



A-Level Physics

Analogue and Digital Signals

Question Paper

Time available: 48 minutes

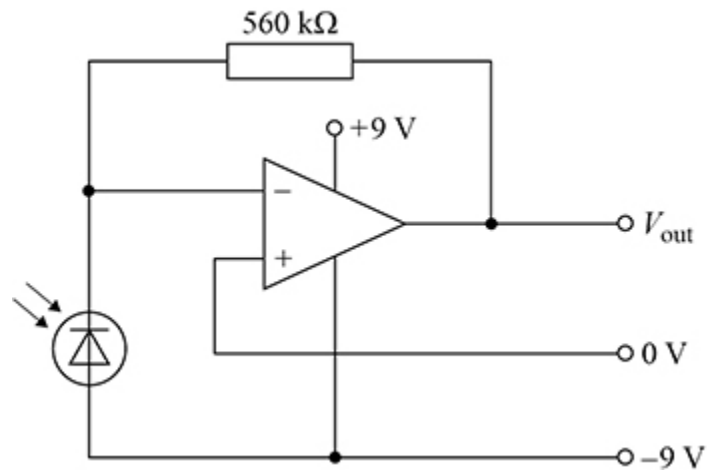
Marks available: 35 marks

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1.

Figure 1 shows the circuit for an infrared detector using a photodiode and an operational amplifier. In this application the operational amplifier uses a feedback resistor to give a voltage signal when the current in the photodiode changes.

Figure 1



(a) State the mode in which the photodiode is being used in **Figure 1**.

(1)

- (b) In the circuit shown in **Figure 1**, there is a current in the photodiode even when there is no light incident on it. This current is called the dark current.

In an optical communication system, the dark current needs to be very small in comparison to the photodiode current.

Explain why.

(1)

The responsivity R_λ of a silicon photodiode is a measure of its sensitivity to light at a given wavelength λ .

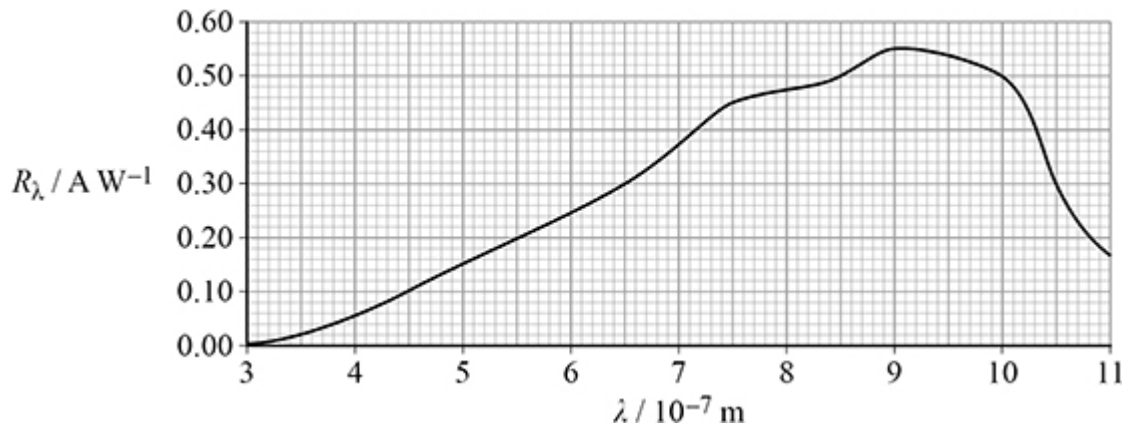
R_λ is defined as:

$$R_\lambda = \frac{I_p}{P}$$

where I_p is the current in the photodiode and P is the incident light power at the given wavelength.

Figure 2 shows the spectral response graph for this photodiode.

Figure 2



- (c) Monochromatic radiation of wavelength 850 nm and power 4.0 μW is incident on the photodiode in **Figure 1**.

Calculate the output voltage of the detector circuit.

output voltage = _____ V

(3)

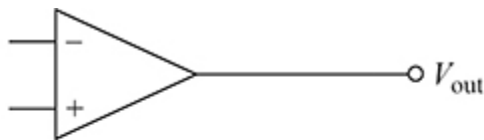
- (d) The output from the detector circuit in **Figure 1** needs to be amplified by a factor of +4
Complete **Figure 3** to show the amplifier circuit required.

In your completed circuit you should:

- label the input point as V_{in}
- label your Figure with the values of resistance for any resistors used in your circuit.
Any resistance values must lie within the range 1 k Ω to 100 k Ω .

Do **not** show the power supplies to the operational amplifier.

Figure 3



(3)

(Total 8 marks)

2.

Pulse code modulation (PCM) is used to encode live music as an uncompressed digital audio file.

Sampling of the analogue signal is carried out at 44.1 kHz.

A 16-bit system is used to encode each of the two channels that make up the stereo signal.

(a) Explain why the sampling frequency used is suitable for this task.

(2)

(b) Calculate the number of quantisation levels available on a 16-bit encoding system.

number of quantisation levels = _____

(1)

(c) A recorded piece of stereo music lasts for 3.5 minutes.

Calculate the size, in megabytes, of the digital file needed to store this recording.

file size = _____ megabytes

(2)

- (d) The music file is used by a call centre to play as background music while a phone call is on hold. However, the telephone network is designed to use a bandwidth of 0.3 kHz – 3.4 kHz.

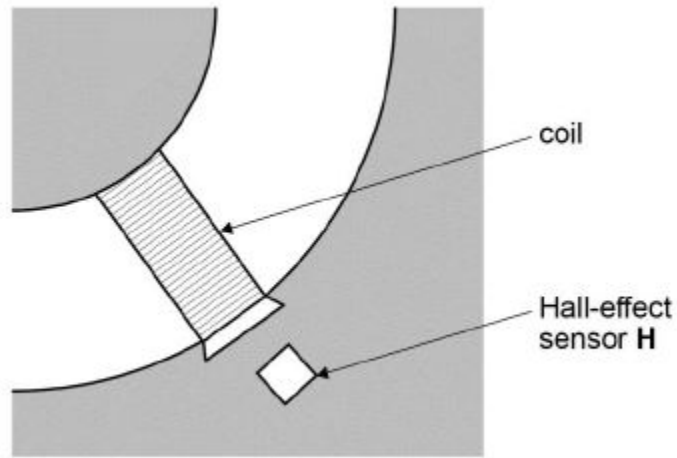
Compare the quality of the music heard by the telephone caller with that of the original file heard when played directly from a compact disc.

(2)

(Total 7 marks)

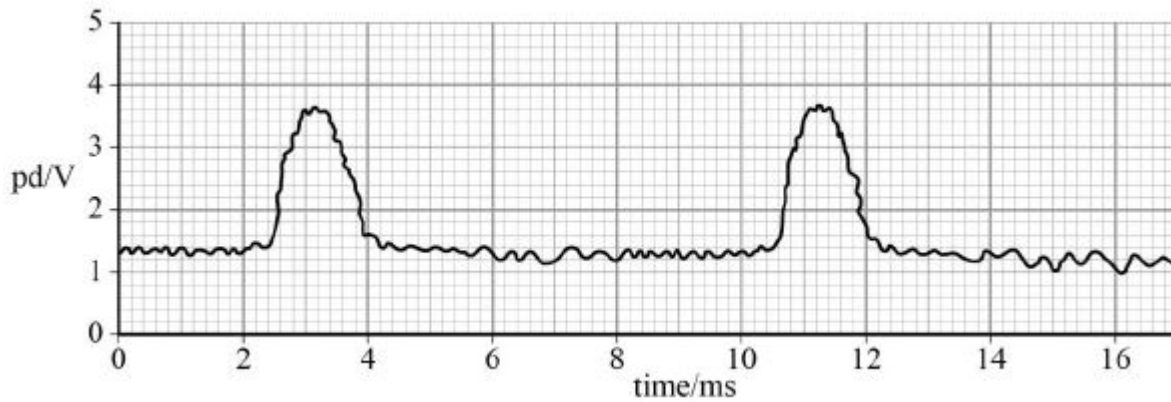
4.

The diagram shows part of the motor from a computer disk drive.



On each rotation a small magnet passes a Hall-effect sensor **H** which detects the change in magnetic field and produces an output potential difference (pd) that varies with time as shown in **Figure 1**.

Figure 1



(a) Determine the speed of the motor in revolutions per second.

speed of motor = _____ rev s⁻¹

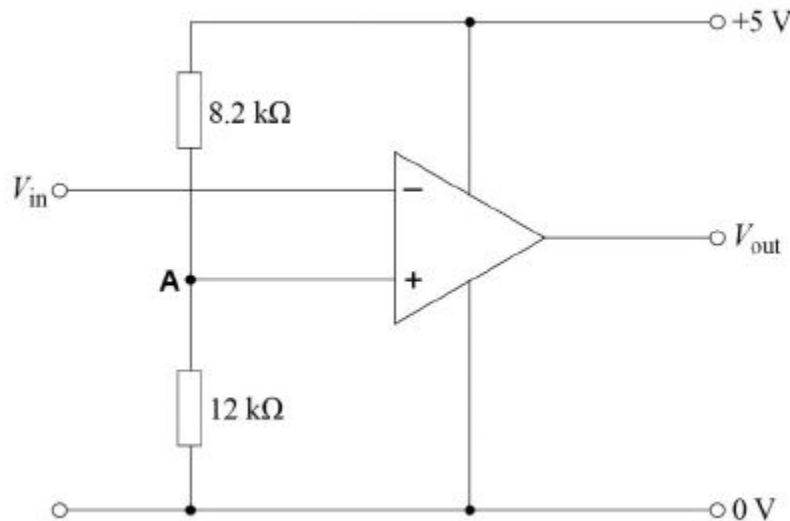
(2)

- (b) Explain why the output from the magnetic field sensor is unsuitable to be applied directly to the logic circuit of the motor controller.

(1)

- (c) The signal from the magnetic field sensor is applied to the circuit shown in **Figure 2**.

Figure 2



Show that the potential of point **A** is about +3 V.

(1)

- (d) Draw on **Figure 1** the waveform showing the variation with time of the output voltage V_{out} of the circuit shown in **Figure 2**.

(2)

5.

The audio signals on an audio CD are digitally encoded. Part of the audio CD specification describes the encoding as:

'PCM with 16-bit values sampled at 44.1 kHz'.

- (a) Explain why 44.1 kHz is a suitable sampling frequency for high quality audio recording.

(3)

(b) Calculate the number of different voltage levels which can be detected in each sample.

(1)

(c) The **quantisation error** is the voltage step difference between each level.
The peak-to-peak signal voltage is 5 V.

Calculate the quantisation error for an audio CD.

(2)

(d) A call centre uses an audio CD to play music to callers while they are waiting for their calls to be answered. The telephone system operates in the frequency range 300 Hz to 3 kHz.

Describe **two** different effects this will have on the quality of the music the callers hear.

(2)

(Total 8 marks)