	Centre Number					Candidate Number				
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A LEVEL

PHYSICS

A2 UNIT 4
Fields and Options

SPECIMEN PAPER

(2 hours)

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	10	
	2.	9	
	3.	11	
	4.	10	
	5.	12	
	6.	14	
	7.	14	
Section B	Option	20	
	Total	**100**	

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.

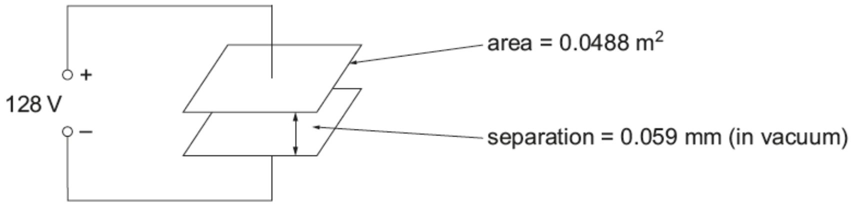
INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B**.
Section **A**: 80 marks. Answer **all** questions. You are advised to spend about 1 hour 35 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.
The assessment of the quality of extended response (QER) will take place in question 6*(e).*

SECTION A
*Answer **all** questions*

1. *(a)*



(i) Calculate the charge stored by the capacitor. [3]

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(ii) Use (i) to calculate the energy stored by the capacitor. [1]

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(iii) Calculate the electric field strength (E) between the plates. [2]

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(b) After the capacitor is charged it is isolated from the power supply so that the charge stored remains constant. Then the plates are pulled further apart.

(i) Explain what happens to the capacitance of the capacitor and hence the energy stored by the capacitor. [2]

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(ii) A student claims that this process contravenes the principle of conservation of energy. Explain why the student is wrong in this case. [2]

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2. *(a)* A long solenoid of length 1.45 m has 9 560 turns. Calculate the magnetic field strength (B) inside the solenoid when it carries a current of 320 mA. [2]

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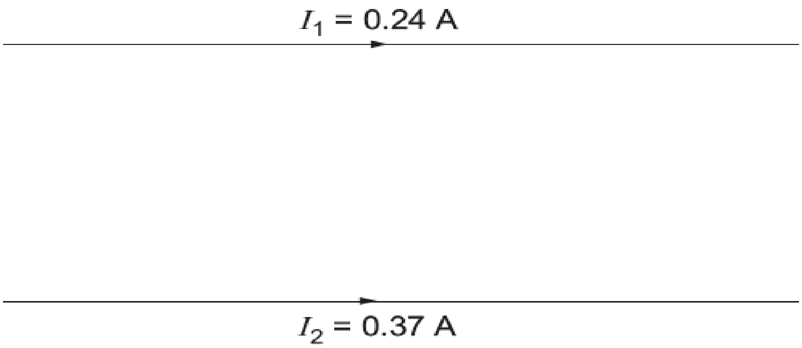
(b) Determine the **direction** of the resultant magnetic field strength (B) half way between the two long wires shown and explain how you obtained your answer. [4]



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(c) The currents in the wires are varied sinusoidally so that the magnetic field varies at a high frequency. Electromagnetic waves of wavelength 2.23 m are produced. Calculate the energy of the photons produced in eV. [3]

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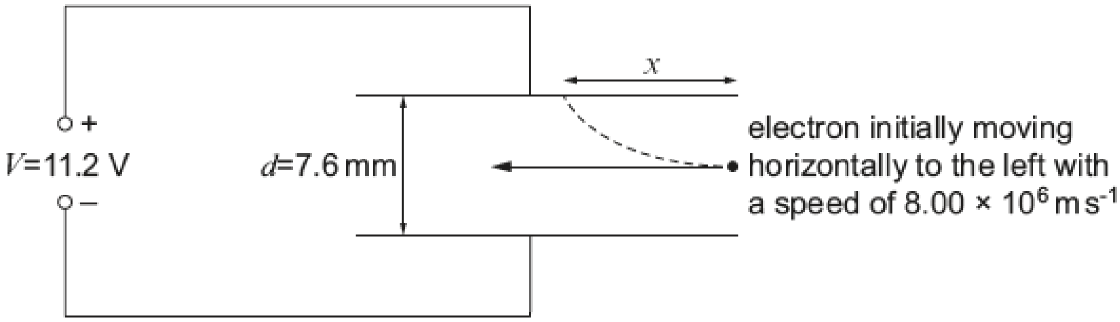
3. An electron enters the uniform electric field half way between the plates of a capacitor as shown. The electron is travelling in a vacuum.



(a) Show that the vertical acceleration of the electron is $\dfrac{Ve}{m_e d}$. [3]

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(b) (i) Explain why the horizontal speed of the electron remains constant. [1]

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(ii) Explain why the vertical acceleration of the electron is constant. [1]

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(c) Electronic sensors detect electrons striking the upper plate 5.0 ± 0.5 ns after the electrons enter the capacitor. Determine whether or not this time agrees with the above data. [4]

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(d) Explain why the amount of kinetic energy gained by the electron before striking the plate is 5.6 eV. [2]

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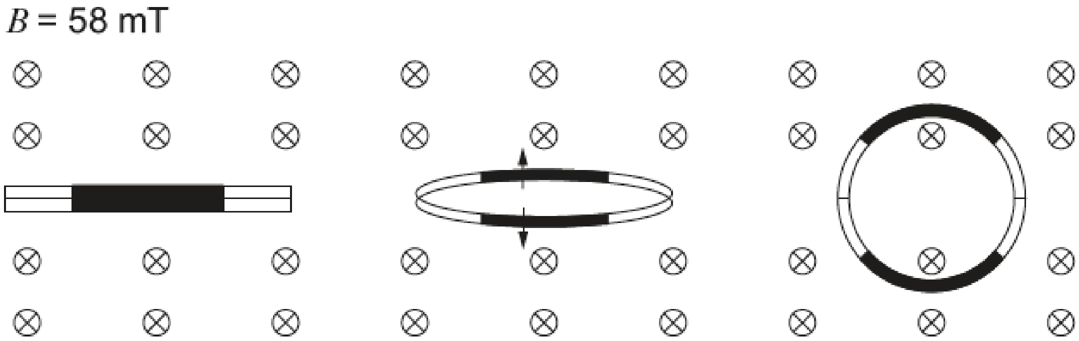
4. A magician's metallic wand can spring apart into the shape of a circular hoop (see below).



(a) The hoop is in a magnetic field. Explain why an emf is induced in the hoop as it expands. [3]

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(b) Explain why the current flows anticlockwise in the diagram. [2]

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(c) The hoop, of radius 31.0 cm, is in a region of uniform magnetic flux density (B) of 58 mT and expands from the wand shape to the hoop in a time of 63 ms. Calculate the mean current flowing in the hoop as it expands if the resistance of the hoop is 0.44 Ω. [5]

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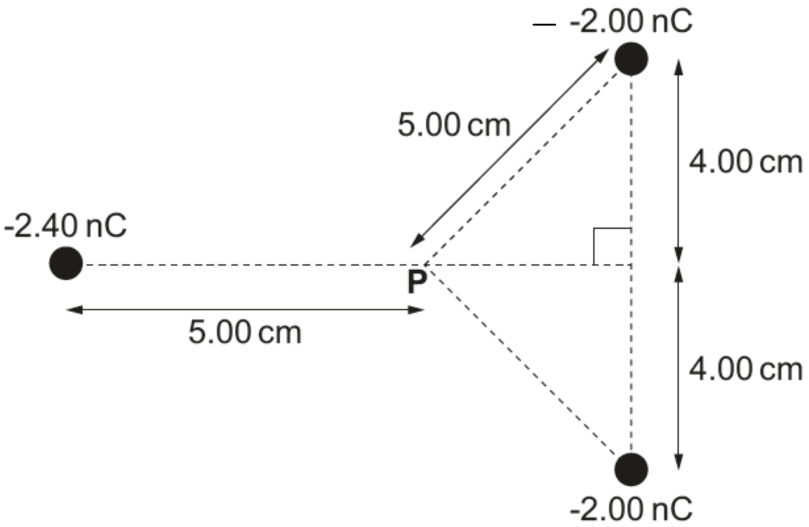
5. Three negative charges are arranged as shown.



(a) Draw arrows at **P** to represent the three electric fields due to the three charges. [2]

(b) Show that the resultant electric field at **P** is zero. [4]

(You may use the approximation $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \text{F}^{-1}\ \text{m}$.)

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(c) Calculate the electric potential at **P**. [3]

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(d) An electron starts to accelerate from rest from point **P** (in a direction out of the plane of the paper). Calculate its speed when it arrives at another point where the potential is -200 V. [3]

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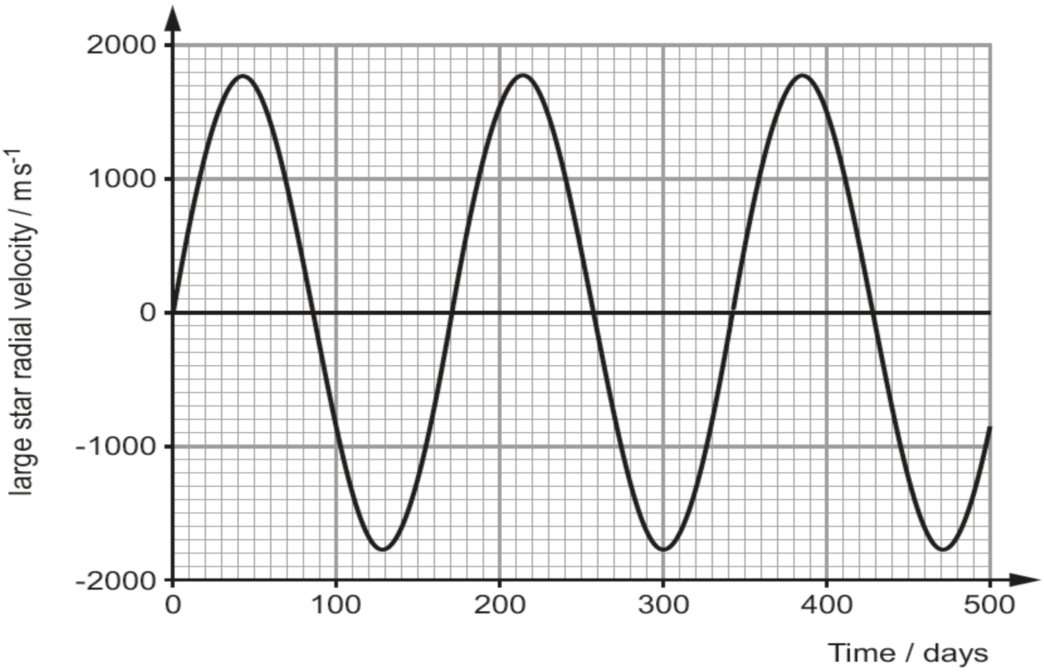
6. In 2008, a large planet was discovered orbiting a large star using the following data obtained from spectral observations of the large star. The graph shows the large star's radial velocity versus time (here, radial velocity is the component of the Star's velocity towards the Earth).



(a) With the use of a diagram, explain why this variation in radial velocity occurs. [2]

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(b) Show that the radius of the orbit of the large star is approximately 4×10^9 m. [2]

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(c) The mass of the large star is 8.0×10^{29} kg and you may assume that this is far greater than that of the planet. Show that the distance, d, between the large star and the planet is around 7×10^{10} m. [2]

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(d) Calculate the mass of the planet. [2]

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(e) Explain how data for the star and the planet might lead scientists to conclude whether or not life exists on the planet. [6 QER]

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7. *(a)* Use Hubble's law ($v = H_0 d$) and conservation of energy to show that the critical density of the universe is given by: [4]

$$\rho = \frac{3H_0^2}{8\pi G}$$

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(b) Calculate a value of the critical density of the universe and estimate the number of hydrogen atoms per m^3 that this density corresponds to. [2]

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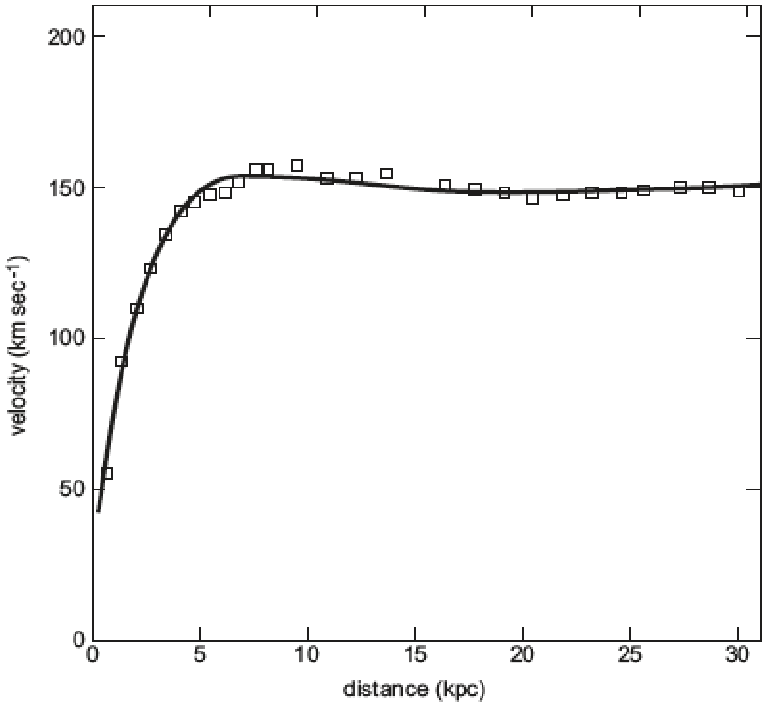
(c) Rotational data for a large spiral galaxy are shown in the diagram. Use data from the graph to calculate the time it takes for an object a distance of 30 kpc from the centre of the galaxy to complete one full orbit of the galaxy ($1\,\text{kpc} = 3.1 \times 10^{19}\,\text{m}$). [3]



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(d) If the spiral galaxy whose data are shown above were a distance of 2.17×10^{22} m from the Earth. Calculate the maximum and minimum possible red shift (or blue shift) for particles a distance of 30 kpc from the centre of the galaxy. [3]

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(e) By considering the data shown in the graphs below, explain briefly how the scientific community have checked the validity and integrity of data relating to Hubble's law. [2]

Figure 1 – Hubble's data (1929)

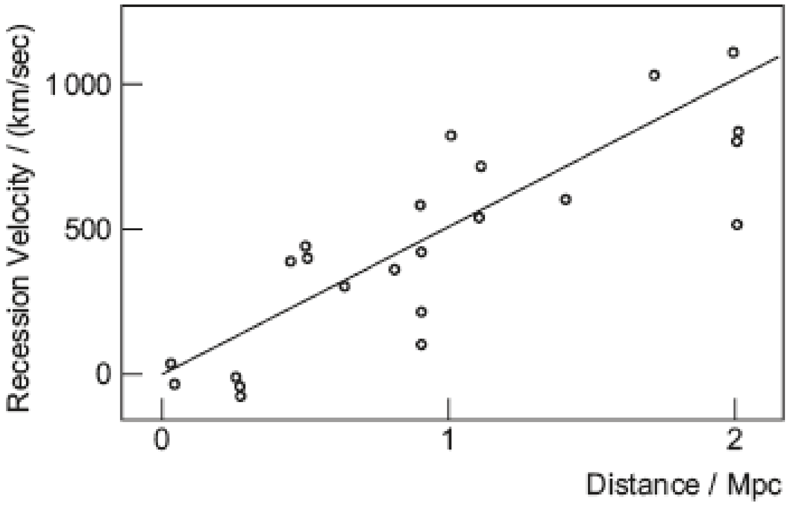
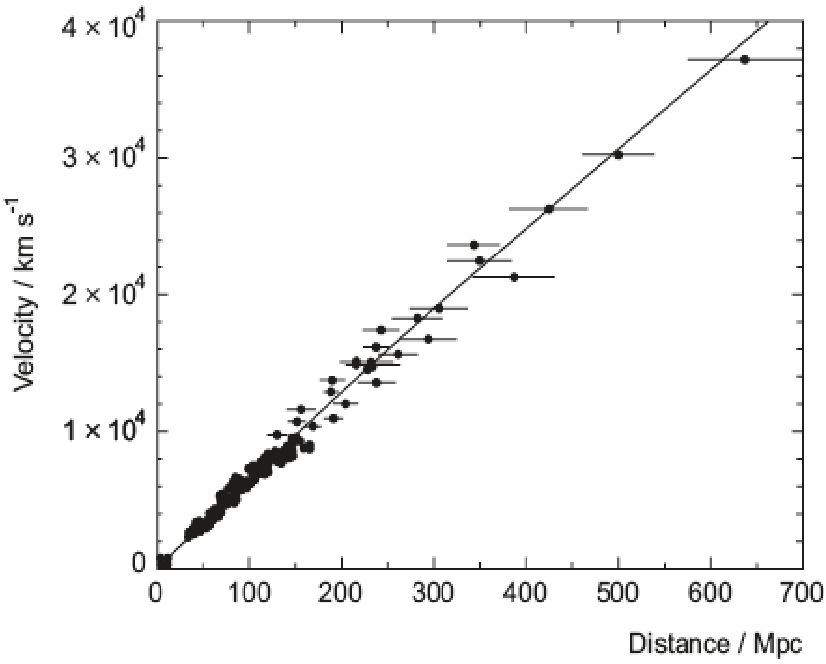


Figure 2 – Recent data based on Type 1a supernovae



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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**

8. *(a)* (i) Explain why a rotating coil in a uniform field produces an alternating emf. [2]

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(ii) Explain how the period of rotation of the coil, its area and the strength of the magnetic field affect the emf that is produced. [3]

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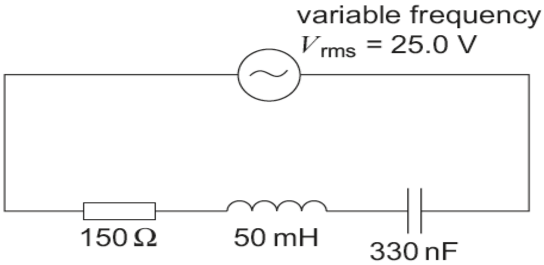
(b) For the following circuit:



(i) calculate the resonance frequency; [2]

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(ii) calculate the rms pd across each component at resonance.
[4]

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(c) The frequency of the a.c. supply is now set to 1.80 kHz.

(i) Calculate the rms current. [3]

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(ii) The Q factor of the circuit is too small. Evaluate two different methods of increasing the Q factor. [3]

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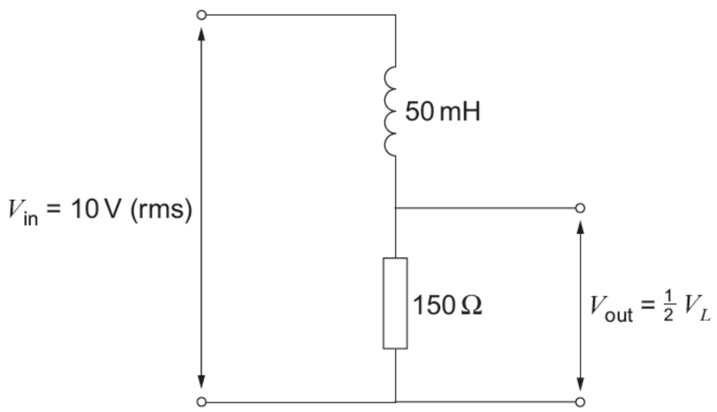
(d) In the circuit shown the rms output pd is ½ of the rms pd across the inductor.



Calculate the frequency of the input pd. [3]

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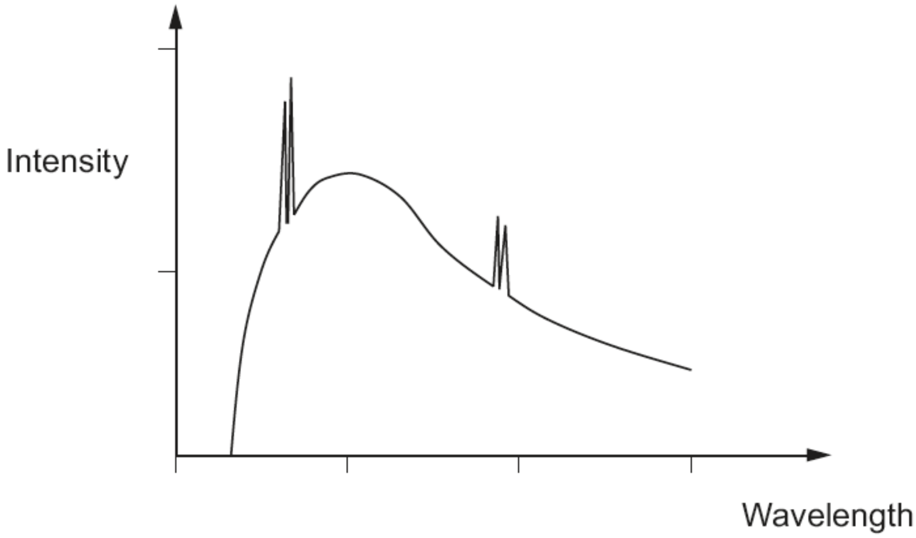
Option B – **Medical Physics**

9. *(a)* The diagram below is a typical X-ray emission spectrum for an X-ray tube with a tungsten target.



(i) Draw on the graph another curve that would be typical for the tube when operated at a lower potential difference. [1]

(ii) What difference would there be if molybdenum was used as the target instead of tungsten? [1]

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(iii) The X-ray tube has a working potential difference of 75 000 V. Calculate the minimum wavelength of an X-ray photon emitted from the tube. [2]

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(iv) If the anode current was 0.15 A and the X-ray tube has an efficiency of 0.5%, calculate the rate of production of heat at the anode. [2]

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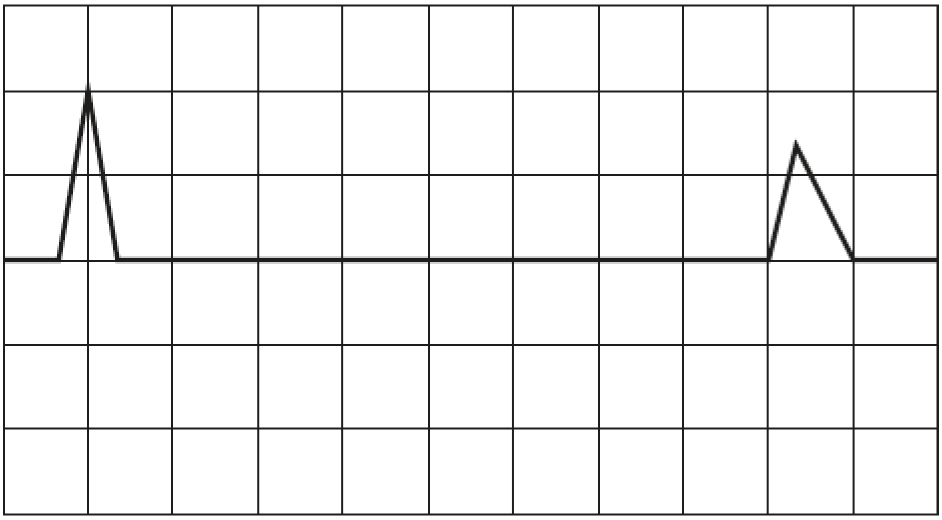
(b) An ultrasound A-scan is used to determine the depth of a layer of fat in a patient's body. The grid below shows the interval between the initial pulse and the reflected pulse on a cathode ray oscilloscope (CRO). The time base is set so that each full square represents 2 μs.



(i) If the speed of ultrasound in fat is 1.45×10^3 m s^{-1} calculate the thickness of the fat. [3]

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(ii) The fraction of ultrasound reflected at a boundary is given by the reflection coefficient, R, where $R = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ and Z = acoustic impedance.

Calculate the reflection coefficient between air and the skin of a patient using the following information. [2]

Medium	Density / kg m^{-3}	Velocity / m s^{-1}
Air	1.30	340
Skin	1 075	1 600

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(iii) Is it possible for ultrasound scans to be used to study a patient's lung? Explain your answer. [2]

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(c) (i) Explain, briefly, how magnetic resonance imaging (MRI) is able to produce detailed images of slices through the body. [2]

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(ii) An MRI scan would be unsuitable to image a lung tumour for a patient wearing a pacemaker. Explain why this is the case, and suggest a suitable imaging technique, justifying your choice. [3]

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(d) Write down an equation linking equivalent dose and effective dose. Define any new terms that appear in the equation, and give the unit for both. [2]

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Option C – **The Physics of Sports**

10. *(a)* (i) Explain what is meant by the statement "the coefficient of restitution between a cricket bat and the ball is 0.73". [2]

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(ii) Calculate the height of the second bounce of a cricket ball falling from a height of 12.6 m if the coefficient of restitution is 0.65. [2]

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(iii) Explain why a bowler applies spin to the ball when bowling.
Your answer should include the forces acting on the ball during flight.
You can include diagrams in your explanation. The effects of air resistance should be considered for this part. [3]

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(b) (i) A diver makes 2.5 revolutions on a dive from a 10 m high platform to the water. Assuming that the initial vertical velocity is zero; calculate the mean angular velocity of the diver during the dive. [3]

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(ii) Another diver initially is rotating with an angular velocity 3.0 rad s^{-1} so that the moment of inertia is 4.0 kg m^2. The moment of inertia is reduced to 1.8 kg m^2. Calculate the increase in the rotational kinetic energy gained by the diver. You may ignore the effects of air resistance. [3]

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(iii) Using an appropriate definition, explain clearly how the diver referred to in part (ii) reduces her moment of inertia. [3]

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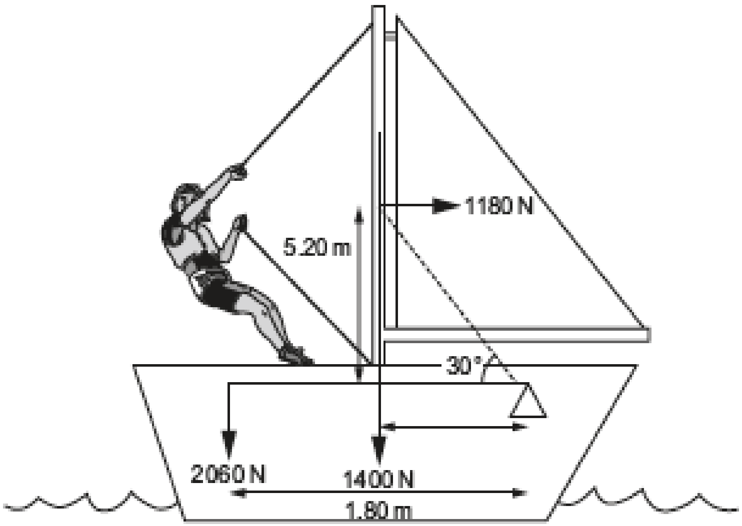
(c) The forces acting on a sailing boat are as shown in the diagram below. The wind provides an effective force of 1 180 N acting at a height of 5.20 m. The weight of the boat is 1 400 N. Three members of the crew of combined weight 2 060 N are used to counter balance the boat. Explain clearly the motion of the boat. [4]



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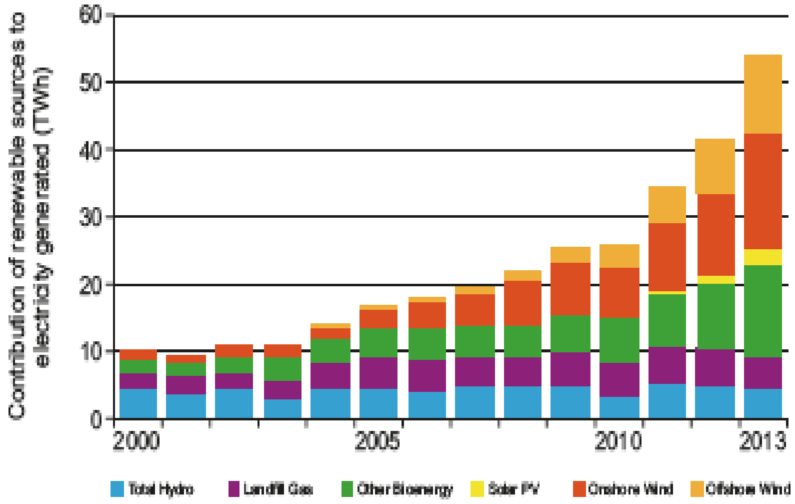
Option D – **Energy and the Environment**

11. *(a)* The chart shows the growth in the contribution of renewable sources of energy to the electricity produced in the UK between 2000 and 2013.



Source: Department of Energy and Climate Change; Energy Trends June 2014

(i) State three conclusions that you can draw from this chart. [3]

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(ii) Show that the energy produced from all renewable sources in 2000 is approximately 3.6×10^{16} J. [2]

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(iii) In 2013 the UK produced 1.9×10^{17} J of electrical energy from renewable sources. Use the chart to estimate the % contribution that offshore wind turbines made to this total. [2]

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(iv) Gwynt y Môr offshore wind farm uses turbines of radius 50 m which are exposed to a mean annual wind speed of 9.0 m s^{-1}.

(I) Write down an expression for the power available from a fluid of density ρ, moving with a speed of v, through cross-sectional area A. [1]

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(II) Estimate the number of offshore wind turbines required to produce a mean output power of 1 TW. Assume each turbine is 45% efficient and the density of air = 1.2 kg m^{-3}. [4]

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(b) (i) The thermal conductivity of a material is given by:

$$K = \frac{\Delta Q}{\Delta t}\frac{\Delta x}{A\Delta\theta}$$

Explain what is meant by: [1]

$\frac{\Delta Q}{\Delta t}$ ....

$\Delta\theta$ ....

(ii) The ceiling of a house is made of a wooden board which is 16 mm thick and measuring 18 m × 15 m. The thermal conductivity of the board is 0.16 W m^{-1}K^{-1}. The temperature inside the house is kept at 20°C whilst that of the loft is 5 °C. Calculate the rate at which thermal energy is transferred through the board. [3]

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(iii) Calculate the U value for the board. [3]

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(iv) State one factor which affects the U value of a material and suggest how your chosen factor may reduce the energy lost through the ceiling. [1]

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