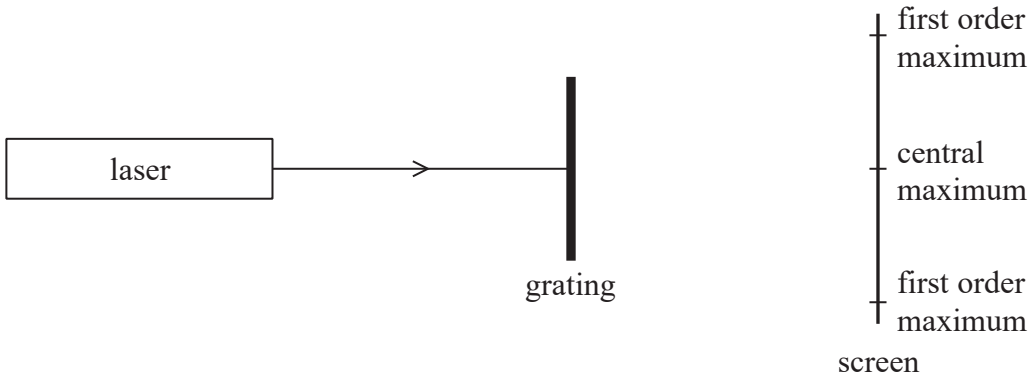
10 A beam of light from a laser is directed at a diffraction grating.

The diagram shows the positions of the central maximum and the first order maxima on a screen.



Which of the following would cause the first order maxima to be closer to the central maximum on the screen?

☒ **A** moving the laser closer to the grating

☒ **B** moving the screen further from the grating

☒ **C** using a grating with more lines per metre

☒ **D** using laser light with a higher frequency

(Total for Question 10 = 1 mark)

8 A line in the hydrogen spectrum of a star in the Milky Way galaxy is observed to have a wavelength of 656.3 nm. In a laboratory on Earth this line has a wavelength of 654.9 nm.

Which of the following expressions gives the magnitude of the velocity of the star relative to Earth?

☒ **A** $\frac{656.3}{654.9} \times 3 \times 10^8 \text{ m s}^{-1}$

☒ **B** $\frac{654.9}{(656.3 - 654.9)} \times 3 \times 10^8 \text{ m s}^{-1}$

☒ **C** $\frac{654.9}{656.3} \times 3 \times 10^8 \text{ m s}^{-1}$

☒ **D** $\frac{(656.3 - 654.9)}{654.9} \times 3 \times 10^8 \text{ m s}^{-1}$

(Total for Question 8 = 1 mark)

9 An object is placed 6.5 cm away from a lens of focal length 3.9 cm. An image is formed 9.8 cm from the lens.

Which of the following is the magnification?

☒ **A** 0.60

☒ **B** 0.66

☒ **C** 1.5

☒ **D** 1.7

(Total for Question 9 = 1 mark)

Answer ALL questions.

All multiple choice questions must be answered with a cross ☒ in the box for the correct answer from A to D. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Which of the following wave properties is **not** exhibited by sound waves?

☒ **A** diffraction

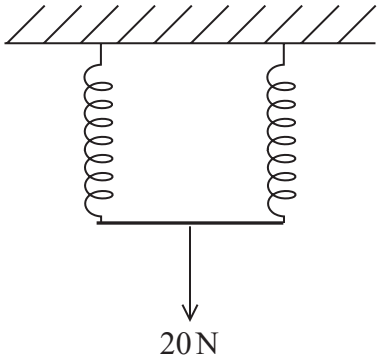
☒ **B** interference

☒ **C** polarisation

☒ **D** refraction

(Total for Question 1 = 1 mark)

2 Two identical springs are arranged side by side as shown.



When a force of 20 N is applied, an extension of 8 cm is obtained.

A force of 5 N is applied to one of the springs on its own.

Which of the following is the extension obtained?

☒ **A** 2 cm

☒ **B** 4 cm

☒ **C** 8 cm

☒ **D** 16 cm

(Total for Question 2 = 1 mark)

12 Our understanding of the atom has developed over time, from early models in which atoms were considered to be hard incompressible spheres, through to the nuclear model of the atom and the ladder model in which electrons exist in a discrete number of allowed energy states.

*(a) The model of atoms as hard incompressible spheres, moving rapidly and randomly, can be used to explain why gases exert a pressure.

Explain, using ideas of momentum, why the pressure exerted by a gas increases as the temperature of the gas increases.

(6)

(b) The nuclear model of the atom was established following a series of experiments in which alpha particles were directed at thin gold foil.

(i) An alpha particle approaching a gold nucleus, $^{197}_{79}Au$, head-on will be brought to rest and returned along its original path.

Calculate the minimum distance between the alpha particle and the nucleus for alpha particles of energy of 5.5 MeV.

(4)

Minimum distance = ...

(ii) It is observed that electrons, with energy of 5.5 keV, are diffracted as they pass through the thin gold foil.

Explain a conclusion about the electrons that can be made from this observation.

(3)

(c) In the energy ladder model of the atom, electrons exist in a discrete number of allowed energy states. The collision of electrons with gold atoms may lead to the production of high frequency electromagnetic radiation.

Explain how high frequency electromagnetic radiation may be produced when electrons collide with atoms in a metal.

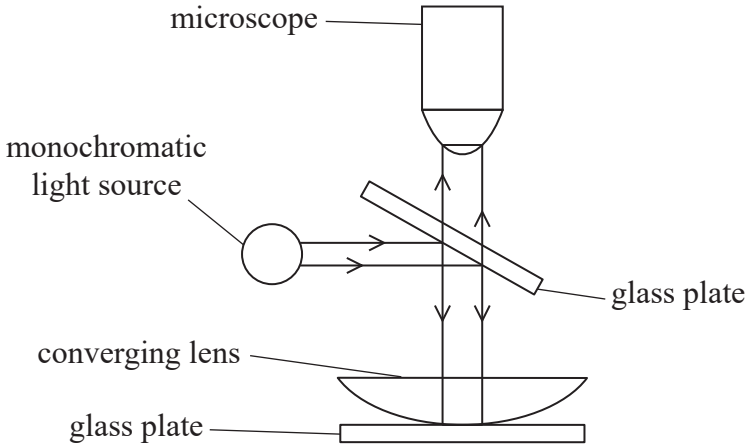
(4)

(Total for Question 12 = 17 marks)

13 A method to determine the wavelength of light using a converging lens was first proposed by Sir Isaac Newton.

A converging lens is placed on a plane glass plate. The lens is illuminated from above with a parallel beam of monochromatic light, as shown.

Some of the light is reflected from the upper surface of the lower glass plate and some from the lower surface of the lens. Interference between these two reflected waves produces circular fringes. The pattern is viewed through a microscope.



Side view of apparatus

Pattern seen through microscope

The diameter D of each circular fringe, numbered N from the centre, is measured using the microscope. The data obtained from such an experiment is shown.

N	D / mm		
1	5.13		
2	7.08		
3	8.71		
4	10.23		
5	11.48		

(a) The relationship between N and D is of the form $D = pN^q$ where p and q are constants.

Determine p and q for this data using a graphical method. Use the additional columns for your processed data.

(8)

p = ...

q = ...

(b) The table below shows the readings from which the diameter of the first dark circle was calculated.

Position of left-hand side of circle / mm	Position of right-hand side of circle / mm	Diameter / mm
54.79	49.66	5.13

(i) Use these readings to estimate the percentage uncertainty in the diameter due to the resolution of the instrument.

(2)

Percentage uncertainty = ...

(ii) State why the actual percentage uncertainty would have been greater than the value calculated in (b)(i).

(1)

(c) When considering the principles of this experiment, a student suggests that interference fringes would only be produced with monochromatic light. This is because interference requires coherent light waves.

Discuss the validity of the student's suggestion.

(4)

(Total for Question 13 = 15 marks)

TOTAL FOR PAPER = 120 MARKS

8 A converging lens can be used to produce a real image on a screen.

(a) A converging lens of focal length 15.0 cm is used to project an image of an illuminated object onto a screen. The object is a circle of diameter 4.0 mm and the image must be as large as possible on a screen of size 0.75 m by 1.25 m.

Calculate the distance between the lens and the screen for this image to be displayed.

(3)

Distance between lens and screen = ...

(b) A magazine article includes the statement:

> If the distance from the lens to the screen is doubled, the brightness of the image is halved.

Assess the validity of this statement.

(2)

(Total for Question 8 = 5 marks)

9 A student has been learning about the photoelectric effect.

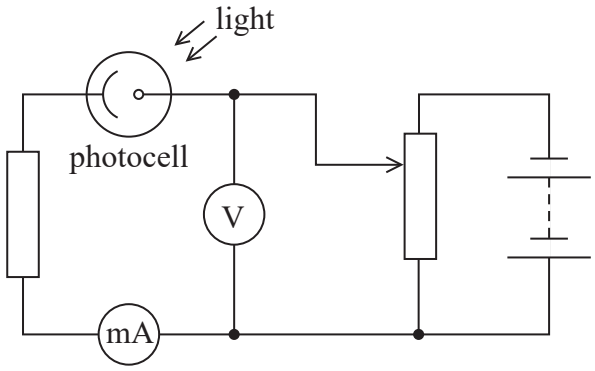
(a) The student was asked by his teacher to explain the photoelectric effect. He gave the following explanation:

Light above a certain threshold is able to free electrons from a metal, because the light gives energy to electrons in the metal.
Some of this energy is used to release the electrons from the metal and the rest becomes kinetic energy of the freed electron.

Discuss whether the student's answer fully explains the photoelectric effect.

(4)

(b) The student sets up a circuit to investigate the photoelectric effect.



The student illuminates the photocell with light of known frequency f. A current is produced in the circuit due to the emitted electrons. He adjusts the potential difference, using a potential divider, until the reading on the milliammeter is zero and records the corresponding reading V_s on the voltmeter. He repeats this procedure for other frequencies of light.

When the reading on the milliammeter is zero the maximum kinetic energy of the emitted electrons is given by eV_s.

Explain how the student can use his results to determine a value for the Planck constant h using a graphical method.

(5)

(c) This experiment demonstrates the particle nature of light.

Explain what is meant by the particle nature of light.

(2)

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(Total for Question 9 = 11 marks)