No. 262

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

University Entrance, Bursaries and Scholarships Examination

PHYSICS: 1999

QUESTION BOOKLET

Time allowed: Three hours
(Total marks: 160)

This paper consists of 12 questions.

Answer **ALL** questions.

The total marks assigned to questions is 152. In addition to this, four marks will be awarded for correct use of significant figures and a further four marks will be awarded for correct use of units of measurements.

The questions are organised under the headings below, with allocations of marks and suggested times indicated.

Mechanics	Questions One to Four	53 marks	63 minutes
Waves	Questions Five and Six	30 marks	36 minutes
Electricity and Electromagnetism	Questions Seven to Ten	46 marks	54 minutes
Atomic and Nuclear Physics	Questions Eleven and Twelve	23 marks	27 minutes

Check that this question booklet has all of pages 2 – 16 in the correct order and that none of these pages is blank.

Write your answers in the appropriate spaces in the printed Answer Booklet No. 262/1 (purple cover).

Page one of the Answer Booklet has instructions for answering the questions.

Some useful formulae are given on page 17 of the Answer Booklet. This page is detachable.

(Turn over

MECHANICS

(53 marks; 63 minutes)

THE PORTABLE CD PLAYER

QUESTION ONE: ROTATIONAL MOTION (10 marks)

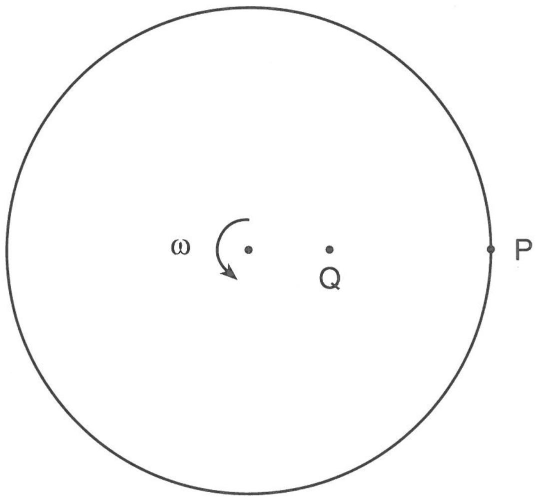
Edward uses a portable compact disc (CD) player to play CDs. Each CD has a diameter of 0.12 m. When operating at full speed, a disc has an angular velocity of 52 rad s^{-1}.

(a) How many revolutions per minute is 52 rad s^{-1}? (2 marks)

When the player was turned on, a disc took 2.5 s to reach full speed.

(b) What was the average angular acceleration of the disc during this turn-on period? (2 marks)

(c) What angle had the disc turned through during this turn-on period? (2 marks)



(d) What was the linear speed of the point P on the outer edge of the disc when the disc was rotating at 52 rad s^{-1}? (2 marks)

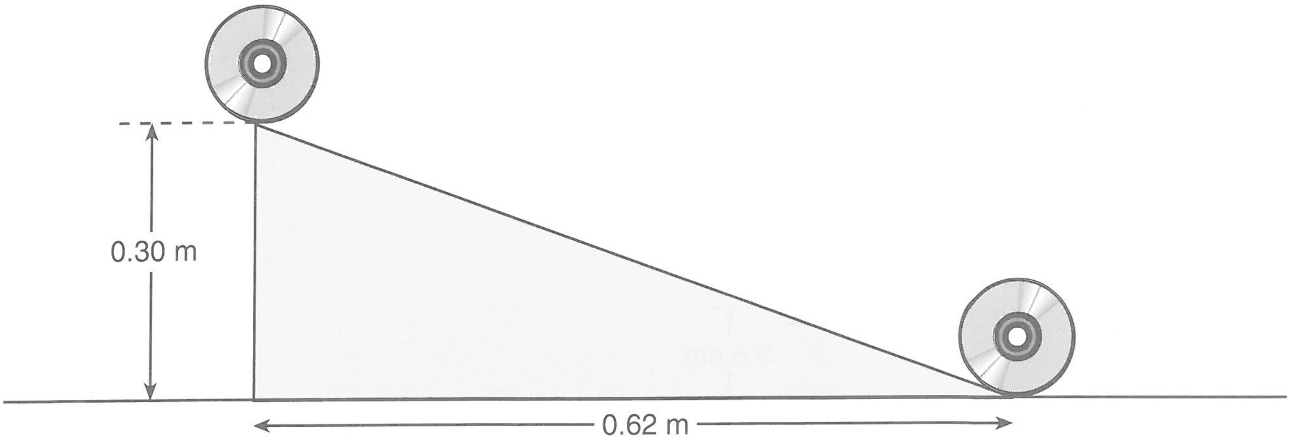
(e) On the diagram in your Answer Booklet draw a vector indicating the direction of the acceleration of the point P on the outer edge of the disc, when full speed is reached. (1 mark)

(f) The point Q is at one third of the radius of the circle. For any given rotational speed, what fraction of the linear speed of point P is the linear speed of point Q? (1 mark)

QUESTION TWO: TRANSLATIONAL AND ROTATIONAL MOTION (14 marks)

Acceleration due to gravity = 9.8 m s^{-2}

Edward rolled a compact disc (CD) down a slope as shown below. The CD had a diameter of 0.12 m and a mass of 1.6×10^{-2} kg. Edward started it from rest at the top of the slope and it rolled without slipping to the bottom.



(a) Calculate the gravitational potential energy lost by the disc when it reached the bottom of the slope. (2 marks)

(b) At the bottom of the slope, the centre of mass of the disc had a linear speed of 2.0 m s^{-1}. What was the linear kinetic energy of the disc at the bottom of the slope? (2 marks)

(c) What was the rotational kinetic energy of the disc at the bottom of the slope? (1 mark)

(d) What was the angular velocity of the disc at the bottom of the slope? (2 marks)

(e) What was the rotational inertia of the disc about its centre? (2 marks)

The slope was smooth and almost frictionless. However, the flat floor beyond the slope was carpeted and there was significant friction which slowed the disc down. The disc rolled off the slope with a horizontal linear speed of 2.0 m s^{-1} and it travelled 1.3 m along the carpet before stopping.

(f) Calculate the force the carpet exerted on the disc to slow it down. (3 marks)

One day Edward accidentally dropped his portable CD player from a height of 1.5 m and it landed on a very hard floor. He calculated that it had a speed of 5.4 m s^{-1} just before it hit the floor. The CD player had a mass of 0.35 kg.

(g) What was the linear momentum of the portable CD player just before it hit the floor? (1 mark)

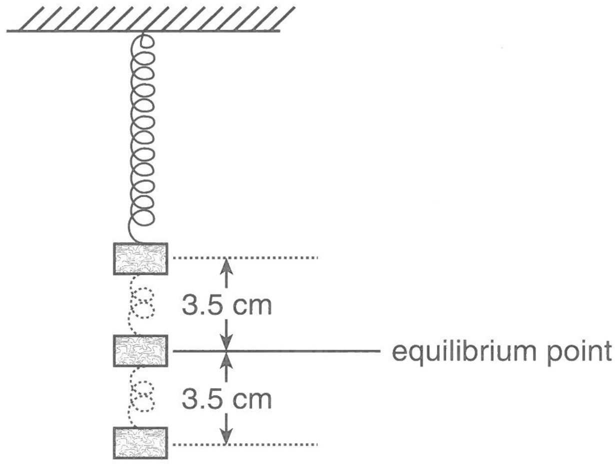
(h) If it took 0.040 s for the CD player to come to rest, calculate the average force acting on it to make it stop. (1 mark)

(Turn over

QUESTION THREE: SIMPLE HARMONIC MOTION (15 marks)

Acceleration due to gravity = 9.8 m s^{-2}

Edward's compact disc player was broken and when he opened it up to repair it, a spring fell out. He measured the spring constant and found it to be k = 7.2 N m^{-1}. Edward then hung a 55 gram (5.5×10^{-2} kg) mass on the spring. He set it oscillating in approximately simple harmonic motion by extending it downwards by 3.5 cm beyond the equilibrium point and releasing it. (See diagram below.)



(a) What period did the oscillations have? (2 marks)

(b) Show that the angular velocity of the oscillations had an unrounded value of 11.44155 rad s^{-1}. (2 marks)

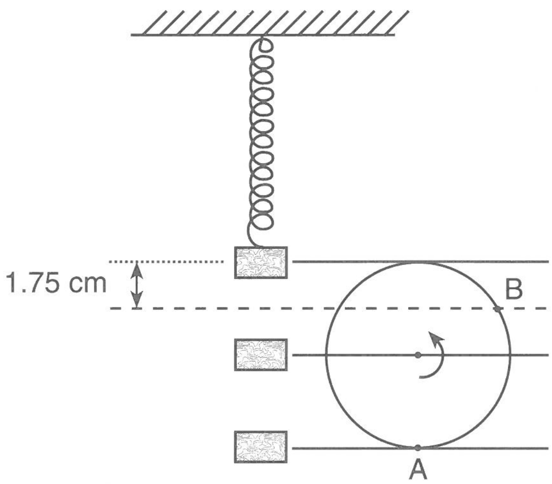
(c) What was the maximum speed of the mass during these oscillations? (2 marks)

(d) Where in the motion did this maximum speed occur? (1 mark)

(e) Calculate the kinetic energy of the mass when it had maximum speed. (2 marks)

(f) Calculate the acceleration of the mass at t = 0.70 s after it was released. (3 marks)

(g) Use the reference circle in your Answer Booklet to find the time the mass took to go from A to B. (3 marks)



QUESTION FOUR: GRAVITY (14 marks)

Acceleration due to gravity at sea level on Earth = 9.8 m s^{-2}.
Universal gravitational constant = 6.67×10^{-11} Nm^2 kg^{-2}.
Mass of Earth = 6.0×10^{24} kg.
Radius of Earth at sea level = 6.37×10^6 m.

Sophie had a portable compact disc (CD) player which also had a radio in it. She would sometimes listen to foreign radio stations at night time. One such station was only audible every two hours and then only for about 27 minutes. She thought the signal must be from a satellite which passed overhead, orbiting the earth with a period of two hours.

(a) Calculate the linear speed of a satellite in circular orbit about the centre of Earth if the satellite has a period of two hours (7 200 s) and an orbital radius of 8.1×10^6 m. (3 marks)

(b) Calculate the centripetal acceleration of the satellite in (a). (2 marks)

(c) What is the acceleration due to the Earth's gravity of any object at a height of 8.1×10^6 m? (1 mark)

(d) Would the period of a satellite increase, decrease or remain the same if the radius of the orbit was reduced? (1 mark)

(e) What is the period, in seconds, of a satellite in a geostationary orbit? (1 mark)

Sophie was a mountaineer and took her 0.220 kg portable compact disc player up a 6 100 m high mountain.

(f) Calculate the force of attraction, at the top of the mountain, between the CD player and the Earth. (3 marks)

When the United States astronauts walked on the moon many years ago they were able to jump higher than they could on Earth. The moon has a mass of 7.3×10^{22} kg and a radius of 1.7×10^6 m.

(g) Explain, in terms of energy, why the astronauts could jump much higher on the moon than on Earth. (3 marks)

(Turn over

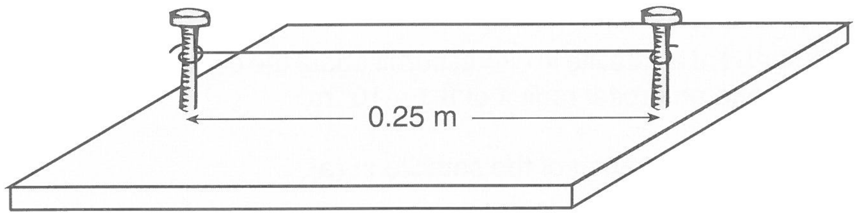
WAVES

(30 marks; 36 minutes)

QUESTION FIVE: SOUND (11 marks)

Velocity of sound in air is 330 m s^{-1}.

Edward had a spring from inside his broken portable compact disc (CD) player. He stretched it out into a wire and tied it firmly between two nails 0.25 m apart on a piece of wood, as shown below.



(a) Edward gently plucked this stretched wire. On the diagram in your Answer Booklet, label the positions of the nodes and antinodes in the standing wave in the wire if only the fundamental frequency was present. (2 marks)

(b) When Edward gently plucked the wire, he heard a sound of frequency 930 Hz. What was the velocity of the wave in the wire? (3 marks)

(c) When he plucked the string with more force Edward heard a higher pitched sound because the lowest frequency excited was the first overtone (second harmonic). On the diagram in your Answer Booklet, label the positions of the nodes and antinodes which would be present in the standing wave in the wire if only the first overtone was present. (2 marks)

Stephanie had an identical spring made of the same wire which she also stretched between two nails 0.25 m apart on a piece of wood. However, when she plucked her spring the sound it made had a fundamental frequency of 730 Hz.

(d) What difference between her set-up and Edward's set-up could cause such a change in the frequency of the sound produced? (Note: the wire was identical and the distance between the nails was the same.) Explain **why** this difference would change the pitch of the sound produced. (2 marks)

Stephanie then modified her stretched wire arrangement until it produced a 910 Hz note. When Stephanie and Edward gently plucked their wires at the same time, the sound they heard had a beat.

(e) What was the frequency of that beat? (1 mark)

(f) Electromagnetic waves are described as transverse. What are sound waves generated by loudspeakers described as? (1 mark)

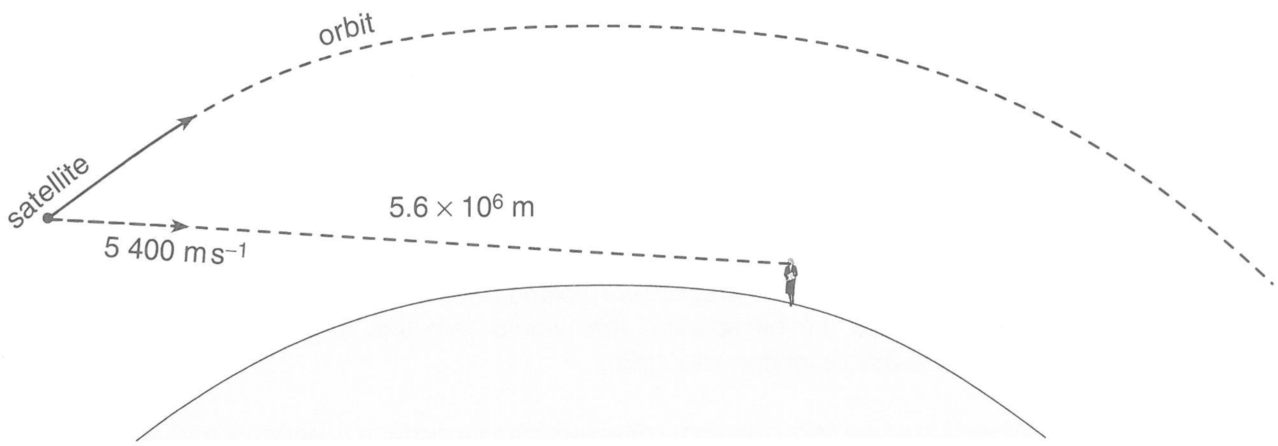
QUESTION SIX: ELECTROMAGNETIC RADIATION (19 marks)

Speed of light in vacuum and air = 3.00×10^8 m s^{-1}

The transmitted frequency of a radio signal that Sophie sometimes listened to on her radio was 9.90×10^7 Hz.

(a) What is the transmitted wavelength of the radio signal? (2 marks)

(b) The signal was produced by a satellite which was 5.6×10^6 m away from Sophie (as in the diagram below, but not to scale). How long would it take the radio waves to travel from the satellite to her radio? (2 marks)



For a short time the satellite was effectively travelling (ie there was a component of its velocity) toward Sophie at 5 400 m s^{-1} (as shown in the diagram above). The frequency of the radio signal received by her radio was therefore Doppler–shifted.

(c) Will the frequency of the radio signal received by Sophie's radio be higher, lower or the same as the transmitted frequency? (1 mark)

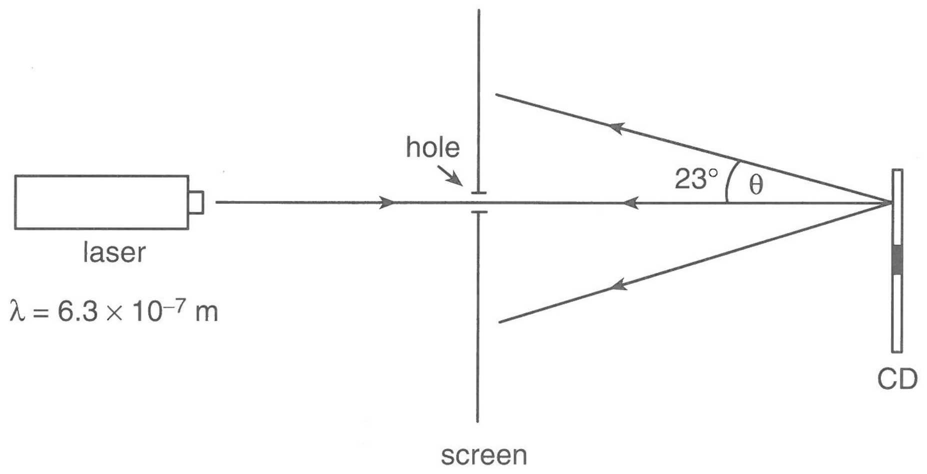
(d) Calculate the frequency of the radio signal received by Sophie's radio. (3 marks)

Sophie's teacher said that light from stars is often Doppler-shifted towards the red end of the spectrum. Light from a certain star is emitted with a wavelength of 6.40×10^{-7} m and appears to us on the Earth as light of wavelength 6.45×10^{-7} m.

(e) For each wavelength, calculate the frequency of the light. (2 marks)

(f) How fast is the star moving, relative to Earth? (4 marks)

Sophie was looking at a compact disc (CD) one day and noticed that white light reflected from it was visible as multiple spectra. She decided that the CD must be acting like a diffraction grating and she set out to find the spacing between the pits in the plastic of the CD. The experimental arrangement is shown below.



(g) Sophie measured the angle θ of the first order maximum for the red laser light ($\lambda = 6.3 \times 10^{-7}$ m) and found it was 23°. Calculate the pit spacing that would give this angle. (Note: the usual diffraction equation can be used in this reflection situation.) (3 marks)

(h) When a CD is viewed in white light, the light reflected from its surface is seen as multiple spectra. Explain why this is so. (2 marks)

ELECTRICITY AND ELECTROMAGNETISM

(46 marks; 54 minutes)

QUESTION SEVEN: DC ELECTRICITY (10 marks)

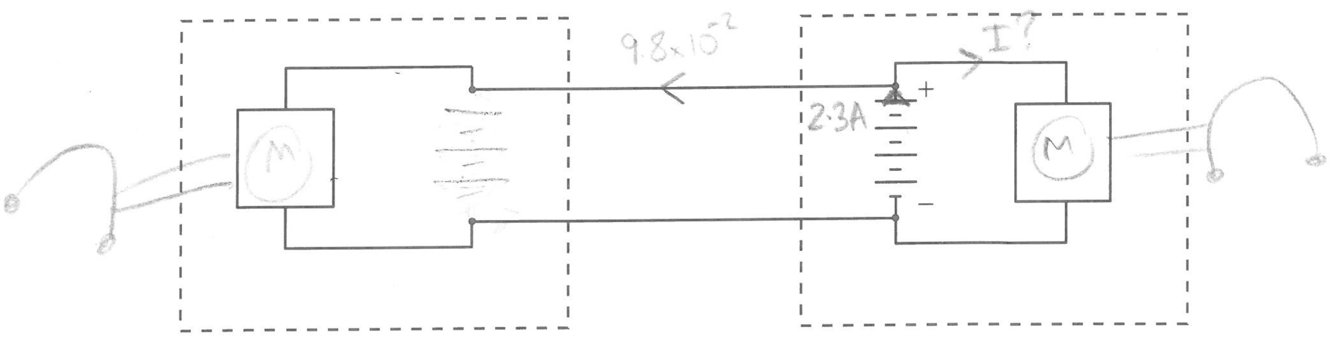
Edward's portable compact disc (CD) player runs off 6.0 volts DC and uses a set of four 1.5 V "AA" batteries in series. When playing CDs the current drawn from new batteries is 9.8×10^{-2} A.

(a) What is the resistance of Edward's CD player when it is operating properly? (2 marks)

(b) How much power does Edward's CD player use? (2 marks)

(c) If a set of four fresh batteries can supply 9.1×10^{3} J of energy, for how long will Edward be able to play his CDs on one set of fresh batteries? (2 marks)

One day Edward had no batteries for his portable CD player. Sophie used some extra wires and made both CD players go from her set of four 1.5 V batteries. She wired them up as shown below.

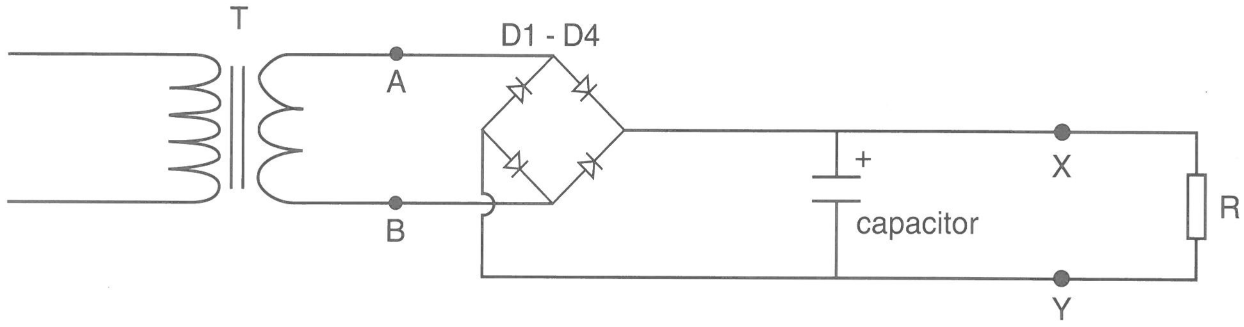


(d) In this new arrangement, a current of 0.23 A was being drawn from Sophie's batteries. How much current was Sophie's CD player drawing from the batteries? Assume Sophie's batteries are new. (2 marks)

(e) In the space provided in your Answer Booklet, draw a circuit diagram which includes another set of four 1.5 V batteries that would increase the length of time the two CD players could both run together at the correct voltage. (2 marks)

QUESTION EIGHT: AC ELECTRICITY (19 marks)

Stephanie and Sophie often used AC adapters to run their compact disc (CD) players. These small boxes were plugged into the 230 V, 50 Hz, AC mains supply and converted the AC electricity to 6.0 volts DC. The circuit for a typical adapter is shown below.



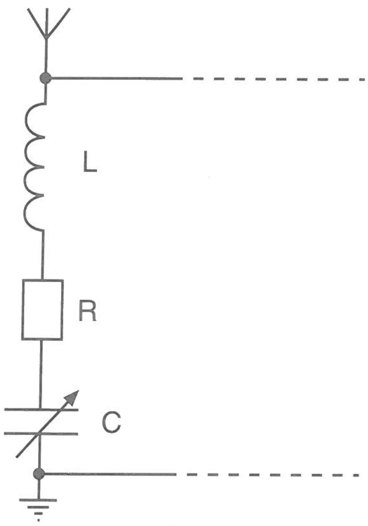
(a) What are the components labelled D1 to D4 usually called when they are wired in this configuration? (1 mark)

(b) What is the function of the component labelled T? (2 marks)

(c) On the axes provided in your Answer Booklet, sketch a graph of voltage between points A and B against time. Include a maximum voltage value (assuming 100% efficiency) and a period value. (4 marks)

(d) On the axes provided in your Answer Booklet, sketch a graph of voltage between points X and Y against time. (Note: no numerical values are required.) (2 marks)

The radio in Stephanie's CD player has an LRC antenna circuit inside it as shown below. The component values are $L = 6.0 \times 10^{-7}$ H, $R = 980\ \Omega$ and C is a variable capacitor.



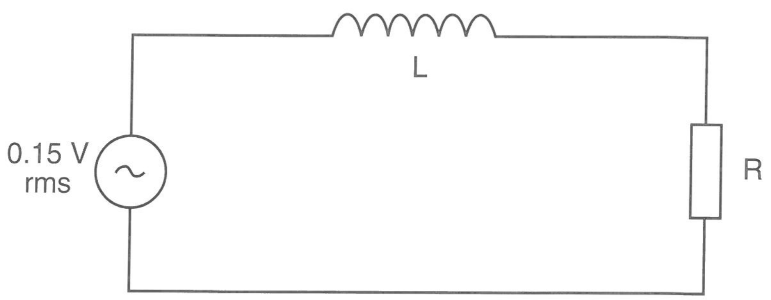
(e) What is the capacitance of the capacitor when the circuit is resonant at 9.8×10^{7} Hz? (3 marks)

(f) If the value of C found in (e) is doubled, what will be the new frequency the radio is tuned to? (2 marks)

(g) If C is kept constant at the value found in (e), on the axes provided in your Answer Booklet, **sketch** a graph of current versus frequency for the range 6.0×10^{7} to 14.0×10^{7} Hz. (Actual numerical values are not required.) (2 marks)

In a particular LR circuit, as shown below, the frequency of the AC voltage source is 2.5×10^{7} Hz and the inductor has an inductance of 3.3×10^{-6} H. The resistor has a resistance of $470\ \Omega$.

(h) What is the phase difference (in radians) between the voltage across the resistor and the source voltage? (3 marks)



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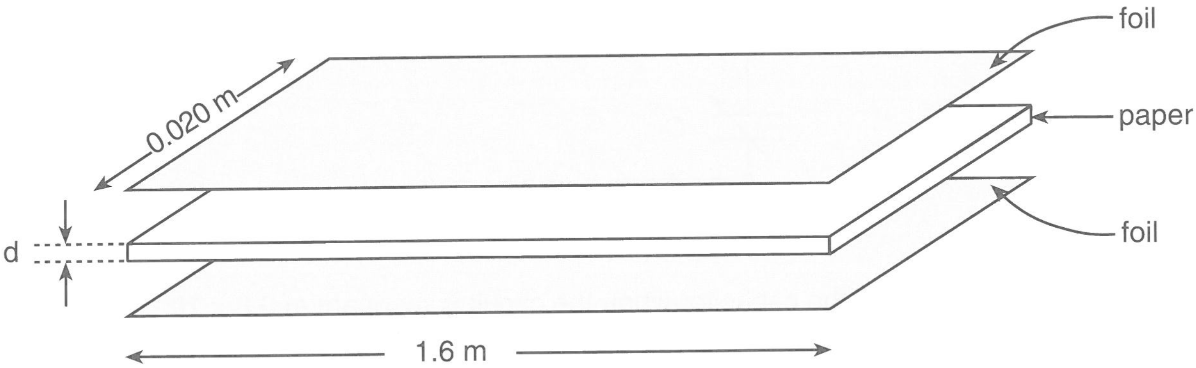
QUESTION NINE: CAPACITORS (10 marks)

Permittivity of free space = 8.85×10^{-12} N^{-1}m^{-2} C^2
Charge on an electron = 1.6×10^{-19} C

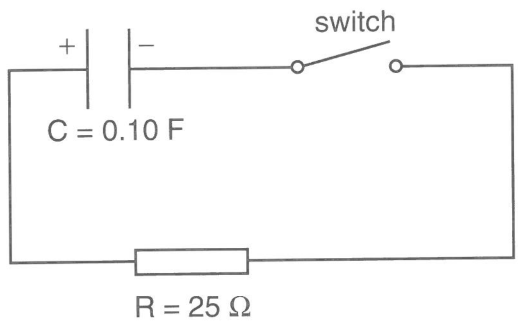
One day Edward dismantled an old radio he was given and found a capacitor inside which he was able to pull apart. It consisted of two long sheets of aluminium foil separated by a sheet of waxed paper, as shown below. The capacitor had a value written on it of 1.0×10^{-8} F.



(a) Edward estimated a value of 7.5 for the relative permittivity (or dielectric constant), ε_r, of the waxed paper in the capacitor and used it to calculate the thickness of the waxed paper. What thickness would he calculate? (3 marks)

(b) When Edward measured the thickness of the waxed paper he found it was 5.5×10^{-5} m. Calculate the actual relative permittivity. (1 mark)

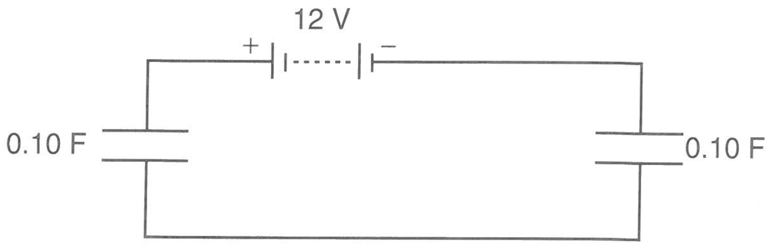
Edward charged a 0.10 F capacitor up to 12 volts. He then discharged it through a 25 Ω resistor by closing the switch in the circuit below.



(c) How long would it take for the voltage across the capacitor to drop to approximately 4.4 V? (2 marks)

(d) On the diagram in your Answer Booklet, sketch the current versus time discharge curve. Include the maximum current value. (2 marks)

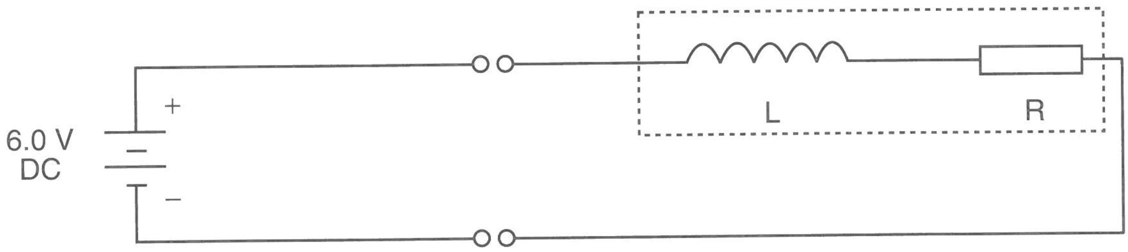
Two 0.10 F capacitors are connected in series and connected across a 12 V battery as shown below.



(e) How much charge would be present on the positive plate of each of the capacitors? (2 marks)

QUESTION TEN: INDUCTANCE (7 marks)

Edward took a small electric motor out of his broken compact disc (CD) player. He connected it to a 6.0 V battery and watched as it rotated very fast. This particular electric motor can be thought of as a simple inductor with some resistance (L = 0.15 H, R = 99 Ω). Just after Edward disconnected it from the battery, he happened to touch both wires from the motor (one with each hand) and received an electric shock.



(a) Explain why the motor was able to give Edward an electric shock just after he had disconnected it. (2 marks)

(b) If Edward had touched both wires (one with each hand) while the motor was running would he have been likely to have received a shock which was more severe or less severe? Explain your answer. (2 marks)

(c) On the axes provided in your Answer Booklet, sketch a graph of current versus time as the motor was **connected** to the 6.0 V supply. Include indications of the steady current value and the time taken to reach this steady current. (3 marks)

ATOMIC AND NUCLEAR PHYSICS

(23 marks; 27 minutes)

QUESTION ELEVEN: ATOMIC PHYSICS (11 marks)

Speed of light in vacuum = 3.0×10^{8} m s^{-1}
Planck's constant = 6.63×10^{-34} J s
Rydberg constant = 1.097×10^{7} m^{-1}

(a) Calculate the energy of the electron in a hydrogen atom when it is in the $n = 4$ orbital (energy state). (3 marks)

(b) The energy of the electron when it is in the $n = 2$ orbital is 5.5×10^{-19} J. Calculate the wavelength of the photon emitted when the electron in a hydrogen atom drops from the $n = 4$ orbital to $n = 2$ orbital. (2 marks)

(c) Will the photon in (b) be visible, ultraviolet or infrared? (1 mark)

When blue light is shone on to a certain metal surface (under vacuum), electrons are emitted from the surface of the metal.

(d) If ultraviolet light is used instead of blue light, will electrons be emitted (yes/no)? Explain your answer. (2 marks)

(e) How much energy does a blue photon have if its wavelength is $\lambda = 4.4 \times 10^{-7}$ m? (2 marks)

(f) What work function must a metal have for the blue light in (e) to be just able to cause electrons to be emitted? (1 mark)

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QUESTION TWELVE: NUCLEAR PHYSICS (12 marks)

Speed of light, $c = 3.0 \times 10^8$ m s^{-1}
Charge on an electron = 1.6×10^{-19} C

(a) In your Answer Booklet, complete the following table of radiation types. (Note: c is the speed of light.)

Common name	Symbol	Usual speed	Charge
alpha particle	α	< 0.1 c	
	β		–1
gamma radiation	γ	c	

(4 marks)

The following is a typical fusion reaction: ${}^{3}_{1}H + {}^{2}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$ + energy.

(b) What is the isotope of hydrogen ${}^{2}_{1}H$ usually called? (1 mark)

(c) A great deal of effort is being made around the world to successfully produce energy from fusion, rather than fission type reactions. Suggest two reasons why energy derived from fusion might be preferable to energy derived from fission. (2 marks)

(d) How many protons and neutrons are left in the remaining nucleus when ${}^{226}_{88}Ra$ emits an alpha particle? (2 marks)

(e) How many electron-volts (eV) are in 1.0 joule of energy? (1 mark)

(f) A fusion reaction liberates 1.7×10^{6} eV of energy. Calculate the mass that can be transformed into this amount of energy. (2 marks)