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

Tuesday 17 January 2006 – 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 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) The Cosmic Background Explorer satellite (COBE), launched in 1989, measured a cosmic background temperature of 2.725 K. Calculate the peak wavelength of the background spectrum that gives this temperature.

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(3)

Which type of electromagnetic radiation forms this background spectrum?

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(1)

(b) Define what is meant by a main sequence star.

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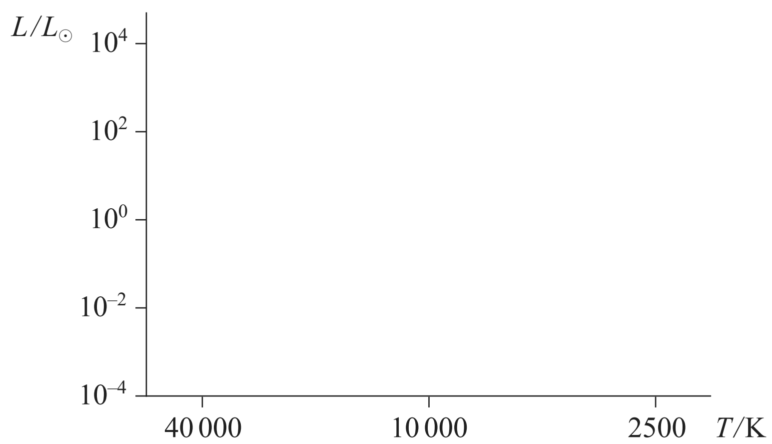
(2)

A Hertzsprung-Russell diagram can be used to plot the luminosity of a star in terms of the luminosity of the Sun ($L_{\odot}$) against the star's surface temperature.



Add to the diagram a line to indicate where main sequence stars occur.

Mark clearly with a cross the location of the Sun.

(3)

N 2 0 8 2 9 A 0 2 2 0

Leave blank

Add to the diagram the regions where (i) white dwarf stars and (ii) red giant stars may typically be found. Label these clearly.

Use the diagram to estimate the average surface temperature of a red giant star.

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(3)

(c) The table shows the properties of three main sequence stars.

Star	Luminosity / $L_{\odot}$	Surface temperature / K
α Cen B	0.53	5250
Sirius A	26	9230
γ Cas	930 000	29 500

State which star would

(i) have the greatest mass ....

(ii) spend the greatest time on main sequence ....

(2)

The luminosity of the Sun is 3.9×10^{26} W. Calculate the luminosity of Sirius A.

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(2)

Show that the area of Sirius A is approximately $2.5 \times 10^{19}\,\text{m}^2$.

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(2)

Hence calculate the diameter of Sirius A.

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(2)

Leave blank

(d) When a star in excess of eight solar masses leaves the main sequence it may become a supernova. Describe the processes which occur as this happens and explain what might subsequently happen to such a star. You may be awarded a mark for the clarity of your answer.

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(5)

Leave blank

(e) When hydrogen nuclei fuse to form a helium nucleus, a small fraction of the mass of the hydrogen going into the nuclear reaction does not show up in the mass of the helium. Use the data below to show that the mass decrease is approximately 5×10^{-29} kg.

Mass of hydrogen nucleus = 1.673×10^{-27} kg

Mass of helium nucleus = 6.645×10^{-27} kg

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(2)

Hence calculate the energy released when one helium nucleus is created from four hydrogen nuclei.

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(2)

Calculate the 'small fraction' that is referred to in the paragraph above. Give your answer as a percentage.

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(3)

Q1

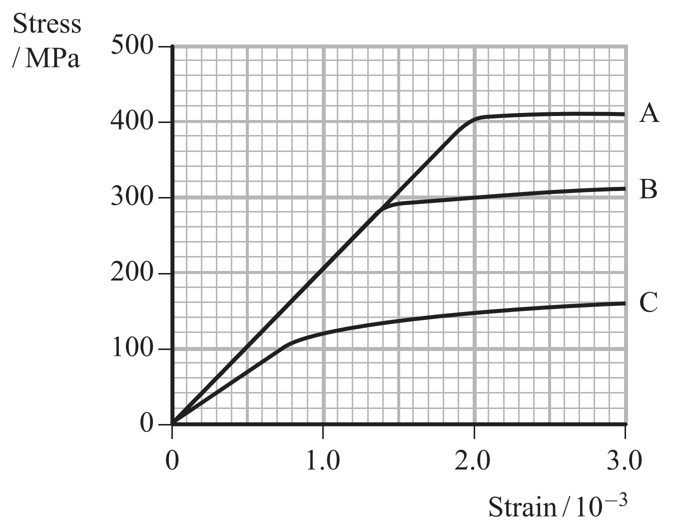
(Total 32 marks)

Leave blank

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

Topic B – Solid Materials

2. (a) The graph shows the behaviour of three materials A, B and C when stress is applied to them.



(i) Show that the material C has a Young modulus of 130 GPa.

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(3)

(ii) Show that material B has an energy density of approximately 700 kJ m^{-3} at a strain of 3.0×10^{-3}.

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(4)

Which material(s) is / are the strongest? Explain your answer.

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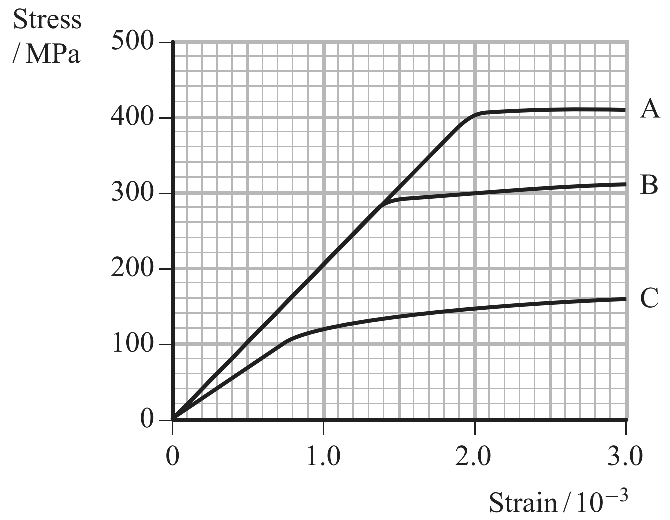
(2)

Leave blank

(b)



Mark with a cross the point on each line where Hooke's law is no longer obeyed.

The three materials shown are copper, mild steel and high carbon steel. Identify which is which.

A: ....

B: ....

C: ....

Which of these materials would you expect to be the most brittle?

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(4)

Describe what happens to the molecular structure of one of these materials as it is stressed with reference to elastic behaviour, plastic flow and fracture. You may be awarded a mark for the clarity of your answer.

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(4)

On the axes above add a further line to show the stress-strain graph produced by loading natural rubber up to a strain of 3.0×10^{-3}. The Young modulus of the rubber is 21×10^{6} Pa.

(1)

Leave blank

(c) Describe the process by which a pre-stressed reinforced concrete beam is produced. Illustrate your answer with diagrams.

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(5)

(d) Define what is meant by the term elastomer.

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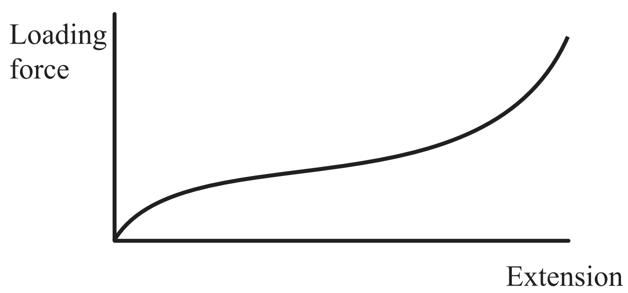
(1)

The graph shows how the extension of a length of rubber varies with the applied force. Describe what happens to the molecular structure of the rubber during this process.



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(3)

N 2 0 8 2 9 A 0 8 2 0

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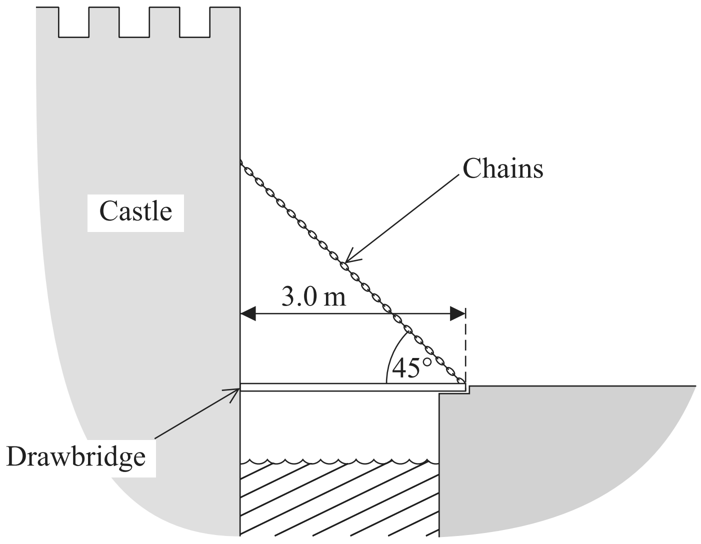
(e) A uniform drawbridge of mass 2000 kg and length 3.0 m is being held in a horizontal position by two chains of negligible mass as shown. The end of the drawbridge is not in contact with the ground. The chains make an angle of 45° to the horizontal.



Calculate the weight of the drawbridge.

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(1)

Add an arrow to the diagram to show the position and direction of the weight of the drawbridge.

(1)

Using the principle of moments, calculate the value of the tension in each chain.

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(3)

Q2

(Total 32 marks)

N 2 0 8 2 9 A 0 9 2 0

Turn over

Leave blank

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

Topic C – Nuclear and Particle Physics

3. (a) In a fast breeder reactor a nucleus of uranium $^{238}_{92}U$ absorbs a neutron to produce uranium, $^{239}_{92}U$. Write a balanced nuclear equation for this reaction.

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(1)

The $^{239}_{92}U$ subsequently undergoes a beta-minus decay to form neptunium Np. Write a balanced nuclear equation for this reaction.

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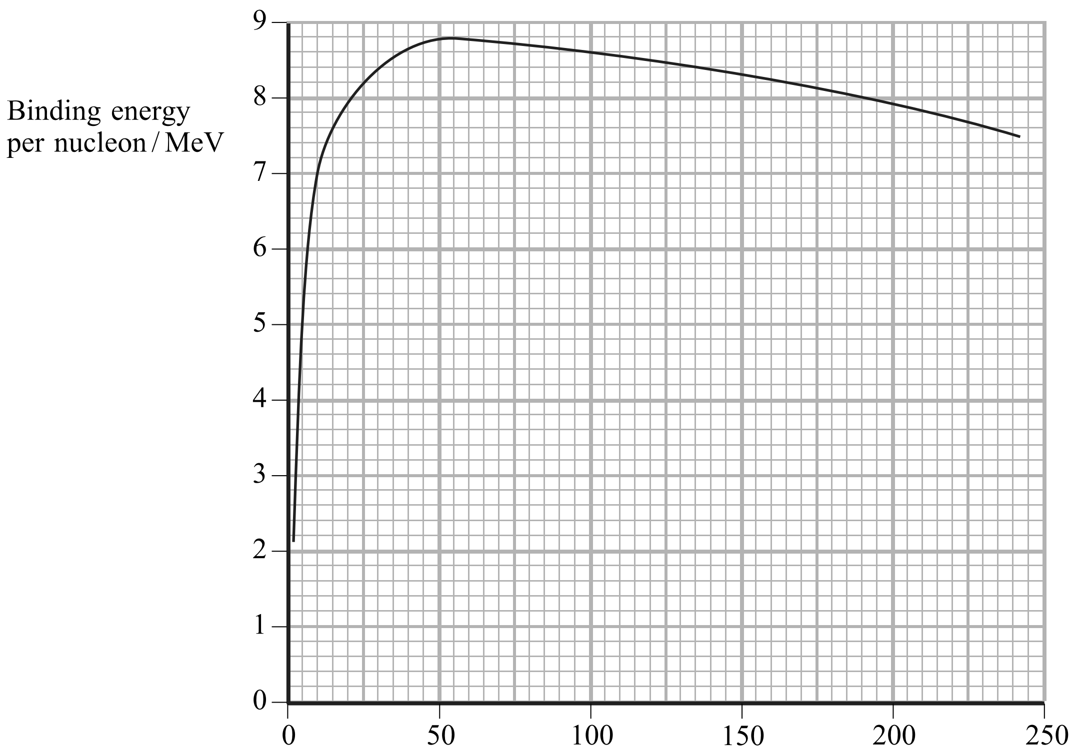
(3)

(b) The graph shows how the binding energy per nucleon varies with another quantity.



(i) Add an appropriate label to the *x*-axis.

(1)

(ii) Mark clearly on the graph the approximate position of

- deuterium $^{2}_{1}H$, labelling this point H,
- iron $^{56}_{26}Fe$, labelling this point Fe,
- uranium $^{235}_{92}U$, labelling this point U.

(2)

(iii) Circle the most stable nucleus on the graph.

(1)

N 2 0 8 2 9 A 0 1 0 2 0

Leave blank

(iv) Use the graph to calculate the binding energy of a uranium-235 nucleus. Give your answer in GeV.

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Binding energy = ... GeV

(3)

(c) Positronium is a light hydrogen-like 'atom' formed when an electron and a positron orbit a common centre.

What is the overall charge of positronium? Explain your answer.

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Why must an electron and a positron have the same mass?

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(3)

Positronium is unstable as the electron and the positron may interact with each other. Suggest the outcome of such an interaction.

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(2)

Leave blank

Explain which fundamental force(s) might be responsible for this interaction. You may be awarded a mark for the clarity of your answer.

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(4)

Give two similarities and one difference between a π^0 meson and a positronium 'atom'.

Similarity 1: ....

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Similarity 2: ....

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Difference: ....

....
(3)

(d) In 1964 the following reaction was observed for the first time. The K particles are kaons (a type of meson) and X was a new particle.

$$K^- + p \longrightarrow K^0 + K^+ + X$$

Use conservation laws to deduce the nature of particle X in order to underline the correct words in the sentence below. Show all your working.

Particle X is a meson / baryon / lepton with a charge of −1 / 0 / +1

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(4)

Leave blank

Add the quark content of the proton and the K^+ to the table.

Particle	Quark content
K^-	$s\bar{u}$
p	
K^0	$d\bar{s}$
K^+	

(2)

Given that this reaction was mediated by the strong force, deduce the quark content of particle X.

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(3)

Q3

(Total 32 marks)

Leave blank

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

Topic D – Medical Physics

4. (a) Give two physiological effects of radiation on cells.

1 ....

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2 ....

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(2)

(b) Iodine $^{131}_{53}\mathrm{I}$ is a radioisotope that is sometimes used in nuclear medicine. It decays with the emission of both a β^- particle and a γ-ray to form xenon Xe. Write a balanced nuclear equation to represent this decay process, showing nucleon and proton numbers for **all** symbols.

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(3)

(c) Technetium $^{99m}_{43}\mathrm{Tc}$ is the radioisotope most widely used in diagnostic studies. Explain the meaning of the symbol ‘m’ and what this implies about this radioisotope.

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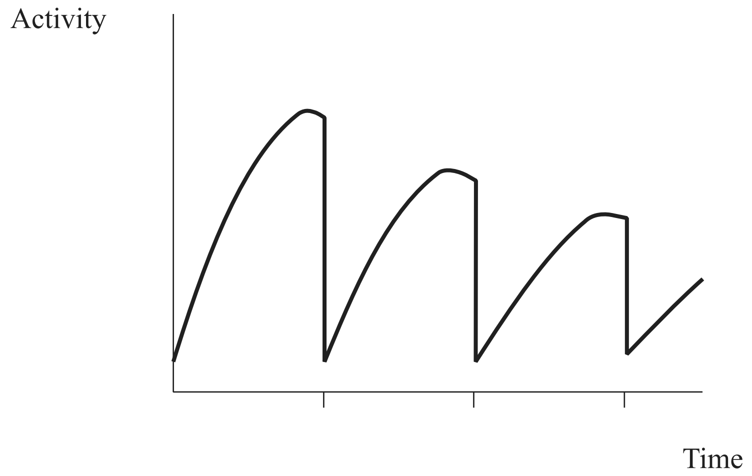
(2)

${}^{99m}_{43}Tc$ is produced in hospitals from molybdenum in an elution cell. The graph shows the activity of the elution cell against time during several elutions.



Add a suitable time scale to the graph.

(1)

Explain clearly the shape of the graph. You may be awarded a mark for the clarity of your answer.

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(4)

Leave blank

(d) What is meant by the term ultrasound?

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(2)

The acronym 'sonar' stands for '**so**und **na**vigation and **r**anging' and is a principle used for ultrasonic diagnosis. Outline the sonar principle and state what sort of information it provides.

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(3)

Show that the speed of ultrasound in soft tissue is approximately 1500 $m\,s^{-1}$ using the data given below.

Ultrasound frequency = 1.50 MHz

Ultrasound wavelength = 1.03 mm

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(2)

Calculate the specific acoustic impedance of soft tissue which has a density of 1060 $kg\,m^{-3}$.

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(2)

An ultrasonic pulse travelling through soft tissue is incident on a bone within the human body which has a specific acoustic impedance of $6.5 \times 10^{6}\,kg\,m^{-2}\,s^{-1}$. Calculate the percentage of the incident intensity of the ultrasound that is transmitted into the bone.

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(4)

Leave blank

Leave blank

(e) X-rays can be used for diagnosis or for therapy. With reference to energies, distinguish between the X-rays used in diagnosis and those used in therapy.

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(3)

The X-ray image below shows a dislocated shoulder.

Explain why some areas of the image are white, whilst others are grey. Use the information given to quantify your explanation.

Medium	Proton number
Bone	20
Soft tissue	9

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