5. A student performed a single experiment to (*a*) verify Joule's law, and (*b*) determine the specific heat capacity of olive oil.

An electrical heating coil of resistance 8.5 Ω was immersed in 350 g of olive oil which was at room temperature. A current I was allowed to flow through the coil for three minutes and the final temperature θ of the oil was determined.

This process was repeated for six different values of I.

The following data were recorded.

Room temperature = 17.0 °C

I (A)	1.0	2.0	3.0	3.5	4.0	4.5
θ (°C)	19.2	26.1	36.6	44.4	53.1	62.1

(*i*) Draw a labelled diagram of how the apparatus was arranged in this experiment.

(*ii*) How was the mass of the olive oil determined? (15)

(*iii*) Draw a suitable graph to verify Joule's law.

(*iv*) Calculate the slope of your graph.

(*v*) Hence calculate the specific heat capacity of olive oil. (25)

2. In an experiment to determine the focal length *f* of a concave mirror, a student first found an approximate value for the focal length. She then measured the image distance *v* for a series of object distances *u*.

The following data were recorded.

u (cm)	20.0	30.0	40.0
v (cm)	66.3	31.1	25.2

(*i*) How did the student find an approximate value for *f*?

(*ii*) Why did the student find an approximate value for *f?* (12)

(*iii*) Draw a labelled diagram of the apparatus used in this experiment. Show *u* and *v* on your diagram.

(*iv*) Describe how the student determined and measured *v*.

(*v*) Use all of the data to calculate *f*. (28)

5. A student investigated the variation of current I with potential difference V for a semiconductor diode in forward bias.

The following data were recorded.

V (V)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7
I (mA)	0	0	0	0	5	20	70	220

(*i*) Draw a circuit diagram for this experiment with the diode in forward bias.

(*ii*) Draw a suitable graph to show the relationship between I and V for a diode in forward bias. (21)

(*iii*) Is Ohm's law obeyed for this diode? Justify your answer. (6)

The student then investigated the variation of current I with potential difference V for a diode in reverse bias. Several adjustments were made to the circuit.

(*iv*) Draw a circuit diagram for this experiment with the diode in reverse bias.

(*v*) Sketch a graph to show the relationship between I and V for a diode in reverse bias. (13)

12. Answer **either** part (*a*) or part (*b*).

(*a*) In 1932 Ernest Walton and John Cockcroft verified experimentally Einstein's equation that relates mass and energy. They accelerated protons through a potential difference of 70 kV before allowing them to collide with lithium metal.

(*i*) Draw a labelled diagram of their apparatus.

(*ii*) Write a nuclear equation for the interaction between a proton and a nucleus of lithium–7. (21)

The mass of the ^{1}H nuclide is given on page 83 of the *Formulae and Tables* booklet as 1.007825 u.

(*iii*) Convert this mass to kg. (Give your answer to six decimal places.)

(*iv*) Explain the discrepancy between the value you have calculated and the value given for the mass of the proton on page 47 of the *Formulae and Tables* booklet. (6)

Calculate

(*v*) the kinetic energy of the proton as it collided with the metal,

(*vi*) the mass lost (in kg) during the interaction,

(*vii*) the energy produced (in J) during the interaction,

(*viii*) the speed of the alpha particles formed during the interaction. (24)

(*ix*) A proton may be classified as a *hadron*. Explain why.

(*x*) A proton may also be classified as a *baryon*. Explain why. (5)

(*b*) A moving-coil galvanometer is a device for detecting and measuring electric current.

(*i*) What is electric current?

(*ii*) Draw a labelled diagram of a moving-coil galvanometer.

(*iii*) Describe, with the aid of your diagram, the principle of operation of a moving-coil galvanometer. (24)

(*iv*) Draw a circuit diagram to demonstrate how a galvanometer can be converted into an ammeter.

(*v*) Draw a circuit diagram to demonstrate how a galvanometer can be converted into an ohmmeter.

A resistor called a multiplier is used to convert a galvanometer into a voltmeter.

(*vi*) A galvanometer has a full scale deflection of 50 mA and a resistance of 0.7 Ω. Calculate the resistance of the multiplier used when this galvanometer is converted into a voltmeter which can read up to 10 V. (21)

A loudspeaker also contains a moving coil.

(*vii*) Explain, with the aid of a labelled diagram, how a loudspeaker produces sound. (11)

13. Read the following passage and answer the accompanying questions.

Europe's greatest scientist during the latter half of the seventeenth century, Christiaan Huygens, was a true polymath. He was a towering figure in the fields of astronomy, mechanics and mathematics, and many of his innovations in methodology, optics and timekeeping remain in use to this day. Among his many achievements, he developed the theory of light travelling as a wave, he invented the mechanism for the pendulum clock, and he discovered the rings of Saturn and its moon Titan – via a telescope that he also had invented.

Huygens is remembered as a problem solver: pragmatic, eclectic and synthetic, sceptical and ready to settle for the most probable rather than hold out for the absolutely certain – in other words, what we expect a scientist to be today.

Adapted from: *'Dutch Light: Christiaan Huygens and the Making of Science in Europe' (Hugh Aldersey-Williams) Pan Macmillan 2020*

(*i*) Diffraction is one of the wave properties of light. What is meant by diffraction? (7)

(*ii*) (*a*) Draw a labelled diagram of an experiment to demonstrate the wave nature of light.

(*b*) What is observed in this experiment?

(*c*) How do the observations demonstrate the wave nature of light? (14)

(*iii*) The eyepiece lens of Huygens' telescope was a converging lens arranged so as to produce a virtual image. Draw a ray diagram to show how a converging lens can produce a virtual image. (7)

(*iv*) The pendulum of Huygens' clock oscillated with a period of 2 s. Calculate the length of this pendulum. (7)

Titan orbits Saturn every 15.9 Earth days. The surface of Titan is 1.16×10^9 m above the surface of Saturn.

(v) Calculate

(*a*) the mass of Saturn,

(*b*) the acceleration due to gravity on the surface of Saturn,

(*c*) the period that Huygens' clock would have on the surface of Saturn. (21)

(*acceleration due to gravity on Earth = 9.8 m s^{-2}; radius of Saturn = 58200 km; radius of Titan = 2570 km*)

7. A spring of natural length 150 mm obeys Hooke's law. When an object of mass 200 g is attached to it, the length of the spring increases to 185 mm.

(*i*) State Hooke's law.

(*ii*) Calculate the elastic constant of the spring.

The object is pulled down until the spring has a length of 200 mm. The object is then released. It moves with simple harmonic motion.

(*iii*) Calculate the period of oscillation of the object.

(*iv*) Calculate the maximum acceleration of the object.

(*v*) What is the speed of the body when it has maximum acceleration? (28)

The object is now detached from the spring and attached to the end of a string of fixed length 11 cm. It is made to rotate in a vertical circle with constant angular velocity and with a period of 0.5 s.

(*vi*) Derive an expression for the linear velocity of an object moving in circular motion in terms of its angular velocity and the radius of the circle.

(*vii*) Calculate (*a*) the angular velocity, (*b*) the linear velocity of the object.

(*viii*) Calculate the minimum tension in the string.

(*ix*) Draw a labelled diagram of the forces acting on the object when the string has its minimum tension. (28)

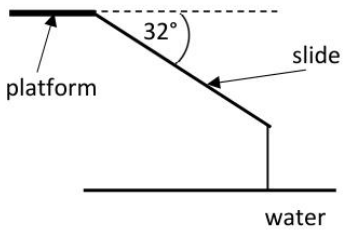
(*acceleration due to gravity = 9.8 m* s^{-2})

14. Answer any **two** of the following parts, (*a*), (*b*), (*c*), (*d*).

(*a*) Ireland's Fittest Family is a competition where families compete across a range of different fitness challenges. These challenges exemplify many physics principles in action.

(*i*) State the law of conservation of energy.

A man is competing in a race where participants are required to slide from a raised horizontal platform down a 2.4 m long slide. The slide is at an angle of 32° to the horizontal from the platform. The end of the slide is a vertical distance of 90 cm above the water.



(*ii*) Calculate the height of the platform above the surface of the water.

(*iii*) The man starts from rest. Calculate his velocity as he enters the water.
Assume that there is no friction on the slide.

(*iv*) Draw a force diagram for the man
(*a*) as he slides down the slide,
(*b*) when he is floating in the water. (28)

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

(*b*) Ra–224 is an unstable nucleus of radium.

(*i*) Ra–224 decays by releasing an alpha-particle. Write a nuclear equation for this decay.

(*ii*) A sample of Ra–224 decays to form Pb–208, an isotope of lead.

(*a*) How many alpha-particles are released?

(*b*) How many beta-particles are released? (13)

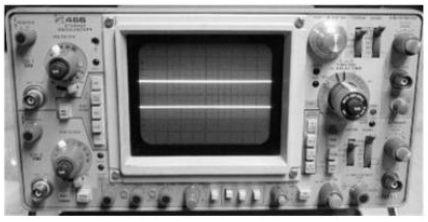
Ra–224 has a half-life of 3.6 days.

(*iii*) Explain what is meant by the term half-life.

(*iv*) Calculate the total number of alpha-particles emitted per second by a sample of Ra–224 containing 4.7×10^{14} atoms. (15)

(*c*) (*i*) What is meant by thermionic emission?

(*ii*) Draw a labelled diagram of a cathode ray tube. (14)



A high-speed electron that strikes the screen of an oscilloscope produces the green light that is seen.

(*iii*) Calculate the minimum voltage required across the tube to give an electron a velocity of 2.7×10^7 m s^{-1}.

(*iv*) How does the photoelectric effect differ from thermionic emission?

(14)

(*d*) A spectrometer can be used to measure the wavelength of light.

(*i*) Draw a labelled diagram of a spectrometer. (8)

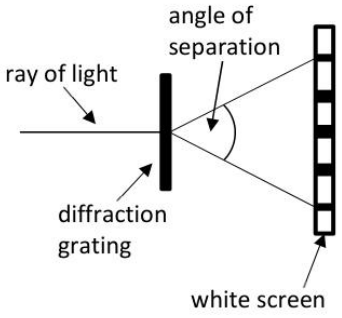
Green light of wavelength 530 nm is passed through a diffraction grating with

400 lines per mm.

(*ii*) Calculate the angle of separation between the second order images.

(*iii*) Identify a different colour of light that could be used to produce a greater angle of separation.

(*iv*) Explain how the number of lines per mm on a diffraction grating affects the angle of separation. (20)



SECTION B (280 MARKS)

Answer **five** questions from this section.

Each question carries 56 marks.

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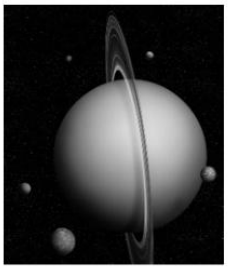
6. Answer any **eight** of the following parts, (*a*), (*b*), (*c*), etc.

(*a*) An airplane starts from rest on a runway and reaches a velocity of 290 km hour^{-1} in 33 s. Calculate the acceleration of the airplane in terms of *g*, the acceleration due to gravity.

(*b*) Explain the term solar constant.

(*c*) A converging lens of focal length 15 cm is placed in combination with a diverging lens of focal length 5 cm. Calculate the power of the combination.



(*d*) Uranus has a mass of 8.7×10^{25} kg and a radius of 25 400 km. Calculate the acceleration due to gravity on Uranus.

(*e*) Draw a diagram to show how a ray of light can be turned through 90° using a 45°–90°–45° prism.

(*f*) State one application of stress polarisation.

(*g*) What is meant by potential difference?

(*h*) Calculate the power output of a resistor of resistance 3.4 Ω when a potential difference of 55 V is maintained across it.

(*i*) The peak voltage of an a.c. supply is 311 V. Calculate its rms voltage.

(*j*) A proton experiences a force of 4.59×10^{-16} N when it moves with velocity *v* perpendicular to a magnetic field of flux density 18.5 mT. Calculate *v*.

(*k*) Explain what is meant by a chain reaction in nuclear fission.

(*l*) The equation to describe an emission line spectrum is $hf = E_2 - E_1$. Explain what each of the symbols in this equation stands for.

(8 × 7)

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