Candidate Name	Centre Number					Candidate Number				

A LEVEL PHYSICS

COMPONENT 3

Light, Nuclei and Options

SPECIMEN PAPER

2 hours 15 minutes

		For Examiner's use only	
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	20	
	2.	20	
	3.	10	
	4.	14	
	5.	6	
	6.	10	
	7.	10	
	8.	10	
Section B	**Option**	20	
	Total	120	

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.
Answer **all** questions.
Write your name, centre number and candidate number in the spaces at the top of this page.
Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B**.
Section **A**: 100 marks. Answer **all** questions. You are advised to spend about 1 hour 50 minutes on this section.
Section **B**: 20 marks; Options. Answer **one option only.** You are advised to spend about 25 minutes on this section.

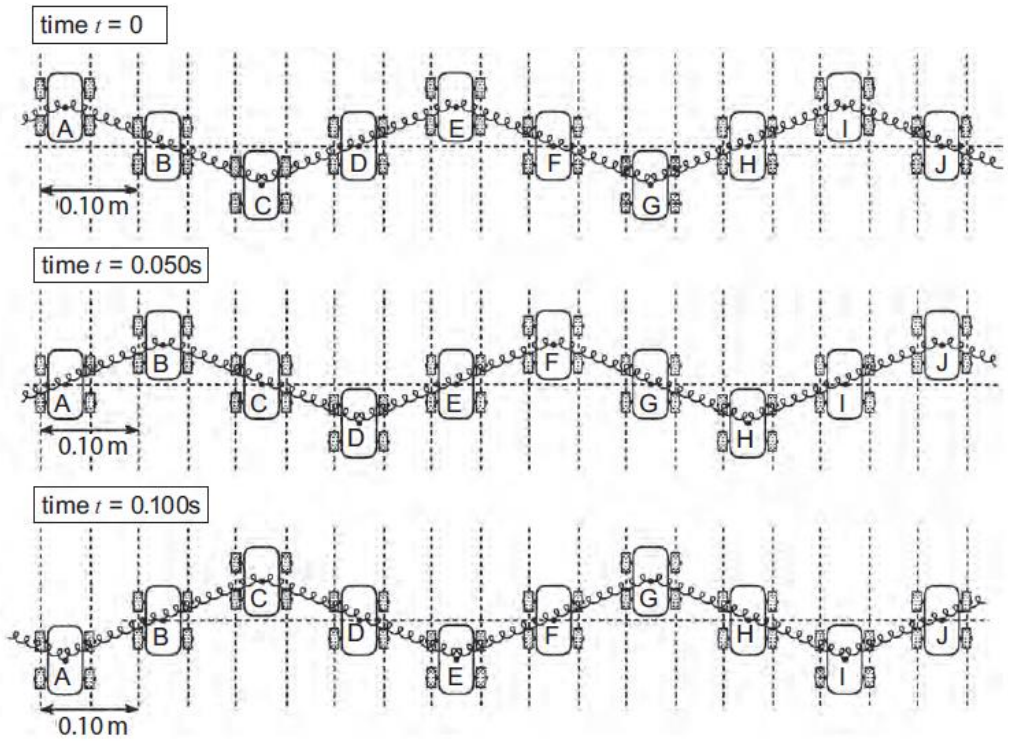
The number of marks is given in brackets at the end of each question or part-question.

No certificate will be awarded to a candidate detected in any unfair practice during the examination.

SECTION A

*Answer **all** questions.*

1. *(a)* Here are three 'snapshots' (three diagrams at different times) of a transverse wave travelling from left to right along a line of toy cars joined by springs.



(i) For this wave determine the value of each of the quantities in the equation $v = f\lambda$ giving your reasoning. [3]

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(ii) Which cars are oscillating in phase with car **B**? [1]

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(iii) Explain why the wave is described as transverse. [2]

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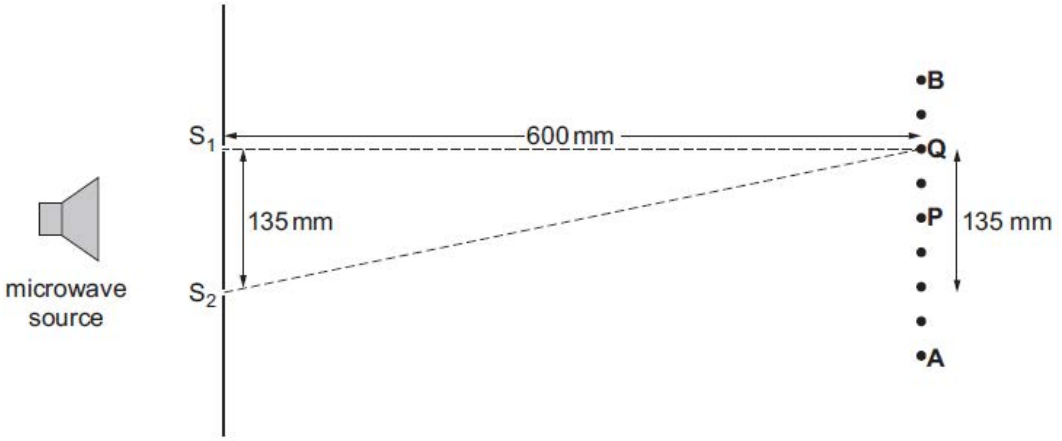
(iv) A longitudinal wave can be sent along a line of toy cars linked by springs if the cars are arranged differently. Sketch the arrangement, showing at least 3 cars. [1]

(b) A microwave source is placed to the left of two narrow slits, **S_1** and **S_2**, so that these slits act as in phase sources.



A microwave sensor moved along the line **AB** detects maxima at the points shown as dots. One of these points, **Q**, is directly in front of **S_1**.

(i) Use the right angled triangle **S_1S_2Q** to determine the path difference **S_2 Q – S_1 Q**, and **hence** determine the wavelength of the microwaves, giving your reasoning. Note that point **P** is equidistant from **S_1** and **S_2**. [4]

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(ii) Check your answer to *(a)*(i) using the two source interference (Young's fringes) formula, showing your working clearly. [2]

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(c) (i) Giving a labelled diagram, derive the diffraction grating equation:

$$n\lambda = d\sin\theta$$

[3]

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(ii) A student uses a diffraction grating to measure the wavelength of light from a laser. The separation between the centres of adjacent slits in the grating is 1 500 nm. The student records beams emerging from the grating at 24° ± 1° and at 57° ± 1° either side of the normal (as well as at 0°). The laser is believed to emit light of wavelength 635 nm. Justify whether the student's readings support this. [4]

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2. *(a)* (i) Light is shone on to a caesium surface ejecting electrons of maximum kinetic energy 1.7×10^{-19} J from the surface. Calculate the frequency of light used. (Work function = 3.0×10^{-19} J.) [2]

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(ii) Light of frequency 5.9×10^{14} Hz is now shone on to the caesium surface at the same time as the original frequency. Justifying your answer in terms of photons, state the effect (if any) of this extra light on:

(I) the number of electrons emitted per second; [2]

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(II) the maximum kinetic energy of the emitted electrons. [1]

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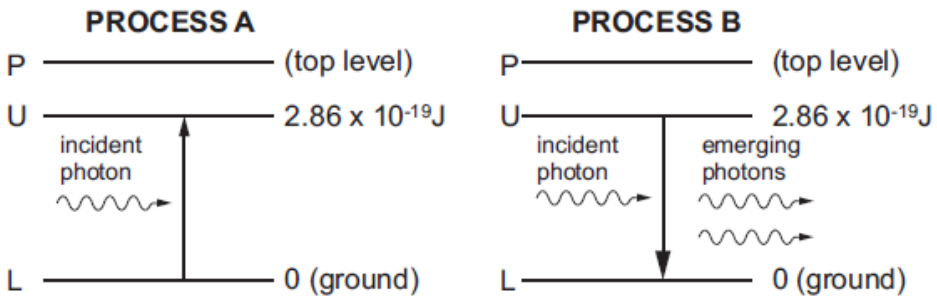
(b) A ruby laser is classed as a 3-level system. The amplifying medium is ruby, which is a crystal containing chromium ions. The diagrams show two processes which could occur when a photon of a certain wavelength is incident on a chromium ion.



(i) Calculate the wavelength of the incident photon. [2]

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(ii) Process **A** is absorption. State what happens to the energy of the incident photon in this process. [1]

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(iii) Process **B**, is *stimulated emission*. State two things, other than wavelength and frequency, that are the same for both the emerging photons**.** [1]

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(iv) Referring to energy levels as labelled on the diagrams, explain what is meant by a *population inversion*. [1]

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(v) Explain in terms of the processes **A** and **B** why the laser would not work unless there was a population inversion. [2]

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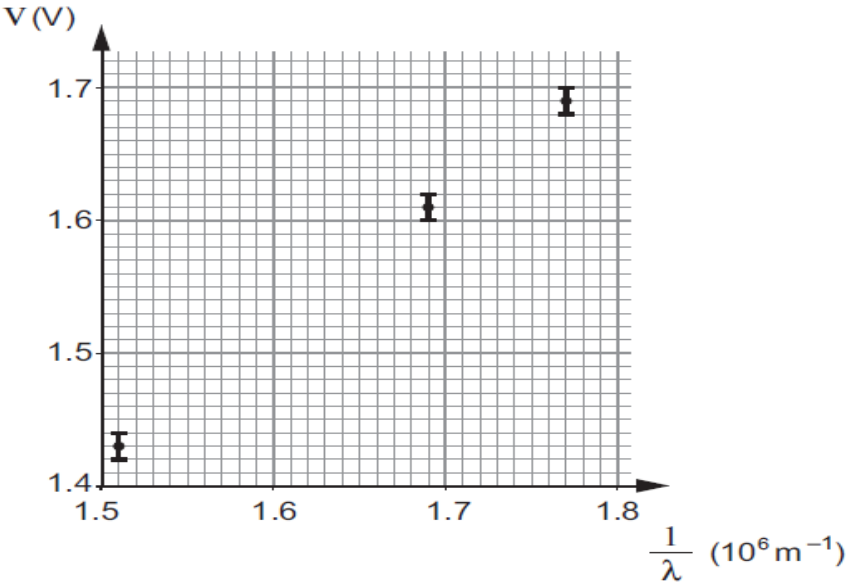
(c) The minimum potential difference, V, applied to a light emitting diode (LED) for it to be seen to emit light is related to the wavelength, λ, of the light by the approximate equation:

$$eV = \frac{hc}{\lambda}$$



V is measured for three LEDs, and a graph of V against λ is plotted using values of λ supplied by the makers of the diodes.

(i) Calculate the maximum and minimum gradients of the graph. [2]

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(ii) Hence calculate a value for the Planck constant, as well as its **percentage** uncertainty. [3]

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(iii) Discuss whether or not the graph confirms the equation. [3]

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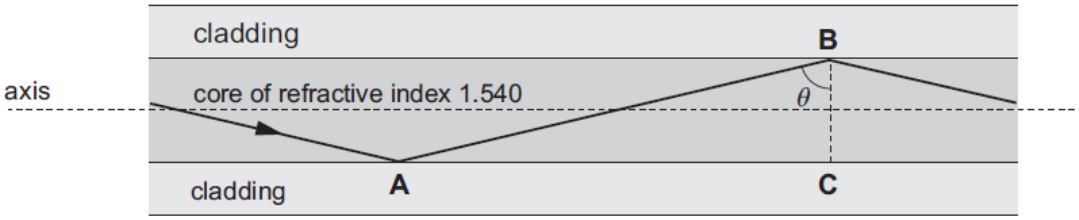
3. The diagram shows a path which light can take along a 'thick' optical fibre.



(a) The smallest angle θ at which total internal reflection can take place is 77°. Calculate the refractive index of the cladding. [2]

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(b) (i) Calculate the time it takes light to travel along 350 m of the fibre, if it travels in a straight line parallel to the axis of the fibre. [2]

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(ii) Show that the **extra** time it takes for light to travel 350 m along the fibre via the zigzag path for $\theta = 77°$ is approximately 50 ns. [Consider triangle ABC.] [3]

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(c) The difference in refractive index between the cladding and core is decreased. Explain carefully how this will affect the maximum frequency of data transmission along the optical fibre. [3]

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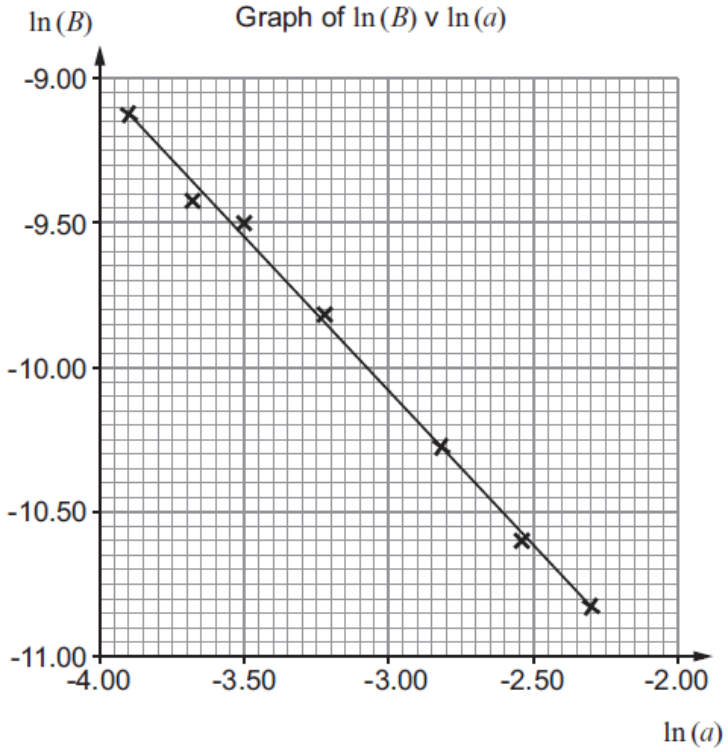
4. *(a)* A Hall probe was used to measure the magnetic field (B-field) due to a long wire carrying current. The experiment was carried out in order to confirm the relationship:

$$B = \frac{\mu_0 I}{2\pi a}$$

A student obtained the following data and plotted the following graph.

Distance a (m)	B-field (μT)	$\ln(a)$	$\ln(B)$
0.020	110	-3.91	-9.12
0.025	85	-3.69	-9.37
0.030	75	-3.51	-9.50
0.040	55	-3.22	-9.81
0.060	35	-2.81	-10.26
0.080	25	-2.53	-10.60
0.100	20	-2.30	-10.82



(i) Explain briefly how the student used the Hall probe to obtain the data. [2]

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(ii) Calculate the gradient of the line of best fit shown in the graph. [2]

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(iii) Does the graph confirm the relationship:

$B = \frac{\mu_o I}{2\pi a}$ (i.e. $\ln B = \ln \frac{\mu_0 I}{2\pi} - \ln a$)

Explain your reasoning. [3]

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(iv) A second student carries out the same experiment with a badly calibrated Hall probe that gives B-field readings that are consistently 40% too large. Explain how this would affect the graph shown on page 51. [3]

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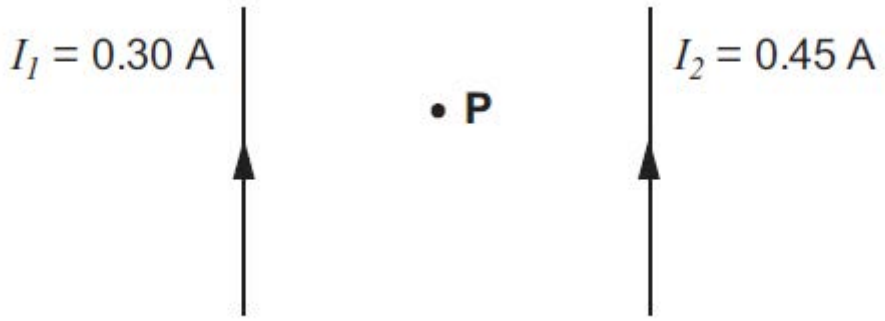
(b) Two long, straight wires carry currents as shown.



Point **P** is halfway between the two current carrying wires. Determine the direction of the B-field at **P** and explain in clear and logical steps how you obtained your answer. [4]

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5. *(a)* State *Faraday's law of electromagnetic induction*. [2]

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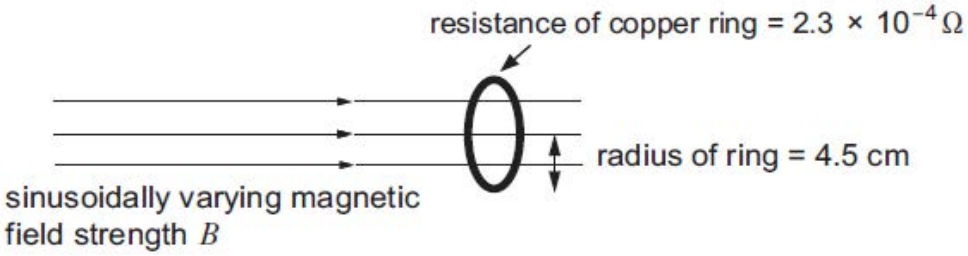
(b) A circular copper heating ring works by being placed in a sinusoidally varying magnetic field. A large sinusoidal current is then induced in the ring and the ring becomes hot (see below).



The maximum rate at which the magnetic field strength changes is 72 T s^{-1}. Show that the maximum current flowing in the ring is approximately 2 000 A. [4]

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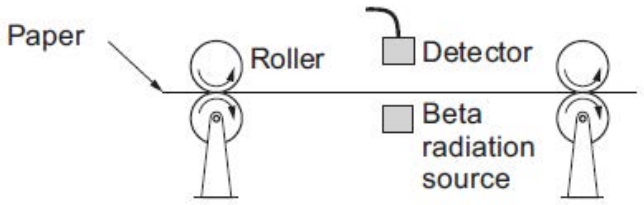
6. The thickness of paper is measured using a beta radiation source and detector (see below).



(a) When the paper is marketed as being "Hi-tech beta radiation" paper, sales figures of the paper decrease rapidly. A scientist claims that this is a reflection of the ignorance of society. Explain briefly whether the scientist is justified in making this statement. [2]

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(b) The beta radiation source most commonly used is strontium-90 which decays as shown. Place the correct numbers on the dotted lines. [1]

$$^{90}_{38}\text{Sr} \longrightarrow \text{\_\_\_\_} \; Y + \text{\_\_\_\_} \; \beta$$

(c) The half-life of strontium-90 is 28.8 years. Show that its decay constant is $7.6 \times 10^{-10}\,s^{-1}$. [2]

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(d) If the initial activity of the strontium-90 source is 140 GBq, calculate its activity after 10 years. [2]

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(e) The beta particles produced have a kinetic energy of 0.55 MeV. Explain why using your A level Physics knowledge will not provide an accurate value of their kinetic energies. Your explanation should be reinforced by a calculation.

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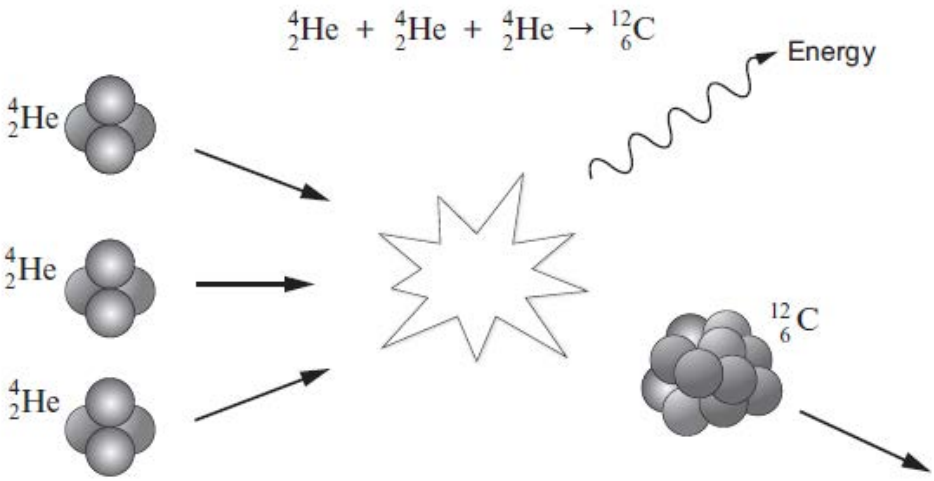
7. The following fusion reaction can occur inside stars with core temperatures of around 100 million kelvin.



(a) (i) Calculate the energy released in the above reaction from the following data. [3]

mass of ^4_2He = 4.0026 u

mass of $^{12}_6C$ = 12.0000 u

1 u = 931 MeV

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(ii) Scientists claim that this reaction is extremely important for life in the universe. Explain whether or not this claim is true. [2]

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(b) The isotope $^{62}_{28}\mathrm{Ni}$ has a binding energy per nucleon of 8.795 MeV/nucleon and this is the highest known binding energy per nucleon.

Calculate the mass of a $^{62}_{28}\mathrm{Ni}$ nucleus in unified atomic mass units (u) and give your answer to 5 significant figures. [5]

mass of proton = 1.00728 u

mass of neutron = 1.00866 u

1 u = 931 MeV

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8. *(a)* (i) State three differences (other than mass) in the properties of down quarks and electrons. [3]

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(ii) The Δ^- (delta minus) particle has the quark make-up ddd. Deduce its charge. [1]

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(b) The Δ^- particle decays in a very short time into a neutron and a pion (π meson):

$$\Delta^- \rightarrow n + \pi^-$$

The meson formation suggests a strong interaction. State two other features of the decay which point to it being a strong interaction. [2]

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(c) The neutron and the pion formed in the decay are themselves unstable. The neutron decays thus:

$$n \rightarrow p + x + y$$

in which p is a proton and x is a charged (first generation) lepton.

(i) Using appropriate conservation laws, identify x and y. [3]

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(ii) State, giving a reason, which force is responsible for this decay. [1]

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SECTION B: OPTIONAL TOPICS

Option A - **Alternating Currents** ☐

Option B - **Medical Physics** ☐

Option C - **The Physics of Sports** ☐

Option D - **Energy and the Environment** ☐

Answer the question on **one topic only.**

Place a tick (✓) in one of the boxes above, to show which topic you are answering.

You are advised to spend about 25 minutes on this section.

Option A **– Alternating Currents**

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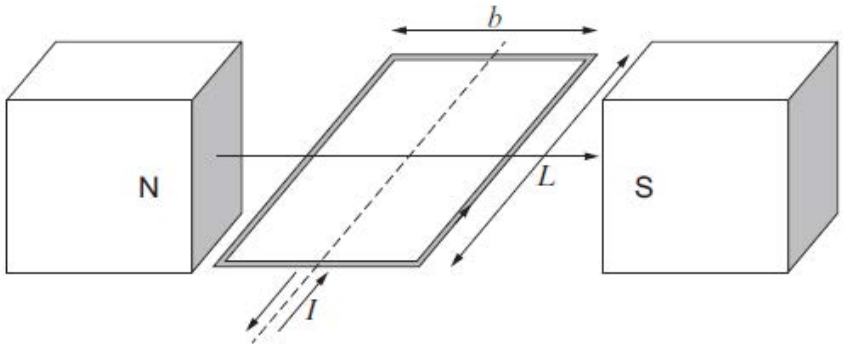

(a) *(*i) The coil shown in the diagram is rotated. Explain why a sinusoidal emf is induced in the coil. [2]

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(ii) The coil has 55 turns and is rotated at a frequency of 50 Hz in a uniform B-field of strength 0.114 T. If L = 3.2 cm and b = 2.5 cm, calculate the peak emf induced in the coil. [3]

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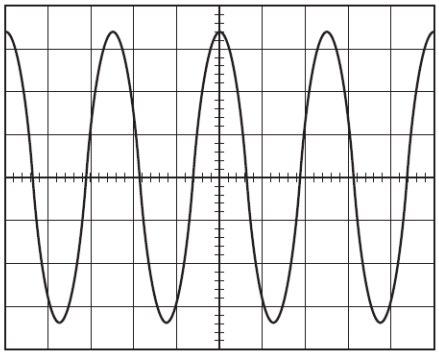
(b) Calculate the peak pd and the period of the signal shown on the oscilloscope. The time base of the oscilloscope is set to 50 μs per division and the gain set to 20 mV per division. [3]



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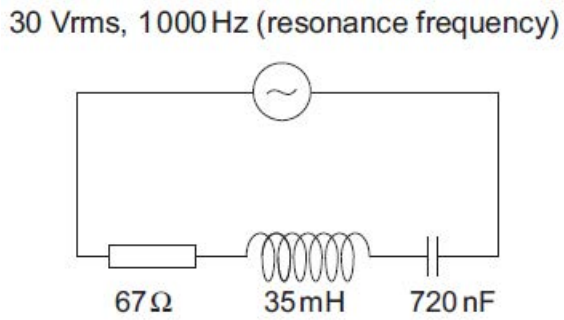
(c)



(i) The resonance frequency of the above circuit is 1 000 Hz. Explain why the rms current is just below 0.45 A. [2]

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(ii) Calculate V_L, the rms pd across the inductor. [2]

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(iii) State the value of V_C, the rms pd across the capacitor. [1]

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(iv) Calculate the Q factor of the circuit. [1]

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(v) Justify what changes you would make to the above circuit to make the resonance curve sharper whilst keeping the resonant frequency constant. [3]

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(d) Sketch a phasor diagram showing the pds across the inductor, capacitor and resistor when the frequency is doubled to 2 000 Hz. [3]

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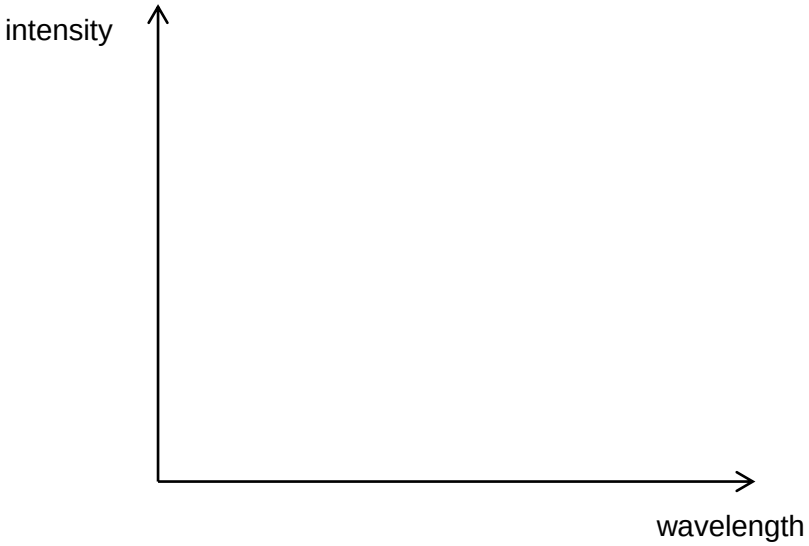
Option B **– Medical Physics**

10. *(a)* An X-ray machine is set to give out X-rays of minimum wavelength, $\lambda_{min} = 15 \times 10^{-12}$ m.

(i) Sketch a graph of intensity against wavelength for the resulting X-ray spectrum. Label the main features of the spectrum. [2]



(ii) Calculate the accelerating voltage used in the tube and explain the role of conservation of energy in your calculation. [3]

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(b) Describe how a CT scan differs from a conventional X-ray and justify why CT scans are **not** offered for the regular checking of healthy patients. [2]

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(c) An MRI scanner has a magnetic field that varies uniformly from 1.0 T to 1.5 T along its length. Calculate the wavelength of radio waves required to scan a slice halfway along its length. [3]

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(d) When using ultrasound to carry out B-scans a single transducer can be used to send and receive pulses of ultrasound.

(i) Describe how the ultrasound pulses are produced. [2]

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(ii) Use the data to explain the importance of coupling gel in ultrasound scans (a calculation should reinforce your argument). [4]

Medium	Density ($kg\,m^{-3}$)	Velocity of ultrasound ($m\,s^{-1}$)
Air	1.300	340
Skin	1 075	1 590

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(e) A patient is irradiated with a uniform beam of gamma rays of intensity 0.21 mW cm^{-2}.

(i) Calculate the intensity of gamma rays 0.4 cm and 9.8 cm below the outer layer of skin given that the mean attenuation coefficient of tissue is 2.2×10^{-2} cm^{-1}. [2]

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(ii) The tissue 0.4 cm below the skin has a cancer weighting factor of 0.08 and the tissue 9.8 cm below the skin has a weighting factor of 0.12. Justify which tissue is more likely to develop cancer from the gamma rays. [2]

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Option C – **The Physics of Sports**

11. *(a)* A golfer prepares to take a shot. Explain clearly how the golfer achieves a stable position in order to take the shot. [2]

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(b) The forces acting on the golfer's foot can be visualised by the following simplified diagram. Calculate the tension, T, in the Achilles tendon. [2]

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(c) The distance between the tee and the hole on a golf course is 148 m in length. A golfer is not sure whether to use a No.6 iron or a No.7 iron.

Determine which club the golfer should use given the following data about the clubs.

Club	Angle of projection	Initial speed of ball ($m\,s^{-1}$)
No.6 iron	30^o	45
No.7 iron	34^o	40

Show your workings clearly. Ignore the effects of air resistance and assume that no spin is applied to the ball. [5]

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(d) (i) In reality a golfer strikes the ball with large amounts of backspin. Explain how applying backspin will affect the mean distance travelled by the ball. Justify your answers by referring to the forces acting on the ball during the flight and how the ball lands. The effects of the air should be considered for this part.

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(ii) When the ball is first struck the ball is spinning at a rate of 50 revolutions per second. Given that the density of the ball is 1.13 g cm^{-3} and its diameter is 4.27 cm, calculate the rotational kinetic energy of the ball.
(Moment of inertia of the ball is given by the equation $I = \frac{2}{5}mr^2$.) [4]

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(iii) Calculate the torque applied to the ball when the golfer takes the shot if the club is in contact with the ball for a time of 0.5 ms. [3]

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Option D – **Energy and the Environment**

12. *(a)* (i) State *Archimedes' principle*. [1]

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(ii) An iceberg floating in the sea and an ice sheet on land each melt releasing equal volumes of water into the sea. Explain which of these processes will have the greater effect on sea level. [2]

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(b) (i) Solar radiation of mean intensity 340 W m^{-2} falls on 2.6×10^{14} m^2 of the Earth's surface where it is absorbed. Calculate the rate of absorption of this solar energy by the Earth. [2]

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(ii) State the power that must be radiated from the Earth's surface in order for the Earth to maintain a steady equilibrium temperature. [1]

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(iii) Assume the Earth radiates this power uniformly from its entire surface. Calculate the radius of the Earth. [Each square metre of the Earth radiates power at 170 W.] [2]

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(c) A new nuclear reactor has been proposed based on the reaction of lithium-7 and a proton to produce two α-particles.

$$^{1}_{1}\mathrm{p} + ^{7}_{3}\mathrm{Li} \rightarrow ^{8}_{4}\mathrm{Be} \rightarrow ^{4}_{2}\mathrm{He} + ^{4}_{2}\mathrm{He} + 17.1\ \mathrm{MeV}$$

Although this is not a new nuclear reaction (it was the original splitting the atom experiment in 1932), there have been some theoretical developments that suggest this might be a useful reaction.

The above reaction is produced by ionising hydrogen and accelerating the resulting protons in a vacuum to an energy of around 300 keV. Unfortunately, in the past, only one in 30 million protons accelerated to the correct voltage have produced this nuclear reaction.

(i) The above reaction is produced by accelerating ionised hydrogen with 300 kV. Explain two possible benefits of the system compared with fission reactors. [4]

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(ii) Calculate the energy required to accelerate 30 million protons to an energy of 300 keV and explain why the above reaction does not seem profitable. [3]

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(iii) There is around 10^{16} kg of $^{7}_{3}\mathrm{Li}$ in the world's oceans and the mass of $^{7}_{3}\mathrm{Li}$ can be taken as 7 u. Calculate the number of $^{7}_{3}\mathrm{Li}$ atoms in the world's oceans. [2]

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(iv) Scientists claim that there are sufficient $^{7}_{3}\mathrm{Li}$ atoms in the oceans to meet the world's energy needs for approximately 5 billion years.

Justify this claim. [Assume that each $^{7}_{3}\mathrm{Li}$ atom can, ideally, provide an energy of 17.1 MeV.] [3]

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WJEC Eduqas
A Level in PHYSICS

Data Booklet

A clean copy of this booklet should be issued to candidates for their use during each A level Physics examination.

Centres are asked to issue this booklet to candidates at the start of the A level Physics course to enable them to become familiar with its contents and layout.

Values and Conversions

Avogadro constant	$N_A = 6{\cdot}02 \times 10^{23}\ \text{mol}^{-1}$
Fundamental electronic charge	$e = 1{\cdot}60 \times 10^{-19}\ \text{C}$
Mass of an electron	$m_e = 9{\cdot}11 \times 10^{-31}\ \text{kg}$
Molar gas constant	$R = 8{\cdot}31\ \text{J mol}^{-1}\text{K}^{-1}$
Acceleration due to gravity at sea level	$g = 9{\cdot}81\ \text{m s}^{-2}$
Gravitational field strength at sea level	$g = 9{\cdot}81\ \text{N kg}^{-1}$
Universal constant of gravitation	$G = 6{\cdot}67 \times 10^{-11}\ \text{N m}^2\text{kg}^{-2}$
Planck constant	$h = 6{\cdot}63 \times 10^{-34}\ \text{J s}$
Boltzmann constant	$k = 1{\cdot}38 \times 10^{-23}\ \text{J K}^{-1}$
Speed of light in vacuo	$c = 3{\cdot}00 \times 10^{8}\ \text{m s}^{-1}$
Permittivity of free space	$\varepsilon_0 = 8{\cdot}85 \times 10^{-12}\ \text{F m}^{-1}$
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$
Stefan constant	$\sigma = 5{\cdot}67 \times 10^{-8}\ \text{W m}^{-2}\text{K}^{-4}$
Wien constant	$W = 2{\cdot}90 \times 10^{-3}\ \text{m K}$
Hubble constant	$H_0 = 2.30 \times 10^{-18}\ \text{s}^{-1}$

$T/\text{K} = \theta/°\text{C} + 273{\cdot}15$

$1\,\text{u} = 1{\cdot}66 \times 10^{-27}\ \text{kg}$

$$\frac{1}{4\pi\varepsilon_0} \approx 9\text{x}10^9$$

$\rho = \frac{m}{V}$	$T = \frac{1}{f}$
$v = u + at$	$v = -A\omega\sin(\omega t + \varepsilon)$
$x = \frac{1}{2}(u+v)t$	$T = 2\pi\sqrt{\frac{m}{k}}$
$x = ut + \frac{1}{2}at^2$	$T = 2\pi\sqrt{\frac{l}{g}}$
$v^2 = u^2 + 2ax$	$pV = nRT$ and $pV = NkT$
$\sum F = ma$	$p = \frac{1}{3}\rho\overline{c^2} = \frac{1}{3}\frac{N}{V}\overline{mc^2}$
$p = mv$	$M \text{ / kg} = \frac{M_r}{1000}$
$W = Fx\cos\theta$	$n = \frac{\text{total mass}}{\text{molar mass}}$
$\Delta E = mg\Delta h$	$E = \frac{3}{2}RT$
$E = \frac{1}{2}kx^2$	$E = \frac{3}{2}kT$
$E = \frac{1}{2}mv^2$	$k = \frac{R}{N_A}$
$Fx = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$	$U = \frac{3}{2}nRT$
$P = \frac{W}{t} = \frac{\Delta E}{t}$	$W = p\Delta V$
$\text{efficiency} = \frac{\text{useful energy transfer}}{\text{total energy input}} \times 100\%$	$\Delta U = Q - W$
$\omega = \frac{\theta}{t}$	$Q = mc\Delta\theta$
$v = \omega r$	$I = \frac{\Delta Q}{\Delta t}$
$a = \omega^2 r$	$I = nAve$
$a = \frac{v^2}{r}$	$R = \frac{V}{I}$
$F = \frac{mv^2}{r}$	$P = IV = I^2R = \frac{V^2}{R}$
$F = m\omega^2 r$	$R = \frac{\rho l}{A}$
$a = -\omega^2 x$	$V = E - Ir$
$x = A\cos(\omega t + \varepsilon)$	$\frac{V}{V_{\text{total}}}\left[\text{or } \frac{V_{\text{OUT}}}{V_{\text{IN}}}\right] = \frac{R}{R_{\text{total}}}$
$T = \frac{2\pi}{\omega}$	$C = \frac{Q}{V}$

$C = \frac{\varepsilon_o A}{d}$	$P = A\sigma T^4$
$E = \frac{V}{d}$	$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$
$U = \frac{1}{2}QV$	$v = H_0 D$
$Q = Q_0\left(1 - e^{-\frac{t}{RC}}\right)$	$\rho_c = \frac{3H_0{}^2}{8\pi G}$
$Q = Q_0 e^{-\frac{t}{RC}}$	$r_1 = \frac{M_2}{M_1 + M_2} d$
$F = kx$	$T = 2\pi\sqrt{\frac{d^3}{G(M_1 + M_2)}}$
$\sigma = \frac{F}{A}$	$c = f\lambda$
$\varepsilon = \frac{\Delta l}{l}$	$\lambda = \frac{a\Delta y}{D}$
$E = \frac{\sigma}{\varepsilon}$	$d\sin\theta = n\lambda$
$W = \frac{1}{2}Fx$	$n = \frac{c}{v}$
$\Delta U_P = mg\Delta h$	$n_1 v_1 = n_2 v_2$
$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$F = G\frac{M_1 M_2}{r^2}$	$n_1 \sin\theta_C = n_2$
$E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}$	$E_{k\max} = hf - \phi$
$g = \frac{GM}{r^2}$	$p = \frac{h}{\lambda}$
$V_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$	$A = -\lambda N$
$PE = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r}$	$N = N_o e^{-\lambda t}$
$V_g = -\frac{GM}{r}$	$A = A_o e^{-\lambda t}$
$PE = -\frac{GM_1 M_2}{r}$	$N = \frac{N_o}{2^x}$
$W = q\Delta V_E$	$A = \frac{A_o}{2^x}$

$W = m\Delta V_g$	$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$
$\lambda_{\max} = WT^{-1}$	$E = mc^2$

	leptons		quarks	
particle (symbol)	electron (e^-)	electron neutrino (ν_e)	up (u)	down (d)
charge (e)	-1	0	$+\frac{2}{3}$	$-\frac{1}{3}$
lepton number	1	1	0	0

$F = BIl\sin\theta$	$B = \mu_o nI$
$F = Bqv\sin\theta$	$\phi = AB\cos\theta$
$B = \frac{\mu_o I}{2\pi a}$	flux linkage = $N\phi$

OPTION A

flux linkage = $BAN\sin\omega t$	$X_L = \omega L$
$V = -\omega BAN\cos\omega t$	$X_C = \dfrac{1}{\omega C}$
$I_{\text{rms}} = \dfrac{I_0}{\sqrt{2}}$	$Z = \sqrt{X^2 + R^2}$
$V_{\text{rms}} = \dfrac{V_0}{\sqrt{2}}$	$Q = \dfrac{V_L}{V_R}\left(= \dfrac{V_C}{V_R}\right)$
$V_{\text{rms}} = \dfrac{\omega BAN}{\sqrt{2}}$	$Q = \dfrac{\omega_0 L}{R}$

OPTION B

$I = I_0\exp(-\mu x)$	$f = 42.6 \times 10^6 B$
$Z = c\rho$	$H = DW_R$
$\dfrac{\Delta f}{f_0} = \dfrac{2v}{c}\cos\theta$	$E = HW_T$

OPTION C

$Ft = mv - mu$	$\tau = I\alpha$
$e = \dfrac{\text{Relative speed after collision}}{\text{Relative speed before collision}}$	$J = I\omega$
$e = \sqrt{\dfrac{h}{H}}$	$KE = \frac{1}{2} I\omega^2$
$I = \frac{2}{5} mr^2$	$p = p_0 - \frac{1}{2}\rho v^2$
$I = \frac{2}{3} mr^2$	$F_D = \frac{1}{2}\rho v^2 AC_D$
$\alpha = \dfrac{\omega_2 - \omega_1}{t}$	

OPTION D

$I = \dfrac{P}{A}$	$\dfrac{\Delta Q}{\Delta t} = -AK\dfrac{\Delta\theta}{\Delta x}$
$E = \frac{1}{2} A\rho v^3$	$P = UA\Delta\theta$

Mathematical Information

SI multipliers

Multiple	Prefix	Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c

Multiple	Prefix	Symbol
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E
10^{21}	zetta	Z

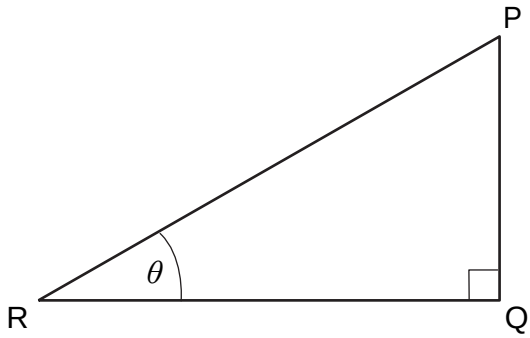
Areas and Volumes

Area of a circle = $\pi r^2 = \frac{\pi d^2}{4}$

Area of a triangle = $\frac{1}{2}$ base × height

Solid	Surface area	Volume
rectangular block	$2\,(lh + hb + lb)$	lbh
cylinder	$2\pi\, r\,(r + h)$	$\pi\, r^2\, h$
sphere	$4\,\pi\, r^2$	$\frac{4}{3}\pi\, r^3$

Trigonometry



$$\sin\theta = \frac{\text{PQ}}{\text{PR}},\ \cos\theta = \frac{\text{QR}}{\text{PR}},\ \tan\theta = \frac{\text{PQ}}{\text{QR}},\ \frac{\sin\theta}{\cos\theta} = \tan\theta$$

$$PR^2 = PQ^2 + QR^2$$

Logarithms

[Unless otherwise specified 'log' can be $\log_e$ (i.e.ln) or $\log_{10}$.]

$\log (ab) = \log a + \log b$ $\qquad$ $\log \frac{a}{b} = \log a - \log b$

$\log x^n = n \log x$ $\qquad$ $\log_e e^{kx} = \ln e^{kx} = kx$

$\log_e 2 = \ln 2 = 0.693$