A-Level Physics

Diffraction

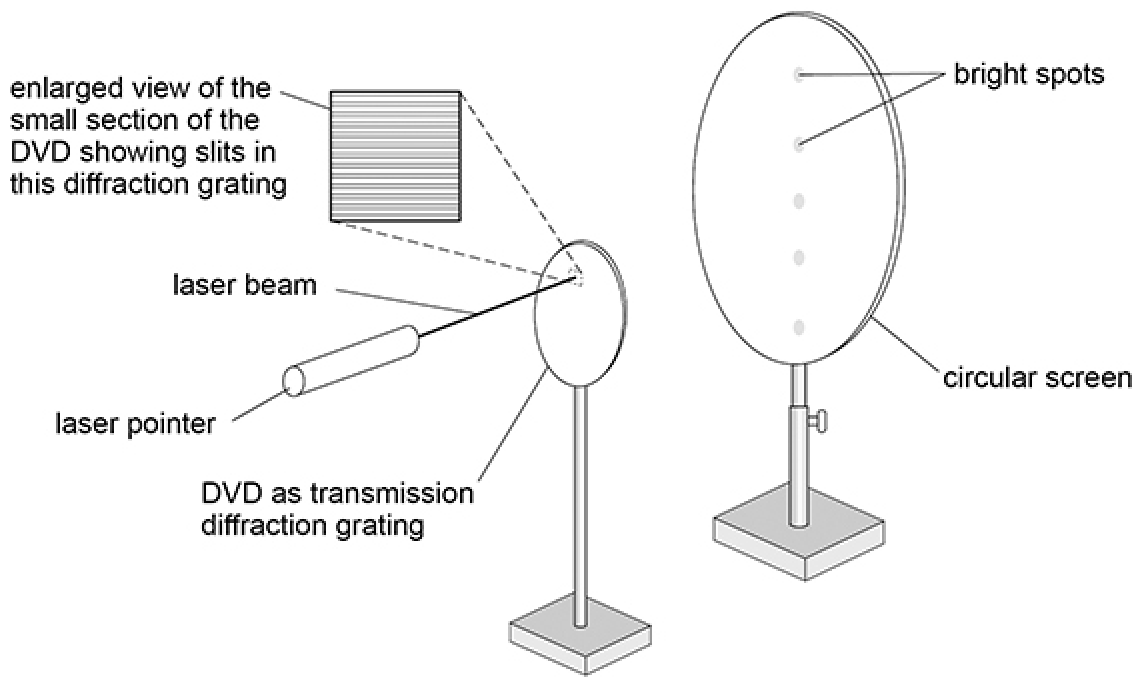
Question Paper

Time available: 61 minutes
Marks available: 48 marks

1. A student removes the reflective layer from a DVD. She uses the DVD as a transmission diffraction grating.

Figure 1 shows light from a laser pointer incident normally on a small section of this diffraction grating. The grooves on this section act as adjacent slits of the transmission diffraction grating. A vertical pattern of bright spots (maxima) is observed on a circular screen behind the disc.

Figure 1



(a) Light of wavelength λ travels from each illuminated slit, producing maxima on the screen.

State the path difference between light from adjacent slits when this light produces a first-order maximum on the screen.

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(1)

(b) Explain how light from the diffraction grating forms a maximum on the screen.

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(3)

The student has three discs: a Blu-ray disc, a DVD and a CD. She removes the reflective coating from the discs so that they act as transmission diffraction gratings. These diffraction gratings have different slit spacings.

The student also has two laser pointers **A** and **B** that emit different colours of visible light.

Table 1 and **Table 2** show information about the discs and the laser pointers.

Table 1

Disc	**Slit spacing / μm**
Blu-ray disc	0.32
DVD	0.74
CD	1.60

Table 2

Laser pointer	**Wavelength of light emitted / 10^{-7} m**
A	4.45
B	6.36

(c) Deduce the combination of disc and laser pointer that will produce the **greatest** possible number of interference maxima.

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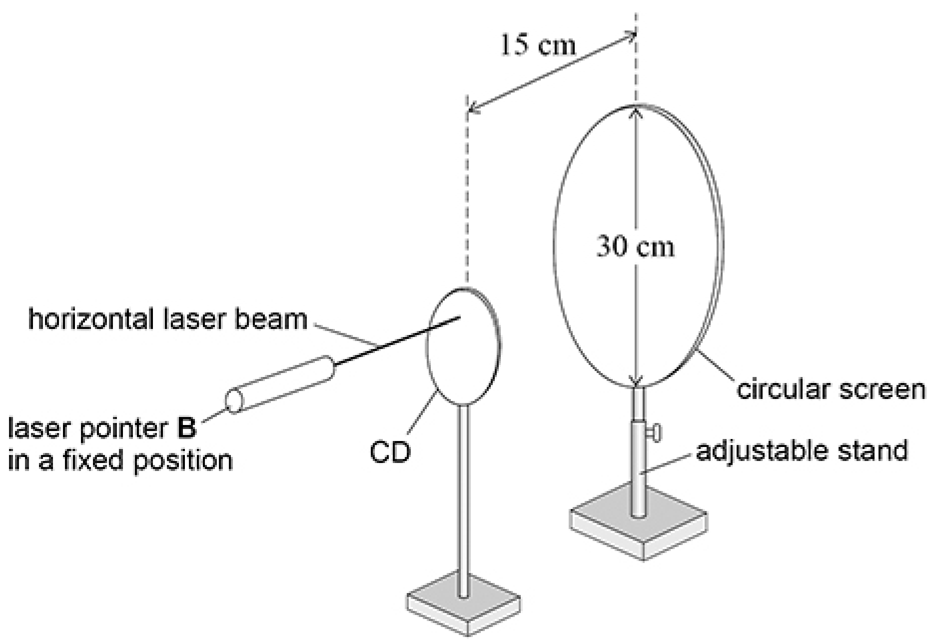
(2)

(d) The student uses the CD and laser pointer **B** as shown in **Figure 2**. A diffraction pattern is produced on the screen. Laser pointer **B** and the CD are in fixed positions. The laser beam is horizontal and incident normally on the CD. The height of the screen can be adjusted.

Figure 2



The screen has a diameter of 30 cm and is positioned behind the CD at a fixed horizontal distance of 15 cm.
The student plans to adjust the height of the screen until she observes the greatest number of spots.

The student predicts that, using this arrangement, the greatest number of spots on the screen will be 3.

Determine whether the student's prediction is correct.

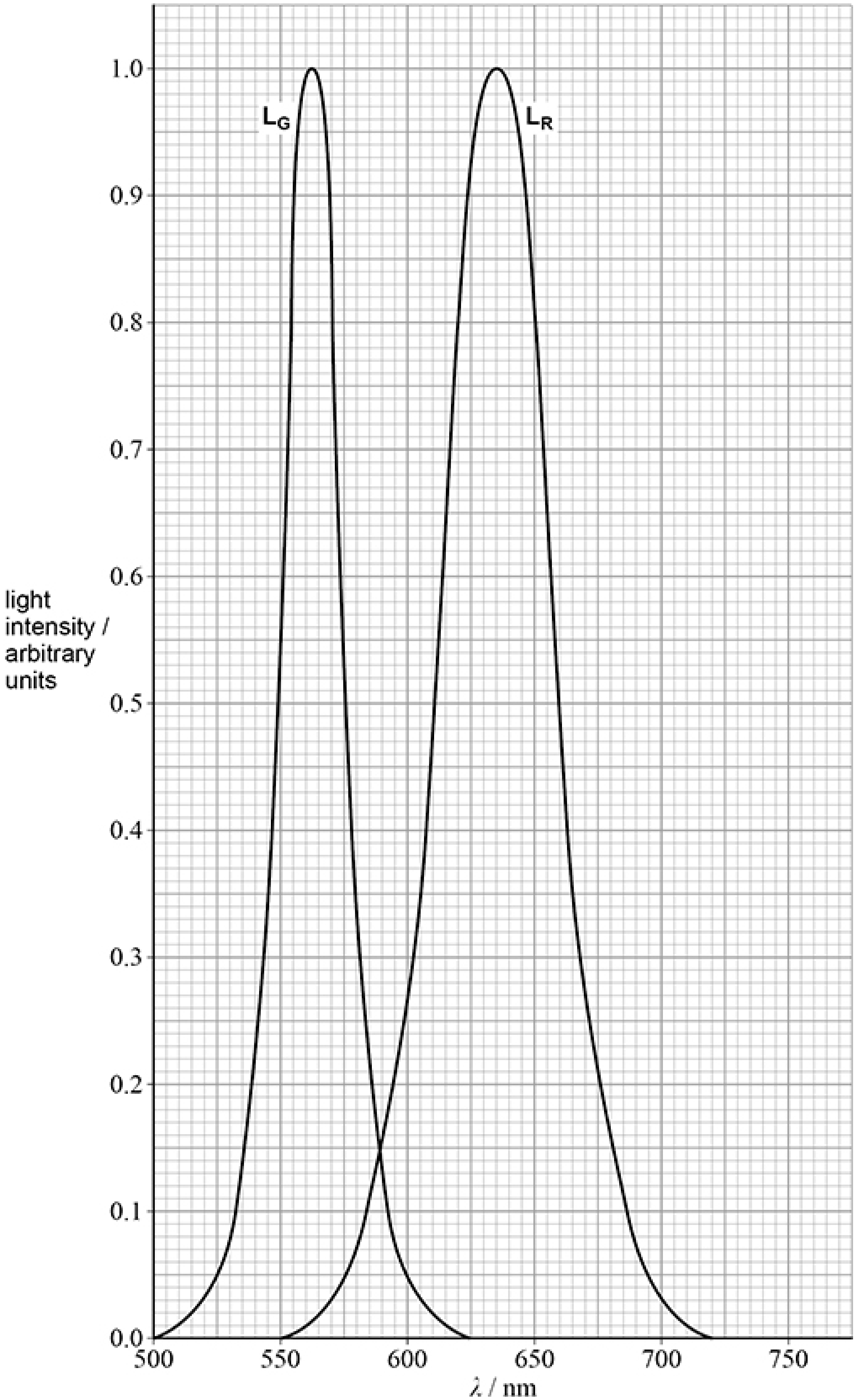
(3)
(Total 9 marks)

2. A light-emitting diode (LED) emits light over a narrow range of wavelengths. These wavelengths are distributed about a peak wavelength λ_p.

Two LEDs $\mathbf{L_G}$ and $\mathbf{L_R}$ are adjusted to give the same maximum light intensity. $\mathbf{L_G}$ emits green light and $\mathbf{L_R}$ emits red light.

Figure 1 shows how the light output of the LEDs varies with the wavelength λ.

Figure 1



1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
light intensity / arbitrary units
L_G
L_R
500
550
600
650
700
750
λ / nm

(a) Light from $\mathbf{L_R}$ is incident normally on a plane diffraction grating.

The fifth-order maximum for light of wavelength λ_p occurs at a diffraction angle of 76.3°.

Determine N, the number of lines per metre on the grating.

N = ________________ m^{-1}

(3)

(b) Suggest **one** possible disadvantage of using the fifth-order maximum to determine N.

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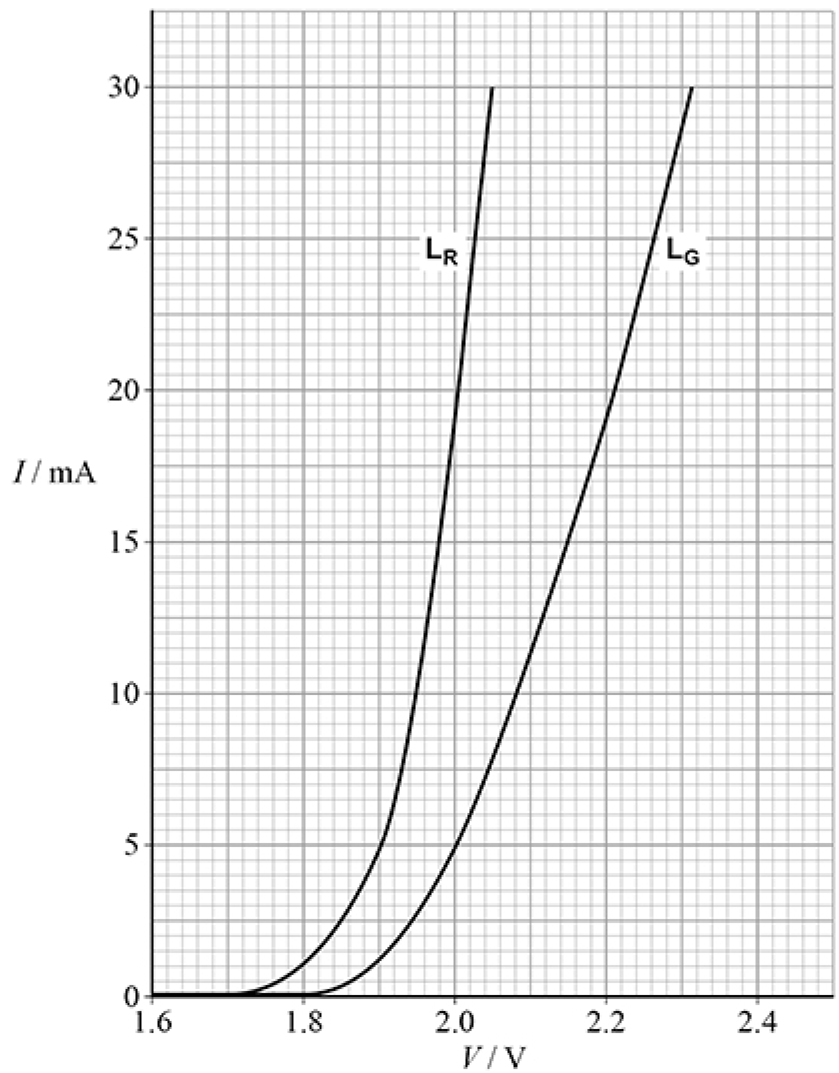
(1)

(c) **Figure 2** shows part of the current−voltage characteristics for $\mathbf{L_R}$ and $\mathbf{L_G}$.

Figure 2



When the linear part of the characteristic is extrapolated, the point at which it meets the horizontal axis gives the activation voltage V_A for the LED.
V_A for $\mathbf{L_G}$ is 2.00 V.

Determine, using **Figure 2**, V_A for $\mathbf{L_R}$.

V_A for $\mathbf{L_R}$ = _______________ V

(2)

(d) It can be shown that:

$$V_A = \frac{hc}{e\lambda_p}$$

where h = the Planck constant.

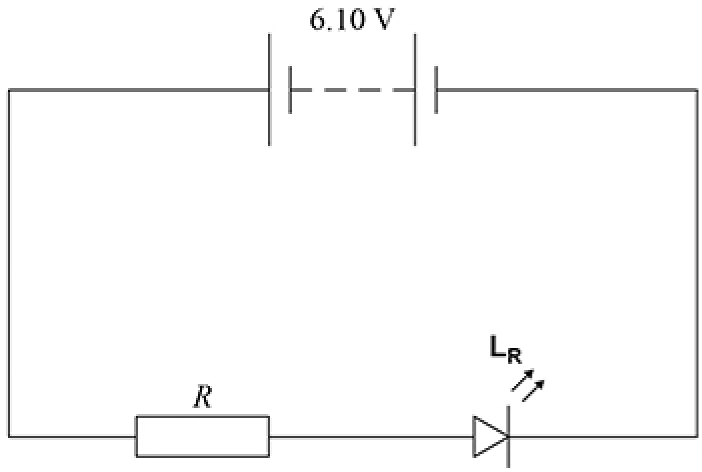
Deduce a value for the Planck constant based on the data given about the LEDs.

h = _______________ J s

(2)

(e) **Figure 3** shows a circuit with $\mathbf{L_R}$ connected to a resistor of resistance R.

Figure 3



The power supply has emf 6.10 V and negligible internal resistance.
The current in $\mathbf{L_R}$ must not exceed 21.0 mA.

Deduce the minimum value of R.

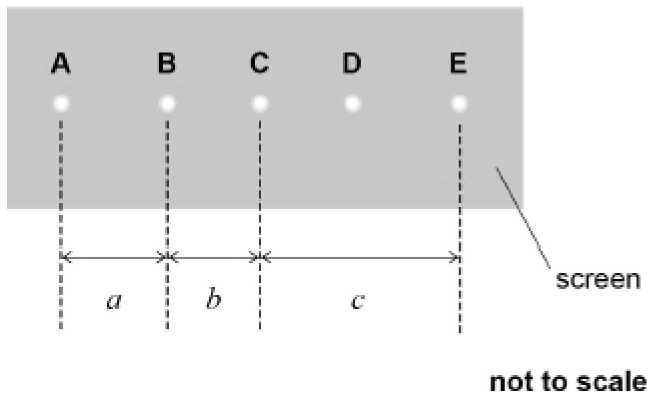
minimum value of R = ______________ Ω

(2)

(Total 10 marks)

3. This question is about the measurement of the wavelength of laser light.
The light is shone onto a diffraction grating at normal incidence.
The light transmitted by the diffraction grating produces five spots on a screen. These spots are labelled **A** to **E** in **Figure 1**.

Figure 1



A student uses a metre ruler with 1 mm divisions to take readings. He uses these readings to obtain measurements a, b and c, the distances between centres of the spots as shown in **Figure 1**.
Table 1 shows his measurements and his estimated uncertainties.

Table 1

Measurement	Distance / mm	Uncertainty / mm
a	289	2
b	255	2
c	544	2

(a) Explain why the student's estimated uncertainty in measurement a is greater than the smallest division on the metre ruler.
You should refer to the readings taken by the student in obtaining this measurement.

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(2)

(b) The distance between the centres of spots **A** and **C** and the distance between the centres of spots **C** and **E** are equal.
That is:

$$a + b = c$$

Calculate the percentage uncertainty in the sum of a and b.

percentage uncertainty = ____________________

(2)

(c) Discuss why the experimental measurements lead to a different percentage uncertainty in c compared to that in $a + b$.

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(2)

(d) Eye protection should be used to prevent eye damage when using a laser.

Describe **one** other safety measure to minimise the risk of eye damage when using a laser in the laboratory.

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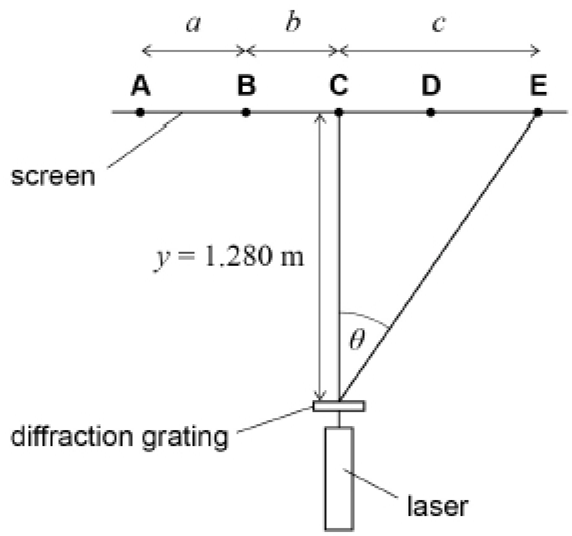
(1)

(e) **Figure 2** shows the experimental arrangement with y, the perpendicular distance between the diffraction grating and the screen, equal to 1.280 m.
Table 2 shows some of the data from **Table 1**.

Table 2

Measurement	Distance / mm
a	289
b	255
c	544

Figure 2



Calculate the angle θ shown on **Figure 2**.

θ = ____________________ degrees

(1)

(f) Spot **E** is the second-order maximum.
The diffraction grating has 3.00×10^5 lines per metre.

Calculate the wavelength of the laser light.

wavelength = ____________________ m

(1)

(g) The student plans to repeat the experiment using the same diffraction grating and laser.

State and explain **one** way the student can change the experimental arrangement to reduce the percentage uncertainty in the measurement of the wavelength.

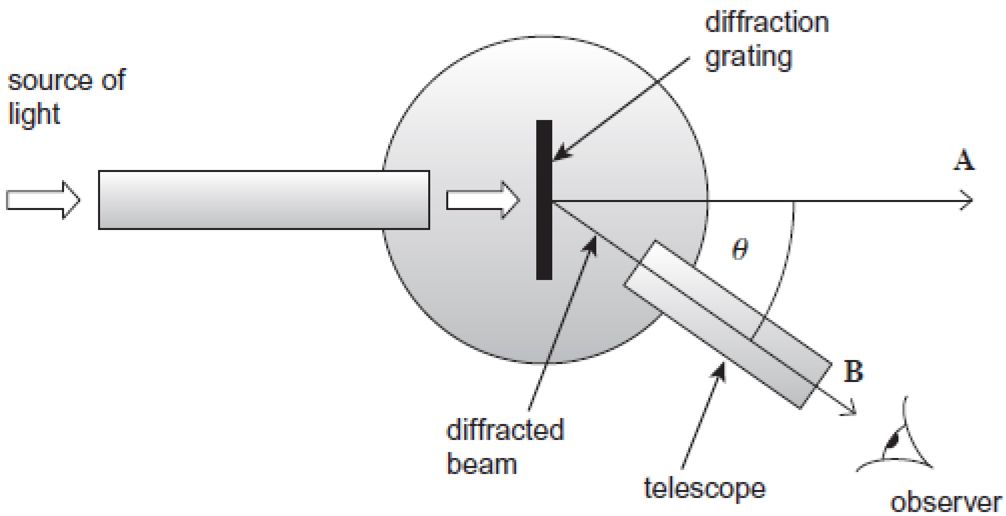
Assume the percentage uncertainty in sin θ is the sum of the percentage uncertainties in y and c.

(2)

(Total 12 marks)

4. The figure below shows a spectrometer that uses a diffraction grating to split a beam of light into its constituent wavelengths and enables the angles of the diffracted beams to be measured.

(a) Give **one** possible application of the spectrometer and diffraction grating used in this way.



(1)

(b) (i) When the spectrometer telescope is rotated from an initial angle of zero degrees, a spectrum is not observed until the angle of diffraction θ is about 50°. State the order of this spectrum.

(1)

(ii) White light is directed into the spectrometer. Light emerges at **A** and **B**. State **one** difference between the light emerging at **B** compared to that emerging at **A**.

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(1)

(c) The angle of diffraction θ at the centre of the observed beam **B** in the image above is 51.0° and the grating has 1480 lines per mm.

Calculate the wavelength of the light observed at the centre of beam **B**.

wavelength ____________________ m

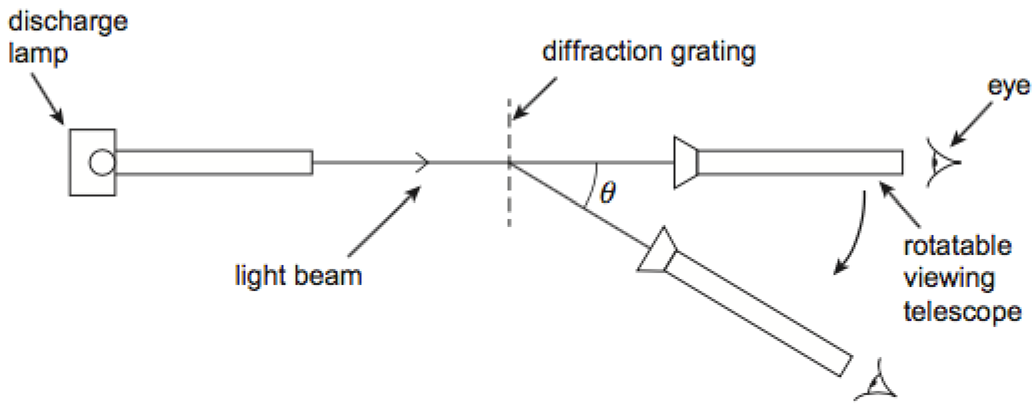
(3)

(d) Determine by calculation whether any more orders could be observed at the wavelength calculated in part (c).

(2)

(Total 8 marks)

5. A discharge lamp emits light of four colours: red, green, blue and violet. The diagram shows light from the lamp incident normally on a diffraction grating with slit separations of 1.8×10^{-6} m. The light is viewed through a telescope which can be rotated as shown.



As the telescope is rotated from the straight-through position, each of the four colours is observed as a bright line at its corresponding first-order diffraction angle.

(a) Which colour would be observed first as the telescope is rotated from the straight-through position?

Place a tick (✓) in the right-hand column to show the correct answer.

	✓ if correct
red	
green	
blue	
violet	

(1)

(b) Explain how a bright line is formed by the diffraction grating at the first-order diffraction angle.

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(3)

(c) (i) The wavelength of the green light is 5.3×10^{-7} m.

Calculate the first-order diffraction angle for this colour.

angle = ____________________ degree

(2)

(ii) As the telescope is rotated further, higher-order diffraction maxima are observed. Calculate the highest order observed for the green light.

highest order = ____________________

(3)

(Total 9 marks)