Year 12 Physics NAME________________________

Test: Light and Waves

Total marks: 62

Wave Behaviour of Light, Photoelectric Effect, Wave Behaviour of Particles

1. A certain radio station's transmitting antenna has a vertical orientation.

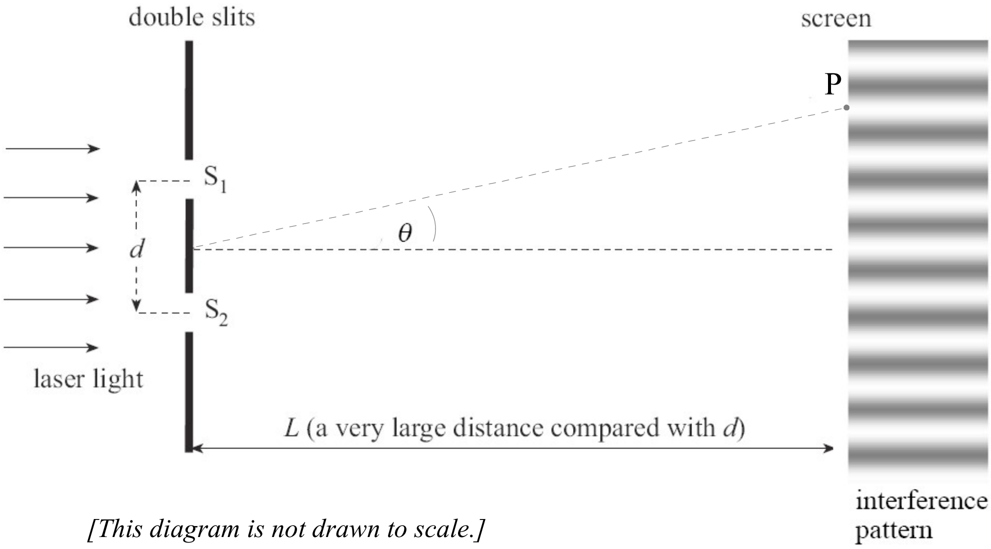
(a) State the orientation a receiving antenna should have to receive these waves.

____ (1)

(b) State the plane of polarisation of the electromagnetic waves produced by the antenna.

____ (1)

2. A two-slit interference apparatus, with slit separation d, is shown in the diagram below.
A beam of visible laser light of wavelength λ illuminates the slits, S_1 and S_2.
An interference pattern is observed on the screen, a distance L from the two slits.



[This diagram is not drawn to scale.]

(a) The third maximum of the interference pattern is seen at point P.

(i) Draw appropriate construction lines on the diagram above, and use them to show that the path difference from the slits to point P is $d \sin \theta$.

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____(4)

(ii) State the value of $d \sin \theta$ in terms of λ at point P.

____(1)

(iii) Describe, in terms of the principle of superposition, why a maximum of the interference pattern is seen at point P.

____(2)

(iv) If the angle θ is 5.5° and the distance L is 3.0 m, show that the distance Δy between adjacent maxima is approximately 9.6 cm.

____(2)

(v) If the distance d between the slits is 2.0×10^{-5} m, determine the wavelength λ of the laser light.

____(2)

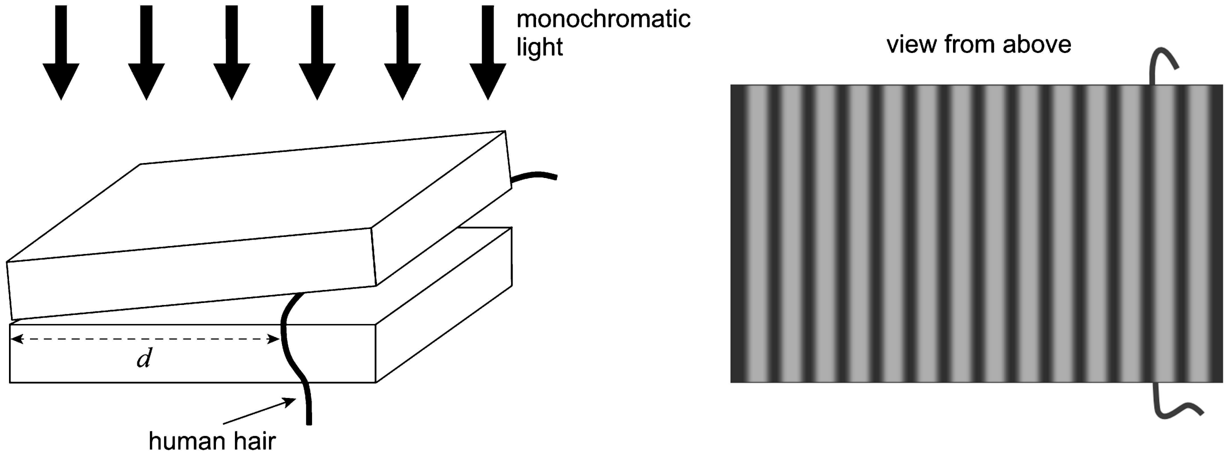
(b) State the change that would need to be made to this experiment if the light source used was not coherent.

____(1)

(c) Explain why incandescent light is neither coherent nor monochromatic.

____(3)

3. One method of determining the thickness of a human hair is to use it to create a wedge of air between two flat glass slabs. When the wedge of air is illuminated from above by monochromatic light, a series of bright and dark fringes can be seen. These fringes result from the interference between rays of light that travel different distances through the wedge of air.



[*These diagrams are not drawn to scale.*]

The hair is placed at a distance d from the point where the two glass slabs touch, and five students count the number of bright fringes per centimetre. The process is repeated a number of times, with the value of d varied each time.
The results of the data collection are shown in the table below:

d (cm)	Number of Bright Fringes per Centimetre				
	Student 1	Student 2	Student 3	Student 4	Student 5
4.0	100	99	102	103	106
5.0	82	82	84	83	79
6.0	67	70	67	71	65
7.0	60	62	58	58	57
8.0	50	51	51	49	53

(a) State one benefit of using data collected by five students.

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____(1)

The number of bright fringes is averaged, as shown in the table below:

d (cm)	Average Number of Bright Fringes per Centimetre	W (m)
4.0	102	
5.0	82	
6.0	68	
7.0	59	
8.0	51	

W is the average distance between bright fringes, measured in metres. It can be calculated using the following equation:

$$W = \frac{1}{\text{number of bright fringes per metre}}$$

(b) Complete the table above by calculating each value of *W*. (2)

(c)

(i) State which one of *W* and *d* should be plotted on the horizontal axis of a graph of the data in the table above.
Give a reason for your answer.

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____ (2)

(ii) On graph paper, plot a graph of the data. Include a line of best fit. (6)

(d) Determine the gradient of your line of best fit.

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____ (2)

(e) *W* and *d* are linked by the equation:

$$W = \frac{\lambda}{2t} d$$

where t is the thickness of the hair used in the experiment.
The monochromatic light used by the students has a wavelength of 589 nm.
Using the gradient of your line of best fit from part (d), determine the thickness of the hair.

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____ (3)

4.

(a) A transmission diffraction grating has 600 lines per millimetre. Calculate the maximum possible orders that could be observed if the incident light had a wavelength $\lambda = 4.9 \times 10^{-7}$ m.

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____ (3)

(b) Describe the interference pattern produced by shining white light through a diffraction grating.

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____ (3)

5. A photoelectric cell is connected to potential difference and a sensitive ammeter. The potential difference is adjusted to give an ammeter reading of zero.

The work function of the metal in the photoelectric cell is 3.6×10^{-19} J.
Photons of energy $E = 8.62\times10^{-19}$ J are directed onto the photoelectric cell.

(a) Calculate the frequency of the photons.

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(b) Determine the stopping voltage.

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____ (2)

(c) State the effect, if any, that increasing the intensity of the incident light would have on the stopping voltage. Explain your answer.

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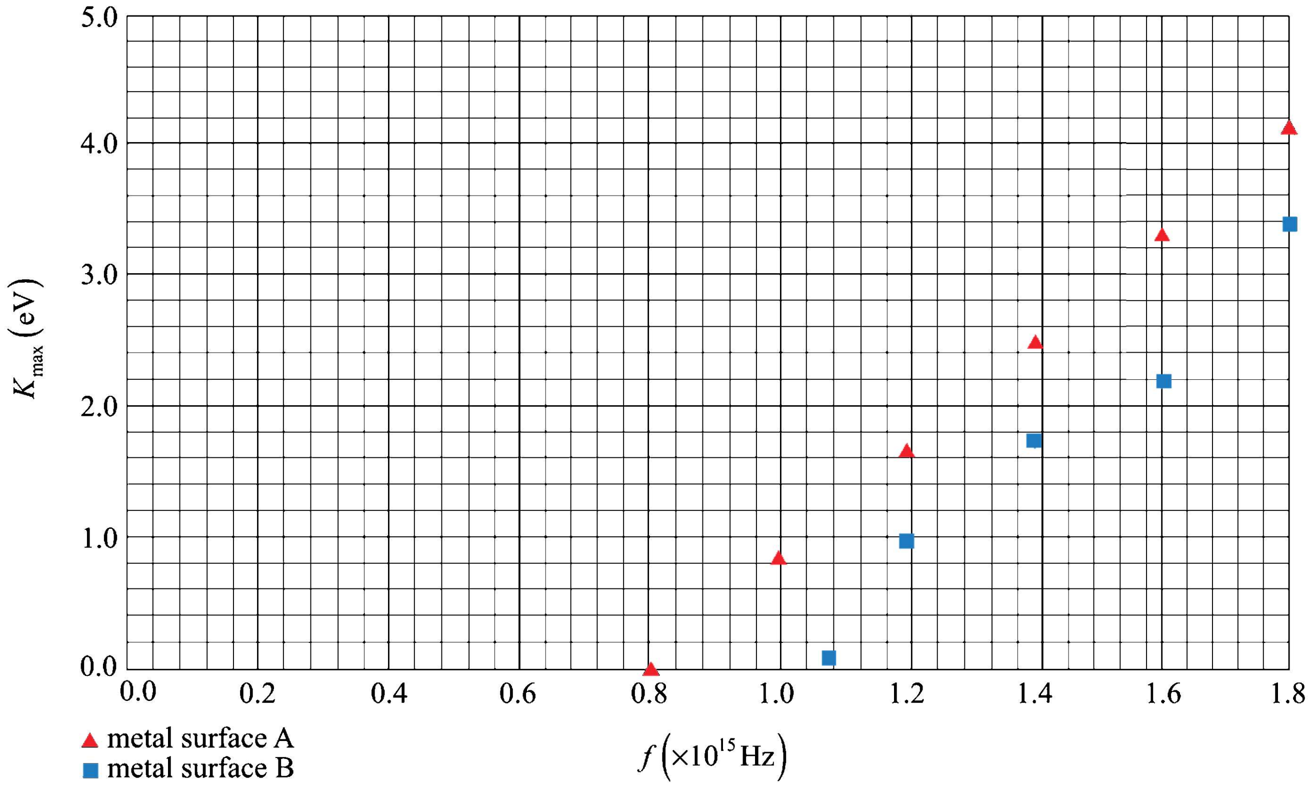
____ (3)

6. An experiment was performed in which light of different frequencies f was incident on two different metal surfaces, A and B. Electrons were emitted from the metal surfaces, and their maximum kinetic energies K_{max} were measured. The graph below shows the results of the experiment:



(a) On the grid above, draw lines of best fit for the points plotted. (2)

(b) State which metal surface has the more precise set of measurements. Give a reason for your answer.

Metal surface: ______

Reason: ____

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____ (2)

(c) If light of wavelength 435 nm was used to illuminate metal surface A, determine whether or not electrons would be emitted from the metal surface.

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____ (3)

7. An electron microscope accelerates electrons through a potential difference of 5.00 kV.

(a) Show that the speed of the electrons accelerated from rest through this potential difference is 4.19×10^7 ms^{-1}.

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____ (3)

(b) Hence calculate the de Broglie wavelength of the electrons.

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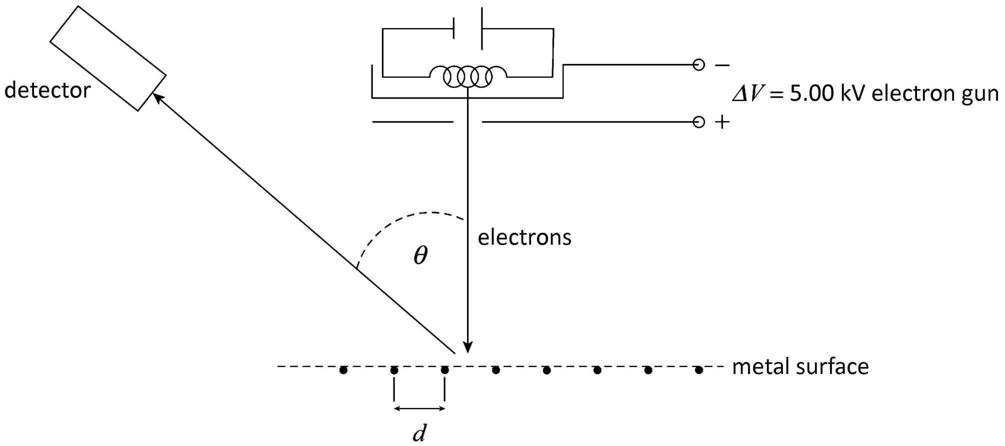
____ (2)

(c) In an experiment similar to that carried out by Davisson and Germer, these electrons are directed normally towards a metal surface in a vacuum, as shown in the diagram below.
The spacing d between atoms in the surface is 0.23 nm. The number of electrons that reach the detector at various angles q is recorded.



Using the wavelength calculated above, determine the angle of the first-order maxima.

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