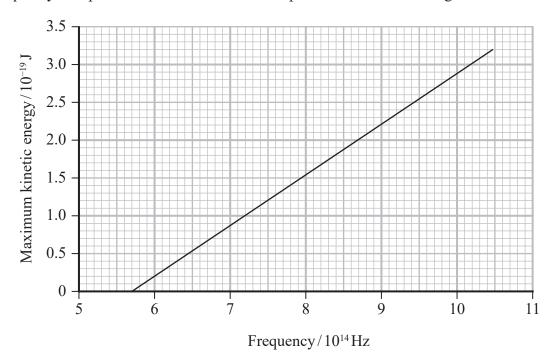
17 In 1905 Einstein published his equation for the photoelectric effect.	
In 1916 Millikan demonstrated that the maximum kinetic energy of photoelectrons is consistent with Einstein's equation.	
*(a) Discuss the extent to which our current understanding of observations of the photoelectric effect supports the idea that light behaves as photons rather than as waves.	
	(6)

(b) Millikan used his data to obtain a value of the Planck constant.

The following graph of maximum kinetic energy of photoelectrons against frequency was produced from his data for the photoelectric effect using lithium.



Millikan suggested that the uncertainty from his results for lithium was as little as 1%.

Determine whether the value of the Planck constant obtained from this graph is within 1% of the value stated on the data sheet for this examination paper.


(3)

(c) Millikan's experiments involved using different frequencies of light. These were obtained using a mercury vapour lamp which produced an emission spectrum with a specific number of known frequencies.

The diagram shows some energy levels for a mercury atom.

— 0 eV

— −1.56 eV

— −1.57 eV

— −2.48 eV

— −3.71 eV

— −4.95 eV

 $-5.52 \,\mathrm{eV}$ 

 $---5.74\,\mathrm{eV}$ 

Not to scale

— −10.38 eV

Determine which transition from the  $-3.71\,\mathrm{eV}$  energy level would produce light of wavelength  $6.1\times10^{-7}\,\mathrm{m}$ .

(4)


Transition from -3.71 eV to

<i>(</i> <b>1</b> )		
(d)	Millikan used a device known as a monochromator to ensure that a single wavelength of light was used to illuminate the surface of the lithium.  A monochromator separates wavelengths using a diffraction grating.	
	Calculate the angle at which a diffraction grating would produce the most intense line at a single wavelength of $6.1\times10^{-7}\text{m}$ .	
	number of lines per mm for grating = $600  \text{mm}^{-1}$	
		(3)
	Angle =	
	(Total for Question 17 = 16 m	narks)

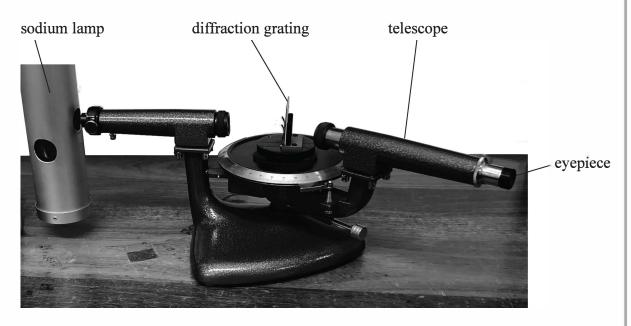
6	When light is incident on the surface of a metal, electrons may be emitted by the
	photoelectric effect. Observations of the photoelectric effect helped to establish that light
	can exhibit particle behaviour.

Which of the following observations of the photoelectric effect could also be explained by light behaving as a wave?

- ☐ A Emission of photoelectrons occurs immediately the surface is illuminated.
- ☐ **B** Photoelectrons are only emitted when the frequency of the light is more than a certain minimum value.
- ☐ **C** The maximum kinetic energy of the photoelectrons is independent of the intensity of the incident light.
- □ **D** When the intensity of the incident light increases, photoelectrons are emitted at a greater rate.

(Total for Question 6 = 1 mark)

17 The photograph shows a school spectrometer.



The spectrometer allows parallel rays of light to be passed through a diffraction grating and the resulting angles of diffraction to be measured.

(a) In the telescope, light from the grating is focused to make a real image 16.7 mm in front of the eyepiece lens. The eyepiece lens then uses this real image as an object to produce a magnified virtual image for the observer.

Calculate the magnification produced by the eyepiece lens.

focal length of eyepiece lens =  $17.9 \,\mathrm{mm}$ 

	FELFORELS
	-0.000
Magnification =	

**(3)** 

(b)	The spectrometer and diffraction grating are used to analyse the light from a sodium
	lamp. In the sodium lamp, sodium is heated until it becomes a vapour and an electric
	current is passed through it. The vapour then emits light.

After the light passes through the diffraction grating a line spectrum is observed.

			_	_	_		_	_
ı	(i)	Evnlain	xxhx	only	cortain	wavelengths	are ohe	arrad
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-	^
Z	U

(ii	i)	Diffraction	gratings	with	the	foll	owing	spacings	are	availa	ble:
\-·	-/		0-1111-0-				~	~ P ********			

d/10 <sup>-6</sup> m	1.0	1.7	2.0	3.3

Explain which would be the best spacing to use to measure the diffraction angle for the third order maximum for yellow light of wavelength 589 nm.

(3)

$\prod$		Ш					Ш	
Ш								
						2		

**(4)** 

(c) The diagram shows some of the energy levels in a sodium atom.

-- 0.00 eV

-1.02 eV

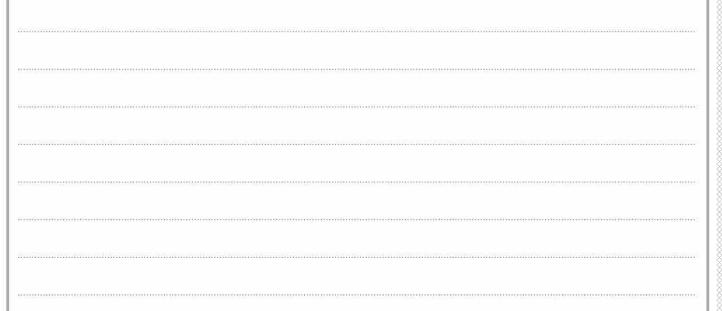
-1.95 eV

— −3.04 eV

— −5.14 eV

Add an arrow to the diagram to show the transition involved in the emission of yellow light of wavelength 589 nm.

Show your working below.



(Total for Question 17 = 16 marks)