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 17 January 2007 – Afternoon

Time: 30 minutes

Materials required for examination	**Items included with question papers**
Nil	Nil

Examiner's use only

Team Leader's use only

Question Number	Leave Blank
1A	
2B	
3C	
4D	
Total	

Instructions to Candidates

In the boxes above, write your centre number, candidate number, your surname, initials 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 Topic 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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Leave blank

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

Topic A – Astrophysics

1. (a) A student writes out some revision notes about astrophysics, putting some keywords in bold. Some of the keywords are wrong.

Circle the word or phrase that is incorrect and write below it a correct word or phrase which would take the place of the wrong word or phrase. An example is given.

A white dwarf has a (**high**) luminosity and a high temperature.
low

There are **three** errors for you to correct in the sentences below.

Photographic emulsion can give a **higher** resolution than a CCD.

A **red giant** can be used to find the distance to nearby galaxies.

A **white dwarf** will eventually turn into a black hole.

Luminosity has the same units as **power**.

A Hertzsprung-Russell diagram shows **luminosity** against temperature.

A star spends most of its life as a **red giant**.

(6)

Leave blank

(b) Wien's law can be written as

$$\lambda_{max} T = 2.90 \times 10^{-3}\ \text{m K}$$

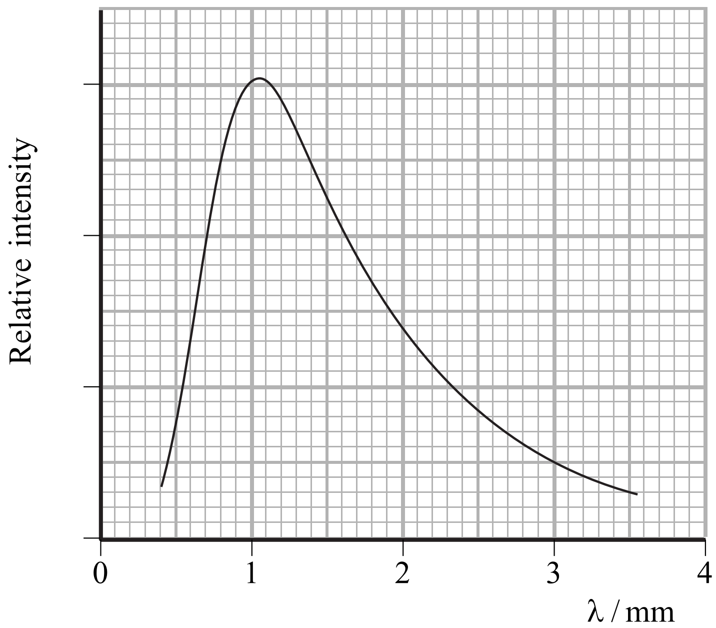
(i) Explain clearly what is meant by each symbol in Wien's law.

λ_{max} ....

T ....

(2)

(ii) The graph shows the wavelength distribution for radiation detected by the COBE satellite.



To what part of the electromagnetic spectrum does this radiation belong?

....

(1)

(iii) Use the graph to determine the temperature of the source of these emissions.

....

....

....

Temperature = ...

(3)

Leave blank

(c) A star that is considerably more massive than the Sun may end its life as a supernova. During a supernova explosion approximately 1×10^{46} J of energy can be released.

(i) State the minimum mass of a star that can become a supernova.

....

(1)

(ii) Use the data below to estimate how much energy is given off by the Sun during its approximate lifetime.

Luminosity = 3.9×10^{26} W

Approximate lifetime = 1×10^{10} y

....

....

....

Energy = ...

(3)

(iii) Estimate the ratio of the energy that is released when a supernova explodes to the total energy given off by the Sun during its lifetime.

....

....

Ratio = ...

(2)

(iv) When a supernova explodes, the mass of its core remnant determines its future. State the two possible outcomes and how each depends on the mass of the remnant.

....

....

....

....

....

....

(3)

Leave blank

(d) (i) If the Earth (mass = 6.0×10^{24} kg) had the same density as a neutron star it would be approximately 150 m in radius. Show that the average density of such an object would be approximately 4×10^{17} kg m^{-3}.

....

....

....

....

(2)

(ii) Explain how the neutrons in a neutron star were formed, both during and after the main sequence. You may be awarded a mark for the clarity of your answer.

....

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....

....

....

....

(4)

(e) (i) Use the data below to calculate the intensity of the Sun as measured from Mars and from Earth.

Luminosity of the Sun = 3.90×10^{26} W

Sun – Mars distance = 2.28×10^{8} km

Sun – Earth distance = 1.50×10^{8} km

....

....

....

....

Intensity from Mars = ... Intensity from Earth = ...

(3)

(ii) Hence show that the brightness of the Sun as seen from Mars is approximately 40% of its brightness from Earth.

....

....

(2)

Q1

(Total 32 marks)

Leave blank

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

Topic B – Solid Materials

2. (a) A student writes out some revision notes about solid materials, putting some keywords in bold. Some of the keywords are wrong.

Circle the word or phrase that is incorrect and write below it a correct word or phrase which would take the place of the wrong word or phrase. An example is given.

A **malleable** material will not deform plastically.
brittle

There are **three** errors for you to correct in the sentences below.

Stress concentrations can build up around **cracks**.

An elastomer can be stretched **plastically** to over twice its original length.

Nylon and Perspex are examples of **rigid thermosets**.

Creep is caused by **plastic** flow in a material over time.

A metal can be **annealed** by heating it to red heat and then allowing it to cool slowly.

Chipboard is an example of a **fibre** composite material.

(6)

(b) Energy density, or work done per unit volume, can be calculated using the equation

$$\text{Energy density} = \tfrac{1}{2} \times \text{stress} \times \text{strain}$$

(i) Show that this equation is homogeneous with respect to units.

....

....

....

....

(3)

N 2 3 5 7 5 A 0 6 2 0

Leave blank

(ii) A material of initial length 2.0 m stretches elastically by 8.0 mm when a stress of 5.2×10^8 Pa is applied. Calculate the work done per unit volume.

....

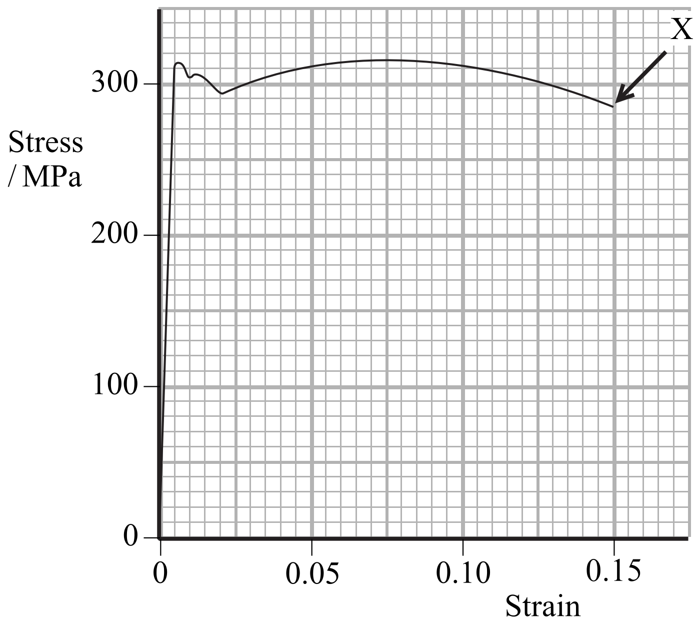
....

....

Work done per unit volume = ...

(3)

(iii) A sample of mild steel stretches as shown.



Estimate the energy density of mild steel when stretched to its breaking point X.

....

....

....

....

Energy density = ...

(3)

N 2 3 5 7 5 A 0 7 2 0

Turn over

Leave blank

(c) Spider silk (or cobweb thread) has incredible properties. It is stronger than steel, extremely tough and can withstand great strain before it breaks. It can stop a relatively large insect, such as a bee, without breaking.

(i) Explain the meaning of the following words as used in the passage.

Tough ....

....

Strong ....

....

(3)

(ii) A bee flies into a cobweb thread of radius 2.0 μm. This causes a stress of 3.0×10^8 Pa in the thread. Calculate the force exerted by the bee.

....

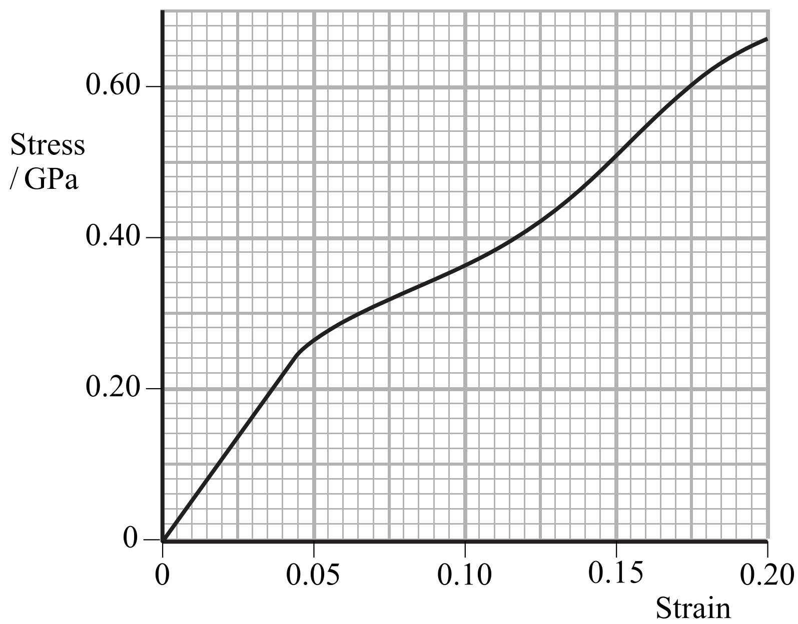
....

....

Force = ...

(3)

(iii) The graph below shows how the strain of spider silk varies as the stress applied to it varies.



Mark clearly on the graph the part of the line where the silk is most stiff.

(1)

N 2 3 5 7 5 A 0 8 2 0

Leave blank

(iv) Calculate the Young modulus of the silk when it is initially stressed.

....

....

....

Young modulus = ...

(3)

(d) (i) Describe the processes of work hardening and quench hardening.
You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

(4)

(ii) Name two properties of a metal that are increased when it is work hardened.

....

....

(2)

(iii) What effect does work hardening have on the dislocations in a metal?

....

....

(1)

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) A student writes out some revision notes about nuclear and particle physics, putting some keywords in bold. Some of the keywords are wrong.

Circle the word or phrase that is incorrect and write below it a correct word or phrase which would take the place of the wrong word or phrase. An example is given.

The exchange particle for the electromagnetic interaction is the **gluon**.
photon

There are **three** errors for you to correct in the sentences below.

In **β^+ decay** an up quark turns into a down quark.

A **muon** is made from one quark and one antiquark.

Quarks with a $+\frac{2}{3}$ charge are called **up, charm and strange**.

Binding energy is defined as the energy needed to split a nucleus into separate nucleons.

A baryon is a type of **hadron**.

Electrostatic repulsion acts between **neutrons** in a nucleus.

(6)

Leave blank

(b) (i) A neutron star is a star composed predominantly of neutrons. If the Earth (mass = 6.0×10^{24} kg) had the same density as a neutron star, it would be approximately 150 m in radius. Show that the average density of such an object would be approximately 4×10^{17} kg m^{-3}.

....

....

....

....

(2)

(ii) Calculate the number of neutrons present in such an object. (u = 1.66×10^{-27} kg)

....

....

Number of neutrons = ...

(2)

(iii) By considering this object as a single, enormous nucleus, calculate the radius of a single neutron.

....

....

....

Radius = ...

(2)

(iv) When a neutron star is formed, protons in a star combine with electrons to produce neutrons and neutrinos. Write a nuclear equation for this reaction, including proton and nucleon numbers.

(2)

Leave blank

(v) State and explain what type of fundamental interaction must mediate this reaction. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

(4)

(c) The following strong reaction has been observed. The charge on the delta particle (Δ) has not been shown.

$$\Delta \rightarrow p + \underset{(u\bar{d})}{\pi^+}$$

(i) Name the exchange particle that is involved in this decay.

....

(1)

(ii) State the charge of the delta particle. Justify your answer.

....

....

....

(2)

(iii) State the quark composition of the proton.

....

(1)

(iv) Using appropriate conservation laws, explain what type of particle the delta particle is and deduce its quark composition.

....

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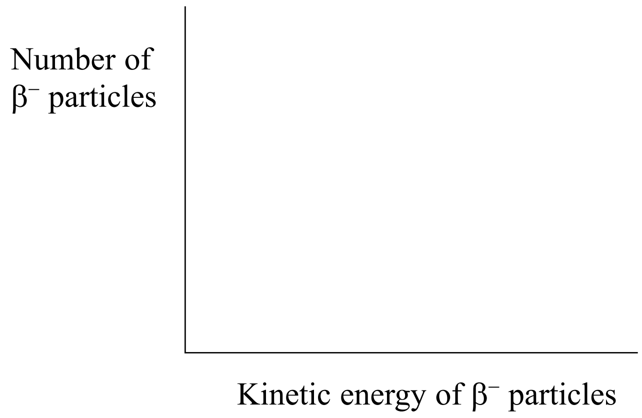
....

(3)

(d) (i) On the axes below sketch a graph showing the energy spectrum for β^- decay from a single source.



(2)

(ii) Explain how this energy spectrum led to the suggestion that an additional undetected particle must be emitted during the decay.

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....

....

....

(3)

(iii) State the full name of the other lepton that is emitted during the β^- decay.

....

(2)

(Total 32 marks)

Leave blank

Q3

Leave blank

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

Topic D – Medical Physics

4. (a) A student writes out some revision notes about medical physics putting some keywords in bold. Some of the keywords are wrong.

Circle the word or phrase that is incorrect and write below it a correct word or phrase which would take the place of the wrong word or phrase. An example is given.

Absorption of X-rays in imaging depends on (**nucleon**) number.
proton

There are **three** errors for you to correct in the sentences below.

A gamma camera uses a scintillating crystal to **cause flashes of light**.

An ultrasonic B-Scan shows **amplitude** against time.

In nuclear medicine, cobalt 60 sources can be used for **diagnosis**.

In an X-ray tube, the **target** rotates so that it doesn't overheat.

Acoustic impedance depends on **speed and density**.

In ultrasonic diagnosis, **long** wavelengths give rise to better resolution.

(6)

(b) (i) Technetium-99m $^{99m}_{43}Tc$ is a radioisotope which is widely used in hospitals throughout the world. State what the letter m represents in $^{99m}_{43}Tc$.

....

(1)

(ii) State and explain two reasons why $^{99m}_{43}Tc$ is so useful in tracer investigations.

1. ....

....

2. ....

....

(2)

Leave blank

(iii) Radioactive half-life is defined as the average time taken for the activity of a sample to fall to half of its initial value. Explain the difference between the radioactive half-life and the effective half-life. You may be awarded a mark for the clarity of your answer.

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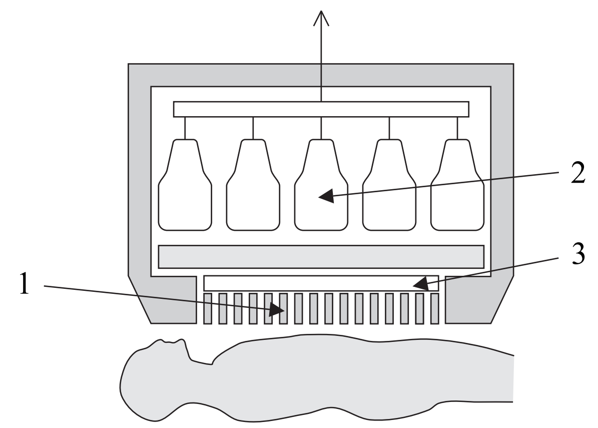
(4)

(c) The diagram shows a simplified cross-section of a gamma camera.



Name and explain the function of the numbered parts of the gamma camera.

	Name	Function
1		
2		
3		

(6)

N 2 3 5 7 5 A 0 1 5 2 0

Turn over

Leave blank

(d) The reflection coefficient α for ultrasound travelling from soft tissue into bone is 0.30.

(i) What percentage of the ultrasound pulse that reaches the bone will be transmitted into the bone?

....

(1)

(ii) The specific acoustic impedance of the soft tissue is $1.63 \times 10^6\,\text{kg m}^{-2}\,\text{s}^{-1}$. Calculate the specific acoustic impedance of this bone. Use the equation below.

$$Z_1 = Z_2\left(\frac{1+\sqrt{\alpha}}{1-\sqrt{\alpha}}\right)$$

....

....

....

....

Specific acoustic impedance = ...

(3)

(iii) The density of the soft tissue is $1060\,\text{kg m}^{-3}$. Calculate the speed of ultrasound as it travels through the tissue.

....

....

....

....

Speed = ...

(2)

Leave blank

(e) (i) Give two reasons why MeV X-rays are preferred to keV X-rays for therapy.

1. ....

....

2. ....

....

(2)

(ii) Explain, with the aid of a diagram, the benefit to the patient of using a multiple beam technique during therapy.

....

....

....

....

....

(3)

(iii) A patient is 0.50 m from a point source of X-rays. The intensity of this X-ray beam at this point is 8.0×10^5 W m^{-2}. Calculate the intensity of this beam for a radiographer who is 10 m from this source.

....

....

....

(2)

Q4

(Total 32 marks)

TOTAL FOR PAPER: 32 MARKS

END

N 2 3 5 7 5 A 0 1 7 2 0

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	1 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	$V = \varepsilon - Ir$	(E.m.f. ε; Internal resistance r)
Circuit e.m.f.	$\Sigma\varepsilon = \Sigma IR$	
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	$L = \sigma T^4 \times$ 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)
	$\cos\theta \approx 1$	