Checkpoints Chapter 9 PHOTONICS

Question 330

Using the voltage divider formula,

$V_A = 6 \times \frac{1.1}{1.1+6.9}$

= **0.825V (ANS)**

Question 331

The maximum voltage is

10V (ANS)

From the graph.

Question 332

The maximum current is

10 μA (ANS)

These are the intercepts of the graph.

Question 333

$P = VI = 6 \times 7$

= **42 μW (ANS)**

Question 334

Power is given by the product of VI, in this case as the voltage increase the current decreases, so the maximum value for voltage gives the minimum value for the current. The maximum occurs around the middle of the graph.

Question 335

When the load is an infinite resistance, the current through the load, and hence the photodiode is zero.

∴ Power = VI = **0** **(ANS)**

Question 336

The maximum current is

1.7 mA, **(ANS)**

Question 337

The photodiode is converting light energy into electrical energy, it can be considered to be the EMF for the circuit.

The current through the load is the same as the current through the diode.

∴ at 1.5 mA, the voltage across the diode is 2.8 V. (Be careful with the scale).

∴ the voltage drop across the load is also

2.8 V. (ANS)

Question 338

$P = VI = 2.8 \times 1.5$

= **4.2 mW (ANS)**

Question 339

$P = I^2R$

$\therefore R = \frac{4.2\times10^{-3}}{(1.5\times10^{-3})^2}$

= **1.9 kΩ (ANS)**

Question 340

You need to use trial and error to do this. It will be near the middle.

Start at V = 2.8, I = 1.5, ∴ P = 4.2

Try V = 3.2, I = 1.44, ∴ P = 4.61

V = 3.6, I = 1.36, ∴ P = 4.90

V = 4.0, I = 1.26, ∴ P = 5.04

V = 4.4, I = 1.15, ∴ P = 5.06

V = 4.8, I = 1.02, ∴ P = 4.90

Using symmetry, the maximum value is midway between 3.6 and 4.8.

∴ 4.2V.

Check your answer with a calculation.

$P = 4.2 \times 1.21 = 5.08$

Question 341

When a LED starts conducting, the resistance drops sharply, as seen from the characteristic graph. With a very small change in voltage, there is a marked increase in current. The purpose of the resistor is to limit the current that flows. This limits damage to the LED.

Question 342

Using Kirchhoff's laws, the sum of the voltage drops around the circuit must be the same as the EMF of the supply.

Then $V_R = 9.0 - V_{LED}$

$= 9.0 - 1.8$

$= 7.2$V.

As both the resistor and the LED are in series, the current through both is the same.

∴ V = iR gives 7.2

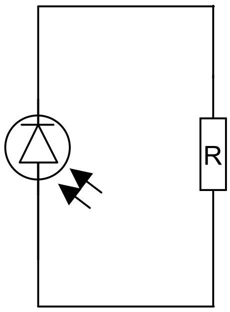
$= 30 \times 10^{-3} \times R$

$\therefore R = \frac{7.2}{0.030}$

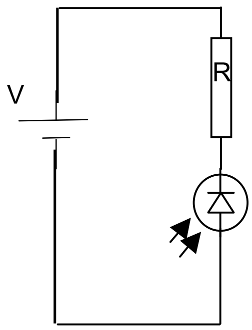
= 240 Ω (ANS)

Question 343

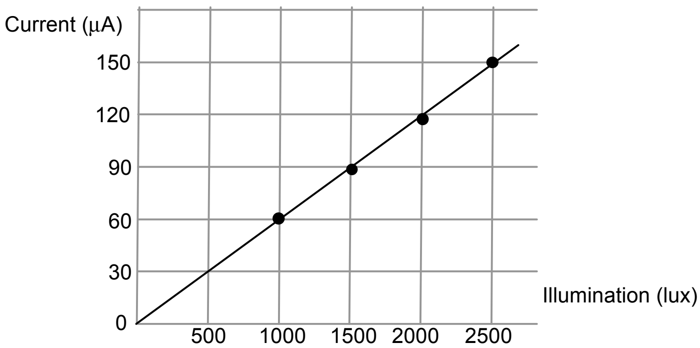
When a photodiode is *unbiased* it acts like a 'solar cell', converting light energy into electrical energy.



When a photodiode is *reverse biased*, very little current flows, but it is very sensitive to changes in light intensity.



Question 344



From the graph, it appears to be linear.

$\therefore$ **C (ANS)**

Question 345

At 1000 lux, the current is 61 μA,

$\therefore$ V = iR gives

$V = 61 \times 10^{-6} \times 10 \times 10^{3}$

$= 0.61$ V.

At 2500 lux, the current is 151 μA,

$\therefore$ V = iR gives

$V = 151 \times 10^{-6} \times 10 \times 10^{3}$

$= 1.51$ V.

$\therefore$ The change in voltage is 1.51 – 0.61

= **0.9 V (ANS)**

Question 346

The attributes you would want to consider are: speed (see above), sensitivity.
Phototransistors tend to be more sensitive than photodiodes but have relatively slower response times. A phototransistor is fast enough for voice transfer, but it is not fast enough for digital information being send down optical fibres. We need to use a photodiode.
Photodiodes are only sensitive to infrared, whilst phototransistors and LDRs respond to infrared and visible.
The input and output signals in an LDR are similar in size, but a photodiode is capable of immense multiplication of the signal.

Question 347

The answer is B for all three transducers. In all three the light energy (from incoming photons) is partly transferred to the electrons in the transducer.
In photonic applications, energy is often being transformed between electrical potential energy and light (photon) energy.

Eg LED Electrical potential energy → photon (light energy)

LDRs: Photon (light) energy → electrical potential energy of electrons in the LDR

Phototransistors: photon energy to electrical potential energy of electrons

Photodiodes; photon energy to electrical potential energy and kinetic energy of electrons

Incandescent lights: electrical potential energy of electrons to photon energy and heat.

Question 348

We only need to consider amplitude modulation. Modulation is when we alter the intensity (amplitude) of a beam of light in a way to transfer information. The information is encoded in the time variation of the intensity.

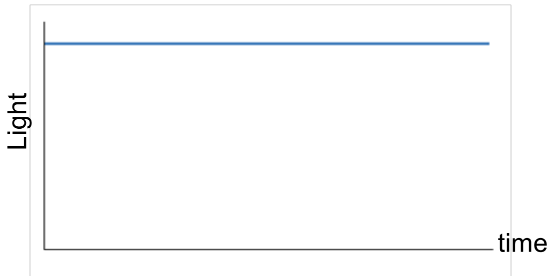
Question 349

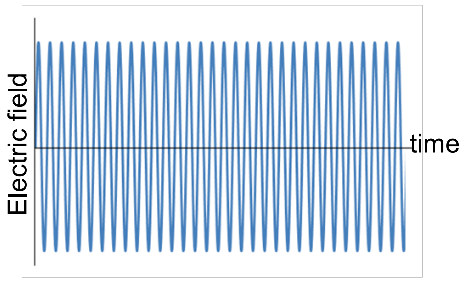
The information is contained within the frequency of the signal. We need to add a DC voltage of 10 volts to the circuit to keep the voltage ≥ 0.

Question 350

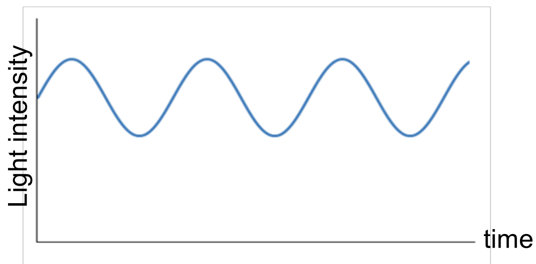
Light is an electro-magnetic wave and the intensity of the light is increased by increasing the amplitude of the electric field (and magnetic field). So if we want to use light as our medium to send our signal on, we will be sending our signal on a wave, so the light is called a carrier wave since it is a wave that carries the signal.

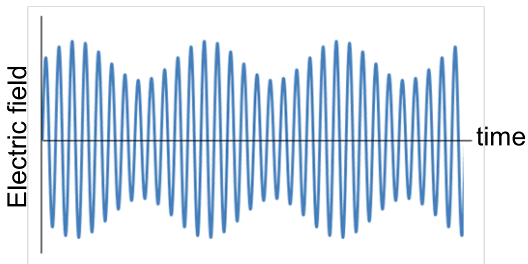
Modulation changes the intensity of the carrier wave, to replicate the variation in the signal.





To modulate (vary) the light intensity as shown below the electric field will be as shown below.





The signal is now being carried on the carrier wave. There is a need for the carrier wave to have a frequency much greater than the signal, otherwise it will do a poor job of representing the signal being sent. (A carrier wave can be any EM radiation).

Question 351

All the answers are possible, but A is the best answer.

Question 352

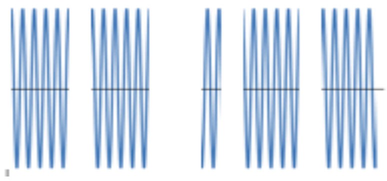
The transducers need to be linear so that any amplification of the signal does not amplify some parts more than others. So the shape of the output signal is the same as the input signal. This means that the information being transferred is not altered (when the shape of the signal alters).

Question 353

A, B, D
If the wave shown was modulated, you would expect to see some form of variation of the signal.

Question 354

The modulated wave needs to reflect the variation in the information signal.



Question 355 (2010 Q5, 2m, 75%)
Percentage efficiency is given by

$$\frac{\text{Power out}}{\text{Power in}} \times 100.$$

Power in = V × I
= 10 V × 10 × 10^{-3} A
= 100 mW
Power out = 50 mW
∴ **Efficiency = 50% (ANS)**

Question 356 (2010 Q6, 2m, 60%)

The voltage drop across the LDR must be 4 V.
∴ the voltage drop across R must be 8 V.
From this ratio, the resistance of R must be twice the resistance of the LDR. (They are in series and have the same current).
With 10 lux falling on the LDR, this gives it a resistance of $1 \times 10^4\ \Omega$.

∴ $R = 2 \times 10^4\ \Omega$ (ANS)

Question 357 (2010 Q7, 3m, 57%)

From the resistance versus illumination graph, as the light intensity (illumination) decreases the resistance of the LDR increases. This means that the resistance of the circuit increases, so the current through both the resistor and the LDR will decrease. This means that the Voltage lost across the resistor will drop, so the potential lost across the LDR (and hence V_{OUT}) needs to increase, because the supply voltage is constant.

∴ INCREASE (ANS)

Question 358 (2010 Q8, 3m, 47%)

I find it best to answer this type of question by actually putting in a set of values.
Ryan wants the lights to come on earlier, i.e. before it gets so dark. Let us say that Ryan wants to lights to come on when the illumination has only fallen 100 lux. The solution now requires you to be able to read a log-log graph.
At 100 lux the resistance is approximately $2 \times 10^3\ \Omega$. This means, Using V = iR, that to have a 4 V potential difference across the LDR you need a current of $i = 4 / 2 \times 10^3$.
Therefore i = 2 mA.
If 2 mA flows through the resistor R, then to maintain 8V across the resistor, its value is determined from
$V = iR\ \therefore\ 12 = 2 \times 10^{-3} R$
$\therefore R = 6000\ \Omega$
This is less than the original value of $2 \times 10^4\ \Omega$.

∴ Decrease (ANS)

Question 359 (2011 Q7, 2m, 65%)

For the LED to operate at maximum brightness the current needs to be 150 mA in both R_1 and the LED. The voltage drop across the LED is 3 V, therefore there is 6V across the resistor
∴ V = iR
∴ 6 = 150 × R
∴ R = 40Ω (ANS)

Question 360 (2011 Q8, 2m, 60%)

At 10 mW, the current is 4 mA.
Use V = iR
$\therefore V = 4 \times 10^{-3} \times 2 \times 10^3$
∴ V = 8 V (ANS)

Question 361 (2011 Q9, 2m, 45%)

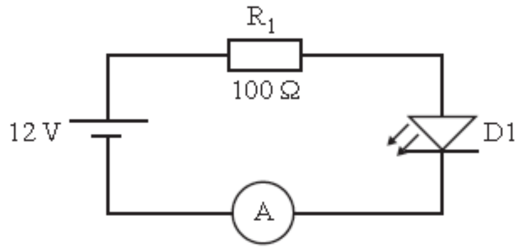
The brightness needs to be above zero, because the LED is always on.

Question 362 (2011 Q10, 2m, 30%)

This is an example of modulation, because the intensity of the carrier wave, the light from the LED, changes to replicate the variation of the current in the circuit.
The current is varied by changing the variable resistor.

Question 363 (2012 Q2a, 2m, 75%)

From the graph, the voltage drop across the diode will be 2 V.



This leaves 10 V (12V – 2V) across the resistor.
Using V = IR, gives
10 = I × 100
∴ I = 0.1 A
∴ I = 100 mA (ANS)

Question 364 (2012 Q2b, 2m, 65%)

NOTE that the voltage of the supply is now 8 V.
The voltage drop across D2 will be 3 V.
∴ Voltage drop across R_2 = 8 – 3
= 5V (ANS)

Question 365 (2012 Q2c, 2m, 35%)

The current through the ammeter will be the sum of the currents through both resistors.
The voltage drop across D1 = 8 – 2 = 6V
Using V = IR

gives $I = \frac{V}{R}$

$\therefore I_1 = \frac{6}{100} = 60$ mA

The voltage drop across D2 = 8 – 3 = 5V
Using V = IR

gives $I = \frac{V}{R}$

$\therefore I_1 = \frac{5}{150} = 33$ mA

$\therefore$ I = 60 + 33

= 93 mA (ANS)

Question 366 (2012 Q2d, 4m, 35%)

Use $P_{in} = VI$

Diode 1

$\therefore P_{in} = 2 \times 100 \times 10^{-3}$

$\therefore P_{in} = 200$ mW

$\therefore$ Effectiveness (another word for efficiency) is given by $\frac{Power_{out}}{Power_{in}} = \frac{150}{200} = 75\%$

Diode 2

$\therefore P_{in} = 3 \times 100 \times 10^{-3}$

$\therefore P_{in} = 200$ mW

$\therefore \frac{Power_{out}}{Power_{in}} = \frac{200}{300} = 67\%$

Therefore **Diode 1 is more effective.**

Question 367 (2012 Q3a, 3m, 70%)

To use the graph to find the light intensity, you need to know the resistance of the diode.
To find the resistance of the diode, you need to know the voltage drop across it and the current flowing through it.
With the current of 2.5 mA flowing, the voltage drop across the resistor is given by V = iR

$\therefore V = 2.5 \times 10^{-3} \times 3000$

$\therefore$ V = 7.5 V

Therefore the voltage drop across the diode
= 10 – 7.5
= 2.5 V

Using V = iR for the diode gives

$2.5 = 2.5 \times 10^{-3} \times R$

$\therefore R = 1000\ \Omega$

From the graph, the light intensity is

10 lux (ANS)

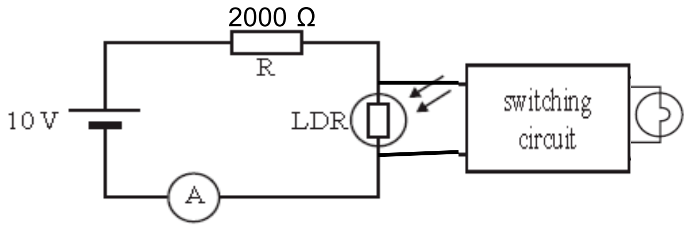
Question 368 (2012 Q3b, 4m, 55%)

At 2.5 lux, the resistance of the LDR is 3000 Ω. The switching circuit requires 6.0 V across it to operate. This means that the voltage drop across the unknown resistor needs to be 4.0 V.

Using ratios $\frac{4}{R} = \frac{6}{3000}$

$\therefore R = 2000\ \Omega$

For the light to stay on as it gets darker, the voltage for the switch needs to be greater than 6 V. This means that the switch needs to be across the LDR, because as it gets darker, the resistance of the LDR will increase and hence the proportion of the voltage drop across it will increase.



Question 369 (2012 Q5, 3m, 53%)

Modulation device: converts the variations of the electrical signal into variations of an optical signal which is added to a carrier signal. The optical signal will vary in intensity.
The light beam: carries the signal by its variation of intensity.
Demodulation device: converts the light intensity variations of the carrier wave into variations in an electrical signal.

Question 370 (2013 Q11a, 2m, 85%)

Use V = iR

$\therefore 2.5 = 5 \times 10^{-3} \times R$

$\therefore$ **R = 500 Ω (ANS)**

Question 371 (2013 Q11b, 2m, 90%)

Use V = iR

$\therefore 1 = 5 \times 10^{-3} \times R$

$\therefore R = 200\ \Omega$

From the graph, when R = 200 Ω, the temperature is

20^0 C (ANS)

Question 372 (2013 Q11c, 2m, 90%)

Use V = iR
∴ $10 = 5 \times 10^{-3} \times R$
∴ R = 2000 Ω
From the graph, when R = 2 kΩ, the light intensity is
15 lux (ANS)

Question 373 (2013 Q11d, 4m, 60%)

The student needs to decrease the potential difference across the resistor.
∴ lower the current in the circuit by increasing the total resistance.

Change 1
Increase the temperature of the room. This will increase the resistance of the thermistor, which will decrease the potential difference across the resistor, to turn the buzzer off.
Change 2
Decrease the light in the room. This will increase the resistance of the LDR, which will decrease the potential difference across the resistor, to turn the buzzer off.

Question 374 (2013 Q12a, 3m, 80%)

From the graph, if the current is 10 mA, then the potential difference across the LED is 2.0 V.
Use V = iR, to find the potential difference across the resistor.
∴ $V = 10 \times 10^{-3} \times 450$
= 4.5 V
∴ Voltage of the battery is 2.0 + 4.5
= 6.5 V (ANS)

Question 375 (2013 Q12b, 2m, 45%)

In the LED
Electrical to light
In the resistor
Electrical to heat.

Question 376 (2014 Q7a, 3m, 67%)

If the power dissipated in the LED is 300mW, then from P = VI, the current in the LED will be
P = V × I
∴ $300 \times 10^{-3} = 2 \times I$
∴ I = 150 mA
The resistor and the LED are in series, so they both have the same current.

The voltage drop across the resistor must be 9V. (The difference between the 11 V supply and the 2 V dropped across the LED.
Using V = ir
∴ $9 = 150 \times 10^{-3} \times R$
∴ $R = 9 \div (150 \times 10^{-3})$
∴ **R = 60 Ω (ANS)**

Question 377 (2014 Q7b, 2m, 65%)

With 3 volts lost across the LED, the potential difference across the resistor must be 9.0 V. The current flowing through the resistor is the same as the current through the ammeter.
∴ P = V × I
$= 9 \times 500 \times 10^{-3}$
= 4.5 W (ANS)

Question 378 (2014 Q8a, 1m, 88%)

From the graph, when the voltage is zero, the current will be
3.6 mA (ANS)

Question 379 (2014 Q8b, 1m, 64%)

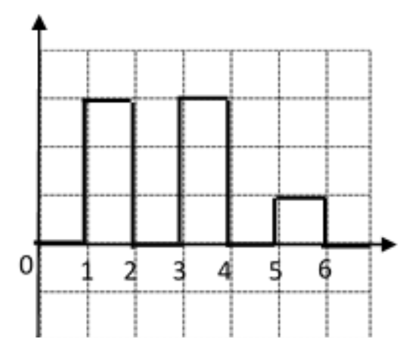
From the graph, when current is zero, the potential drop is
1.3 V (ANS)

Question 380 (2014 Q8c, 3m, 73%)

When the photodiode is operating at 1.0 V, the current through it is 1.6 mA. This will also be the current through the variable resistance.
Use V = iR
Then $1 = 1.6 \times 10^{-3} \times R$
∴ $R = \dfrac{1}{1.6 \times 10^{-3}}$
∴ **R = 625 Ω (ANS)**

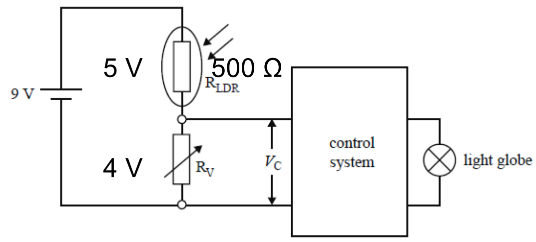
Question 381 (2014 Q9, 2m, 30%)

Modulated wave intensity



Question 382 (2014 Q11, 4m, 65%)

From the graph, when the light intensity is 300 lux, the resistance of the LDR is 500 Ω.



If the voltage across the control system needs to be 4 V for the light to turn on, then the voltage across the LDR is 5 V.
This 5 V is across a 500 Ω resistor.
∴ the resistance that has a 4 V difference will be 400 Ω.

∴ **400 Ω. (ANS)**

Modulated wave intensity