 \times 10^{-15}$ m

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(2)

(iii) Hence estimate the density of a carbon-12 nucleus.

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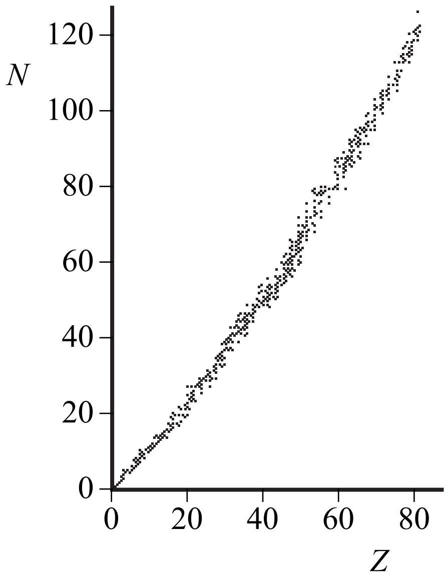
(4)

(iv) Complete the table below to show the number of each type of particle that makes up a **single** carbon-12 **atom**.

leptons	
baryons	
hadrons	
quarks	

(4)

(c) The scatter diagram below shows the relationship between *N* and *Z* for stable nuclides.



(i) State what the letters *N* and *Z* represent.

N: ....

Z: ....

(1)

(ii) With reference to the diagram explain why certain unstable nuclides decay by emitting beta-minus radiation. You may be awarded a mark for the clarity of your answer.

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(3)

(d) In the production of top quarks and anti-top quarks, a large amount of energy is required. A proton and an antiproton are accelerated to a very high speed and then smashed into each other. The energy from this creates gluons for a tiny fraction of a second, which then turn into a top–antitop pair.

(i) State the names of the four possible quarks and antiquarks which could be initially annihilated in this reaction.

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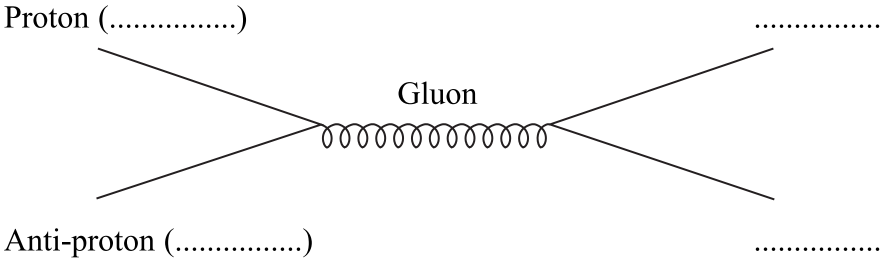
....

(2)

(ii) Complete the labelling of the Feynman diagram below representing the production and subsequent decay of the gluons by adding quark flavours on the dotted lines provided.



(2)

(iii) State the fundamental interaction responsible for this decay.

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(1)

(iv) The top quark subsequently decays into a bottom quark and an exchange particle Y.

$$t \longrightarrow b + Y$$

State the fundamental interaction responsible for this decay. Justify your answer.

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(2)

Leave blank

(v) The top quark has the same charge as an up quark; the bottom quark has the same charge as a down quark. Use the law of conservation of charge to determine the charge on Y. Hence state the name of Y.

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(3)

(vi) The antitop quark that was originally produced decays as shown.

$$\bar{t} \longrightarrow \bar{b} + d + \bar{u}$$

State two conditions, other than charge and momentum conservation, which must be satisfied for one particle to decay into three particles.

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....

(2)

Q3

(Total 32 marks)

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

Topic D – Medical Physics

4. (a) State one similarity and two differences between alpha and beta radiations.

Similarity ....

....

Difference 1. ....

....

Difference 2. ....

....

(3)

(b) (i) A radioisotope of iodine ^{131}I has a radioactive half-life of 8.0 days and a biological half-life of 21 days. Show that the effective half-life of ^{131}I is approximately 6 days.

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(2)

(ii) A tracer containing ^{131}I is given to a patient as part of a thyroid investigation. Estimate the **percentage** of the original ^{131}I remaining in the patient approximately one month after the investigation. Give your answer to the nearest whole number.

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(3)

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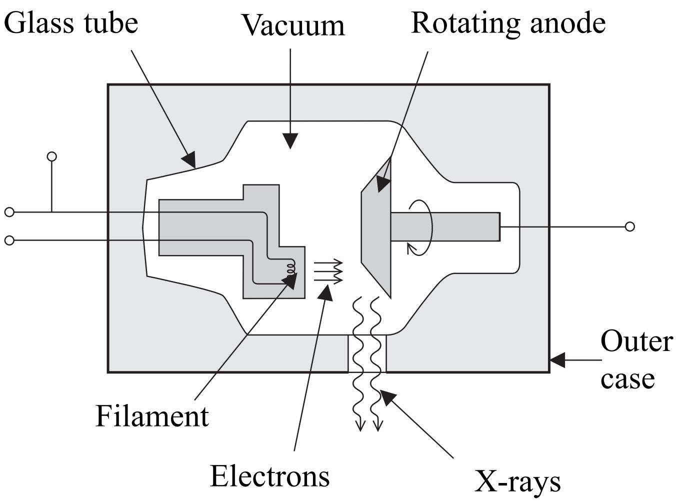
(c) The diagram shows part of a diagnostic X-ray tube.



(i) State the purpose of the filament.

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(1)

(ii) Explain why a vacuum is required in the X-ray tube.

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(2)

(iii) State the name of the material the surface of the anode is made from and explain why the anode must rotate.

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(3)

(iv) An X-ray tube produces a beam of intensity 2.0 MW m^{-2} at a distance of 1.3 m from the X-ray tube. Calculate the theoretical power of the X-ray source, assuming that it acts as a point source.

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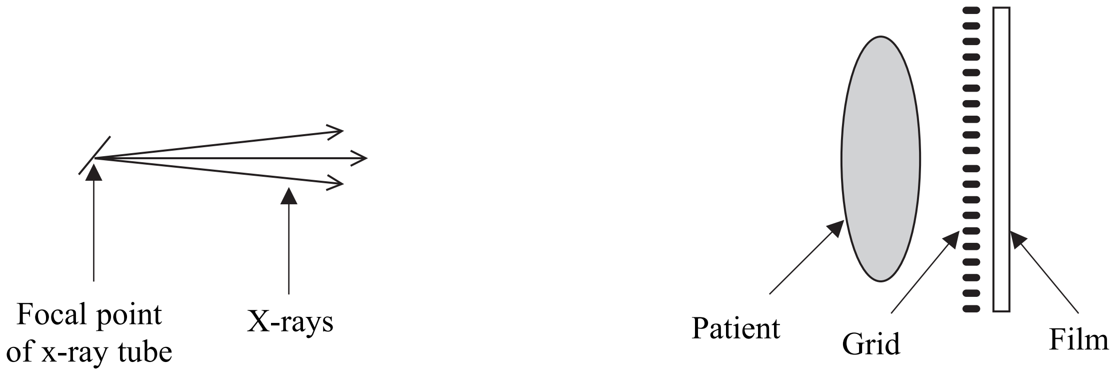
(2)

(d) The diagram shows an anti-scatter grid used in X-ray imaging.



(i) State the name of the material the grid is made from.

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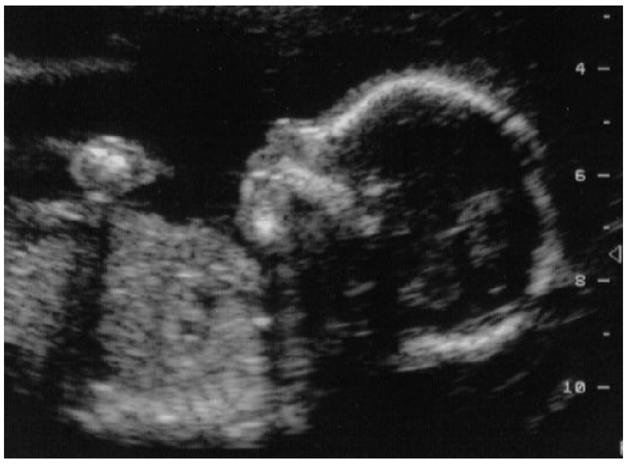
(1)

(ii) Add several X-ray paths to the diagram to show how an anti-scatter grid works.

(3)

(e) An ultrasound image of a foetus is shown.



(i) State whether this is an A-scan or a B-scan.

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(1)

(ii) State three differences between A-scans and B-scans.

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(3)

(f) The table shows data for the properties of ultrasound in air and soft tissue of the body.

Medium	Density / kg m^{-3}	Velocity / m s^{-1}	Specific acoustic impedance / kg m^{-2} s^{-1}
Air	1.3	330	Z_{air}
Soft tissue	1060	1540	1.63×10^6

(i) Show that Z_{air} is approximately 400 kg m^{-2} s^{-1}.

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(2)

(ii) Show that the reflection coefficient at the boundary between air and skin (soft tissue) is almost 1.00 (100%).

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(3)

(iii) Hence explain why a coupling medium such as a gel must be used during an ultrasound scan of a patient. You may be awarded a mark for the clarity of your answer.

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(4)

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

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

$$\begin{array}{c}\text{Sum of clockwise moments}\\ \text{about any point in a plane}\end{array} = \begin{array}{c}\text{Sum of anticlockwise moments}\\ \text{about that point}\end{array}$$

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	$L = \sigma T^4 \times \text{surface area}$	(Luminosity L; Stefan constant σ)
Wien's law	$\lambda_{\text{max}}T = 2.898 \times 10^{-3}\ \text{m K}$	
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)
	$\cos\theta \approx 1$	