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 8 June 2007 – 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
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) Explain the difference between the luminosity and the intensity of a star.

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(3)

(b) (i) The Sun has a surface temperature of 5800 K. Calculate the wavelength at which the intensity of its spectrum is a maximum.

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(2)

(ii) The radius of the Sun is 6.96×10^8 m. Show that its surface area is approximately equal to 6×10^{18} m^2.

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(2)

(iii) Hence calculate the luminosity of the Sun.

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(3)

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(c) A brown dwarf is a star-like object that is composed of hydrogen but has insufficient mass to become a main sequence star. Explain, in terms of nuclear fusion, why stars need to exceed a certain minimum mass to join the main sequence. You may be awarded a mark for the clarity of your answer.

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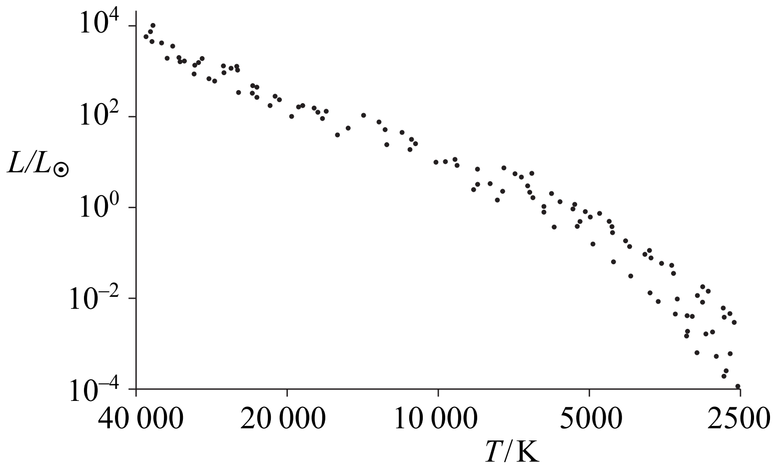
(4)

(d) The Hertzsprung-Russell diagram shows the luminosity of a star plotted against its temperature.



(i) Both scales of the diagram are logarithmic. State what is meant by logarithmic. Illustrate your answer by referring to the numerical values on the temperature axis.

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(2)

(ii) Add to the graph to indicate

1) a low mass star which is on the main sequence, marking this point L

2) the area where white dwarf stars occur, marking this area W

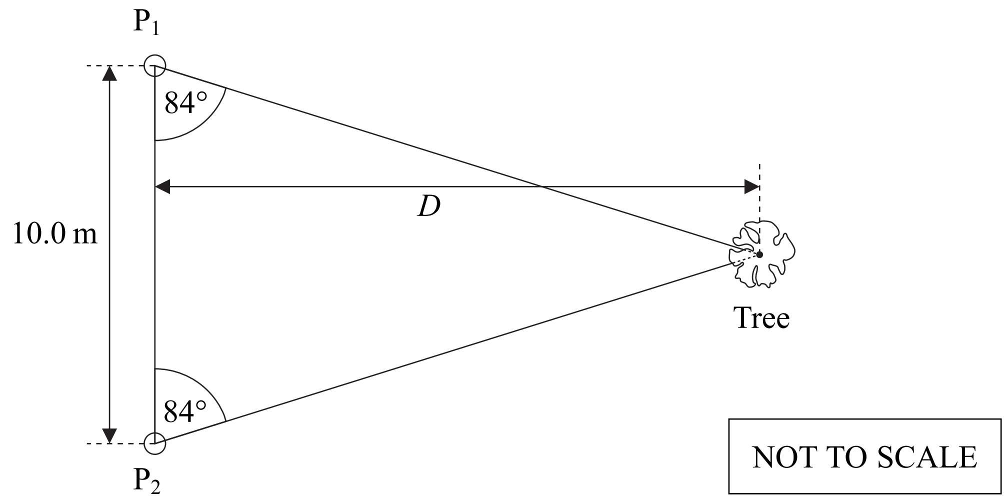
3) the region where red giant stars occur, marking this area R

4) the position of the Sun, marking this point S.

(4)

Leave blank

(e) Two pupils use a parallax method to calculate the distance to a nearby tree. They stand 10.0 m apart (the baseline, P_1P_2) and measure the angle between each other and the tree. The angle measured by each student is 84°. A plan view of this is shown.



(i) Calculate the distance *D*.

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(2)

(ii) State what astronomers use as their baseline in trigonometric parallax measurements of nearby stars.

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(1)

(iii) State why trigonometric parallax cannot be used to measure the distance to stars over 100 light years from Earth.

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(1)

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(f) The theoretical radius R of a black hole depends on its mass M. This radius is the distance from its centre to its event horizon and is given by the equation

$$R = \frac{2GM}{c^2}$$

where G and c are constants: $G = 6.7 \times 10^{-11}\ \mathrm{N\,m^2\,kg^{-2}}$ and $c = 3.0 \times 10^{8}\ \mathrm{m\,s^{-1}}$.

(i) Show that if the Earth were somehow to turn into a black hole it would have to be compressed to a diameter of approximately 2 cm.

Mass of Earth = 6.0×10^{24} kg

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(3)

(ii) In order to become a black hole, a main sequence star must have a mass that is many times bigger than the Sun. State what such a massive star will become **immediately** before it collapses to form a black hole.

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(1)

(iii) State the minimum mass of the core remnant if a black hole is formed.

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(1)

(iv) Calculate the mass, in terms of $M_{\odot}$, of a black hole that has a radius of 26.8 km.

Mass of the Sun, $M_{\odot} = 2.0 \times 10^{30}$ kg

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(3)

Q1

(Total 32 marks)

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

Topic B – Solid Materials

2. (a) Explain the difference between elastic and plastic behaviour in a metal. You should include reference to molecular behaviour in your answer.

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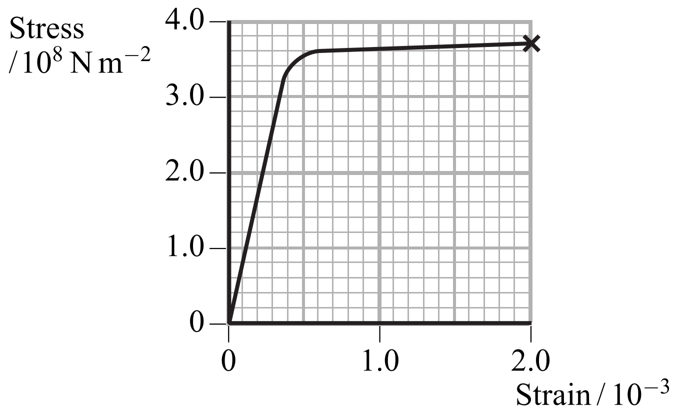
(3)

(b) The graph shows the behaviour of a metal when it is stressed until it breaks.



(i) State the ultimate tensile stress of this metal.

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(1)

(ii) Use the graph to estimate the energy density of the metal just before it breaks.

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(iii) Calculate the Young modulus of the metal.

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(iv) State whether the metal is tough or brittle. Justify your choice with reference to the graph.

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(3)

(c) (i) Define the terms stress and strain.

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(1)

(ii) Hence show that the Young modulus E can be written as

$$E = \frac{Fl}{A\Delta l}$$

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(iii) A tensile force of 150 N is applied to a 3.5 m length of copper wire. The resulting extension is 15 mm. Given that the Young modulus of the copper is 1.3×10^{11} Pa, show that the radius of the wire is approximately 0.3 mm.

(3)

(d) (i) When a golf ball is struck it briefly absorbs a lot of energy, most of which is then released as kinetic energy. Explain why rubber would be a suitable material for the core of a golf ball. You may be awarded a mark for the clarity of your answer.

(4)

(ii) Sketch a graph to show how rubber behaves when a stress is applied and then removed. Add labels to indicate loading and unloading.

(2)

Leave blank

(iii) Use your graph to explain why a golf ball has gained some internal energy after it has been struck.

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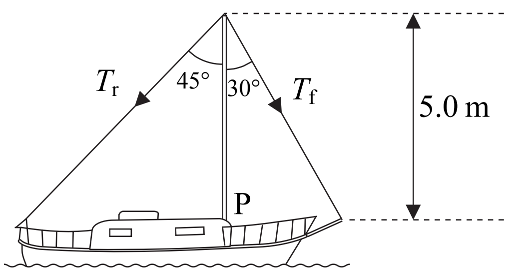
(2)

(e) The mast on a ship is held in place vertically by two steel cables as shown. The tension in the front cable T_f is 4.0 kN and the tension in the rear cable T_r is 2.8 kN. Point P is the base of the mast.



(i) What is the total downward force on the top of the mast?

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(ii) By taking moments about P show that the mast is in rotational equilibrium.

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Q2

(Total 32 marks)

N 2 6 1 4 6 A 0 9 2 4

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

Topic C – Nuclear and Particle Physics

3. (a) List the differences between the strong interaction and the weak interaction. Include the exchange particles in your answer.

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(4)

(b) (i) Show that an alpha particle has a radius of approximately 2×10^{-15} m.

$r_0 = 1.2 \times 10^{-15}$ m

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(3)

(ii) Hence estimate the density of an alpha particle.

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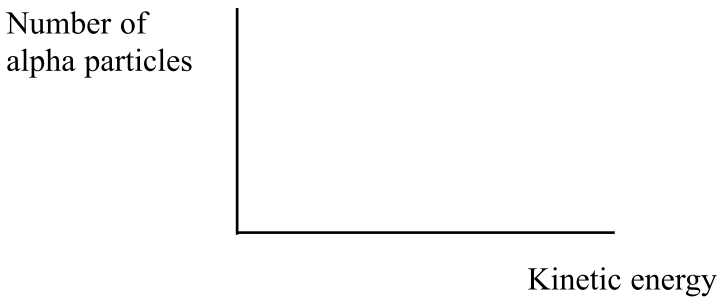
(iii) Sketch the energy spectrum of alpha particles produced in the alpha decay of a particular nuclide.



(1)

(c) (i) Carbon $^{14}_{6}C$ can be formed in the Earth's upper atmosphere when a nitrogen (N) atom absorbs a beta-minus particle. An electron neutrino is also formed. Write a full nuclear equation for this reaction, including nucleon and proton numbers.

$$\longrightarrow$$

(3)

(ii) State what change takes place in the nucleus of the nitrogen atom during this reaction.

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(1)

(iii) The carbon produced in this reaction has a half-life of 5730 years. A sample of this carbon in an archaeological specimen which is approximately 12 000 years old has an activity of 1200 Bq. Estimate the **initial** activity of this sample.

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N 2 6 1 4 6 A 0 1 1 2 4

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(d) Describe the process of pair production, giving two examples. You may be awarded a mark for the clarity of your answer.

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(4)

(e) The Large Hadron Collider (LHC) at CERN is designed to smash hadrons together to investigate the structure of these particles.

(i) State what is meant by a hadron.

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(1)

(ii) Complete the table to show the quark flavours.

Charge / *e*	Quark flavour (with increasing mass)		
$+\frac{2}{3}$	up		
$-\frac{1}{3}$	down		bottom

(2)

Leave blank

(iii) In terms of the charge on an electron, calculate all possible values of charge that a baryon could have. You need not consider antibaryons. Show **all** your working.

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(3)

Hence state the most negative charge that an **antibaryon** could have.

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(1)

(iv) A pion (π) is a meson composed only of up and down quarks and their antiquarks. Complete the table to show all possible pion compositions.

Pion type	Possible composition
π^+	
π^-	
π^0	

(3)

Q3

(Total 32 marks)

N 2 6 1 4 6 A 0 1 3 2 4

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

Topic D – Medical Physics

4. (a) Add to the sketches below to show the relative positions of the source, the patient and the detector in ultrasound and X-ray imaging. State two differences between ultrasound and X-ray imaging.

Ultrasound X-ray

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(4)

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

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(1)

(ii) State how the radioactive molybdenum is produced in a nuclear reactor.

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(1)

N 2 6 1 4 6 A 0 1 5 2 4

Turn over

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(iii) When ^{99m}Tc decays it emits gamma radiation that can be used in tracer studies. Explain three advantages of using gamma radiation from the ^{99m}Tc source for such studies.

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(3)

(c) (i) X-rays can be used for both diagnosis and therapy. State the difference between diagnosis and therapy.

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(1)

(ii) State the typical energies, in electronvolts, that are used for each process.

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(2)

(iii) State the effect that the proton number has on the absorption of X-rays in both diagnosis and therapy.

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(1)

Leave blank

(iv) A patient with a tumour is to receive X-ray therapy. Explain how the dose received by the surrounding tissue is kept as low as possible during treatment. Use a labelled diagram as part of your answer. You may be awarded a mark for the clarity of your answer.

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(4)

(d) The table shows data for the properties of ultrasound in different parts of the body.

Medium	Density / kg m^{-3}	Velocity / m s^{-1}	Specific acoustic impedance / 10^6 kg m^{-2} s^{-1}
Blood	1013	*A*	1.59
Brain	*B*	1540	1.58
Fat	950	1450	1.38
Muscle	1075	1590	1.70

(i) Two values, *A* and *B*, are missing from the table. Calculate these values.

A ....

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B ....

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(3)

Leave blank

(ii) Calculate the reflection coefficient for the muscle–fat boundary and hence show that approximately 99% of the incident ultrasound is transmitted through this boundary.

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(3)

(e) (i) Define biological half-life.

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(1)

(ii) A radioisotope X has a radioactive half-life of 13 hours and a biological half-life of 11 hours. Show that its effective half-life is about 6 hours.

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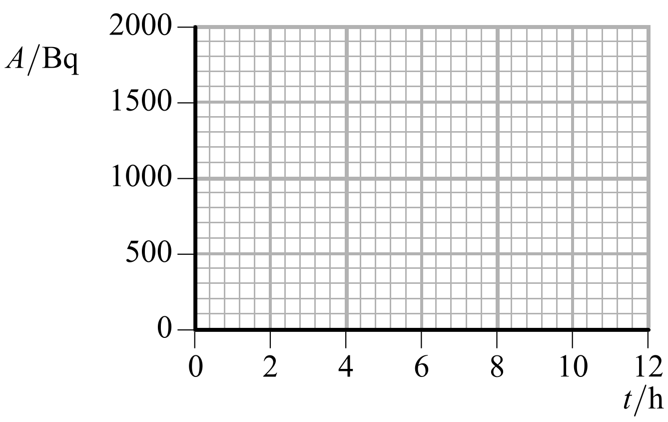
(2)

(iii) Radioisotope X is injected into a patient. Its initial activity is 1000 Bq. Plot a graph to show how its activity in the body varies over the next 12 hours. Label this line X.



(3)

N 2 6 1 4 6 A 0 1 8 2 4

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(iv) Radioisotope Y has a radioactive half-life of 6 hours and a biological half-life of 12 hours. Calculate its effective half-life.

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(1)

(v) Radioisotope Y is injected into a patient at the same time as X. It has an initial activity of 2000 Bq. Add to the graph to show how its activity in the body varies after injection. Label this line Y.

(1)

(vi) State the time after injection at which X and Y would have the same activity in the patient.

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(1) **Q4**

(Total 32 marks)

TOTAL FOR PAPER: 32 MARKS

END

N 2 6 1 4 6 A 0 1 9 2 4

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 $$F = m\frac{\Delta v}{\Delta t} = \frac{\Delta p}{\Delta t}$$

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

Mechanical energy

Power $$P = Fv$$

Radioactive decay and the nuclear atom

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

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

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	$\frac{1}{t_\text{e}} = \frac{1}{t_\text{r}} + \frac{1}{t_\text{b}}$	(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)
	$\cos\theta \approx 1$	

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