NATIONAL SENIOR CERTIFICATE EXAMINATION
EXEMPLAR 2009

PHYSICAL SCIENCES: PAPER I

Time: 3 hours 200 marks

READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This paper consists of:
   - a question paper of 11 pages;
   - a booklet of data and formulae.

   Please make sure that your question paper is complete.

2. Use the data and formulae whenever necessary.

3. Read the questions carefully.

4. In Question 1 answer EITHER 1.9 OR 1.10.
   In Question 3 answer EITHER 3.9 OR 3.10.

5. Show your working in all calculations.

6. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.

QUESTION 1 CLIMBING STRAIGHT UP A KRANS

A group of hikers come to a krans (a sheer cliff). The first hiker uses a chain ladder to climb from the soft dry river bed below to the top of the 20 m krans. He takes 1 minute to reach the top.

1.1 State the law of conservation of energy. (2)

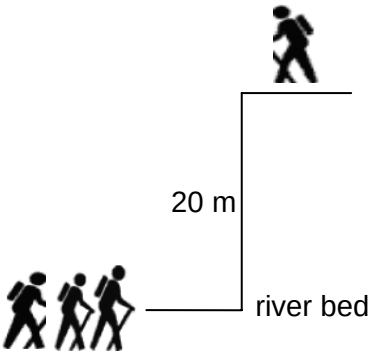
1.2 His mass (rucksack included) is 80 kg. Calculate the gain in his potential energy when he reaches the top. (3)

1.3 Calculate the average power he exerted during his climb to the top. (3)

1.4 He is carrying oranges in his rucksack. Each orange has a mass of 100 g.

The hikers below ask him to send some oranges down to them before they climb the ladder. The oranges strike the soft river bed below. Assume that air resistance is negligible.

- He drops the first orange (A) from a height of 20 m.
- He sends the second orange (B) down to them, throwing it with a velocity of 10 $m \cdot s^{-1}$ downwards.
- He throws a third orange (C) upwards into the air with velocity of 10 $m \cdot s^{-1}$.



1.4.1 Calculate the time taken for orange (A) to reach the river bed below. (3)

1.4.2 **Use energy considerations** to calculate the magnitude of the impact velocity of each of the oranges when it reaches the river bed 20 m below him.

(a) Orange A (4)
(b) Orange B (3)
(c) Orange C (3)

1.4.3 Draw velocity vs. time graphs (on the same set of axes) for the flight of each of the three oranges.
Label each graph A, B and C to correspond with each of the oranges A, B and C. (12)

1.4.4 In which way are the flights of the three oranges similar? (1)

1.4.5 In which way do the flights of the three oranges differ? (1)

1.5 When the oranges land on the soft river bed their impact forms a small crater, and the oranges burst open on impact.

The depth of the crater made by the first orange (A) is 5 cm.

1.5.1 Calculate the average resultant force experienced by orange A during impact. (4)

1.5.2 Predict the depth relative to the first crater of the craters made by:

(a) Orange B (1)
(b) Orange C (1)

1.6 Give advice to the hikers on how to catch an orange which falls from such a height, without causing it to burst. Explain your reasoning. (4)

1.7 How did the oranges gain potential energy? (1)

1.8 Describe what happened to the kinetic energy of orange A. (2)

ANSWER EITHER QUESTION 1.9 OR OPTIONAL QUESTION 1.10

1.9 The hiker at the top of the krans throws another orange (D) horizontally at 10 $m \cdot s^{-1}$ away from the krans (over the heads of the hikers).

1.9.1 Determine the magnitude of its impact velocity with the river bed. (3)

1.9.2 Where would Orange (D) land relative to the other oranges? (4)

ANSWER QUESTION 1.10 IF YOU HAVE NOT ANSWERED QUESTION 1.9

QUESTION 1.10 (Optional)

1.10 One of the hikers is curious about how the depth of the crater formed by a falling orange varies with the impact velocity of the orange. He asks you to design an experiment to answer his question.

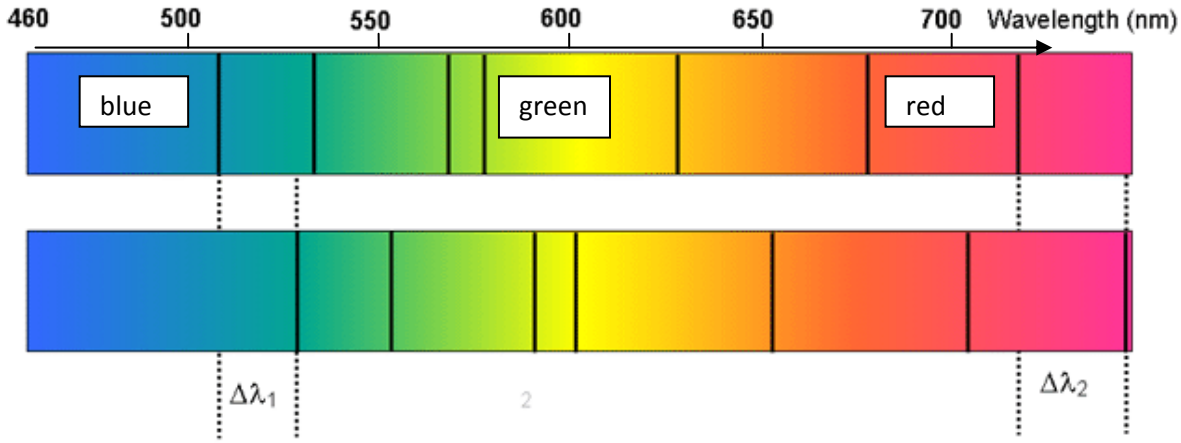
1.10.1 Write a hypothesis for his question. (2)

1.10.2 Design an experiment to test your hypothesis. (5)

55 marks

QUESTION 2 THE DOPPLER EFFECT, LIGHT AND COLOUR

The diagram below shows the emission spectrum of hydrogen from a stationary discharge tube, and then the emission spectrum from a star moving away from earth.



[<http://www.iop.org/>]

The emission spectrum of an element is said to be 'the fingerprint of its atomic structure'. Each element has its own established emission spectrum.

The astronomer Dr Edwin Hubble recognised the shift of spectral lines towards the red (longer wavelength) as an example of the Doppler Effect, which is more commonly associated with sound waves. He used this evidence to predict that most of the stars are moving away from us.

2.1 What is meant by the term 'an emission spectrum'? (3)

2.2 Explain why each element has its own specific emission spectrum. (4)

2.3 Use an example associated with sound waves to illustrate and explain what the Doppler Effect is. (4)

2.4 Explain how the Doppler Effect accounts for the shift in the spectral lines of hydrogen. (4)

2.5 Use the diagram above to estimate the magnitude of $\Delta\lambda_1$.
(Show your working clearly) (3)

2.6 Calculate the corresponding shift in frequency for $\Delta\lambda_1$. (5)

2.7 Is the speed of the light coming from the star less than, the same as, or greater than the speed of the light coming from the discharge tube? (2)

2.8 Name a process which may be used to disperse light into a spectrum. (2)

2.9 Calculate the energy of a photon with a wavelength of 600 nm. (4)

Ultraviolet (UV) electromagnetic radiation reaches earth from Space. These photons enter our atmosphere and can be harmful to us. Light behaves as a particle and as a wave. Having observed the phenomenon of destructive interference, a learner wonders whether using destructive interference could cancel the effect of the UV rays which reach us.

2.10 Explain what is meant by 'destructive interference'. (3)

2.11 Give two reasons why a photon of ultraviolet light (UV light) is more dangerous than a photon of red light. (4)

2.12 Name one other example of dangerous electromagnetic radiation reaching the earth from Space. (1)

2.13 Do you think that destructive interference can be used to cancel the UV radiation which reaches earth from Space? Use your knowledge of waves to justify your answer. (5)

The diagram of the emission spectra of hydrogen shown above is printed on a colour printer which uses colour subtraction (the CMY system).

2.14 Name the three primary subtractive colours. (3)

2.15 What is meant by 'complementary colours'? (2)

2.16 Name the complementary colour of red. (1)

2.17 Explain how the colour red can be produced using colour subtraction. (6)

56 marks

QUESTION 3 ELECTROMAGETISM AND ELECTRIC CURRENT

The photograph alongside shows a kinetic torch being shaken up and down.

The advertisement for the kinetic torch explains its operation as follows:

> Shaking the torch causes a high strength magnet to pass back and forth between a wire coil (Faraday's Law of Induction at work here for all you science boffins), powering an ultra bright LED for about 5 minutes from a simple 30 second charge - excellent wrist exercise, right?
> **The Eternal Torch is virtually guaranteed for life as the LED lasts over 100,000 hours and the flashlight can be recharged over a million times.**

[<http://www.shopwiki.com.au/LED+Compact+Torch>]

3.1 Identify two energy transfers that are taking place in order to produce a beam of light. (4)

3.2 The advertisement refers to Faraday's Law of Induction. State this Law. (3)

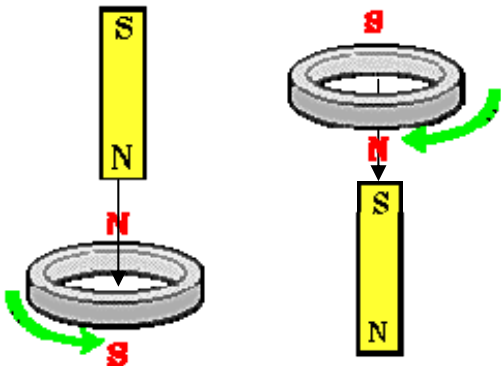
3.3 Describe three modifications which could be made to this type of torch and/or to its operation so that the amount of energy transferred by each shake of the torch is increased. (3)

A kinetic torch costs R 80.00. A conventional torch of similar brightness costs R 25.00, and its two batteries (cells) cost R 7.00 each. The expected life of the cells when the torch is switched on, is 8 h.

3.4 Draw up a table showing the advantages and disadvantages of both kinetic torches and conventional torches. (8)

3.5 Use your table to write a short paragraph which gives **your opinion** of the value using a kinetic torch compared the value of using a conventional torch. (3)

The diagram below shows the magnet falling down through the coil in the tube of the torch. As the magnet enters the coil above, a clockwise current is produced. As the magnet leaves the coil an anticlockwise current is produced.

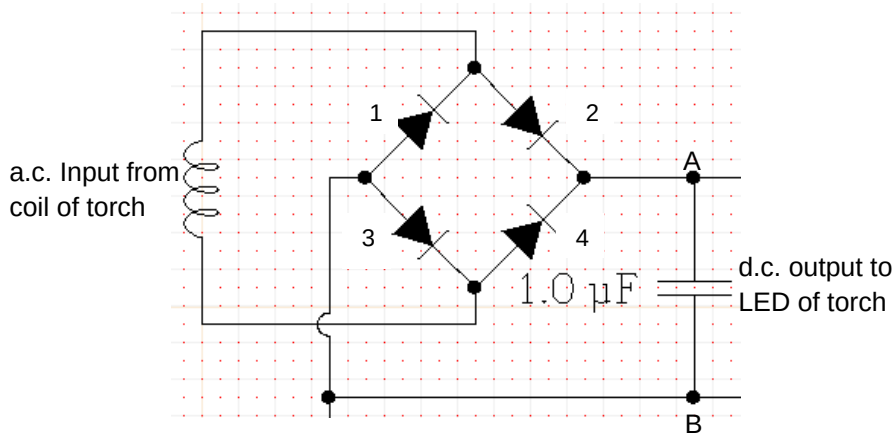


3.6 Explain how magnetic poles are produced on the coil when the magnet is entering the coil. (4)

The time taken for the magnet to fall down the length of the tube is 0,025 s.
The time taken for a similar piece of copper to fall down the length of the tube is 0,019 s.

3.7 Use the principle of conservation of energy to explain why it takes less time for the piece of copper to fall down the tube than for the magnet (of same mass and size) to fall down the tube. (6)

3.8 The alternating current (a.c.) generated in the coil of the kinetic torch is rectified to flow in one direction only using a bridge rectifier shown in the circuit diagram below.



3.8.1 Draw a sketch graph of the a.c input from the coil of the torch. (2)

3.8.2 What is the function of any one of the diodes in this circuit? (1)

3.8.3 Draw a sketch graph of the d.c. output to the LED of the torch. (2)

3.8.4 Explain briefly how light is emitted from the LED when it is forward biased. (4)

ANSWER EITHER QUESTION 3.9 OR OPTIONAL QUESTION 3.10

3.9 The complete circuit for the kinetic torch includes a LED, a switch and a 10 Ω resistor connected to the d.c. output. The resistor limits the current to the diode.

3.9.1 Starting from connection points A and B respectively draw the remainder of the circuit diagram to show how the LED, switch and resistor are connected to the d.c. output. (4)

3.9.2 Calculate the amount of charge which passes through the LED in 5 minutes when a steady d.c. current of 10 mA passes through it. (4)

3.9.3 Calculate the amount of electrical energy used by the LED in 5 minutes when a steady potential difference of 1,8 V is applied across it. (4)

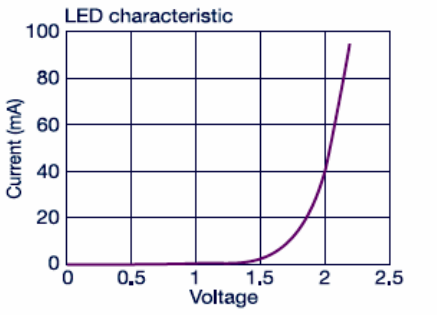
3.9.4 What is the function of the capacitor in this circuit? (2)

3.9.5 Which side of the capacitor (A or B) is positive in this circuit? (1)

ANSWER QUESTION 3.10 IF YOU HAVE NOT ANSWERED QUESTION 3.9

Question 3.10 (Optional)

3.10 The graph shows the characteristic of a LED which is to be used in the circuit for the kinetic torch shown. For optimum life and light efficiency the current through the LED should be 40 mA. At higher currents the LED will be brighter, but its life is shortened and it will burn out rapidly if the current exceeds 90 mA.



3.10.1 Is the LED ohmic or non-ohmic? Explain. (3)

3.10.2 Determine the resistance of the LED under the best conditions. (4)

3.10.3 What is the maximum power that can be consumed by the LED ? (4)

3.10.4 Explain how a resistor connected in series with the LED can limit the power that is consumed by the LED. (4)

55 marks

QUESTION 4 MATTER AND MATERIALS: USING A PHOTODIODE

A photodiode is an electric circuit component which works on a similar principle to the photoelectric effect.

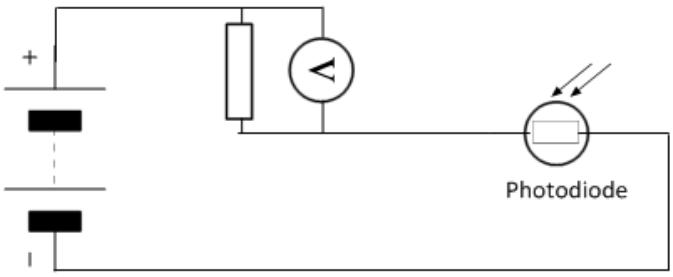
The photodiode emits electrons when light shines on it. This particular photodiode is sensitive to the entire visible light spectrum, including ultra violet (UV) light, but it does not respond to infra red light.

[<http://cfcpwork.uchicago.edu/kicp-projects/nsta/2007/pdf/nsta_2007-photoeleclab.pdf>]

4.1 Briefly describe what the photoelectric effect is. (3)

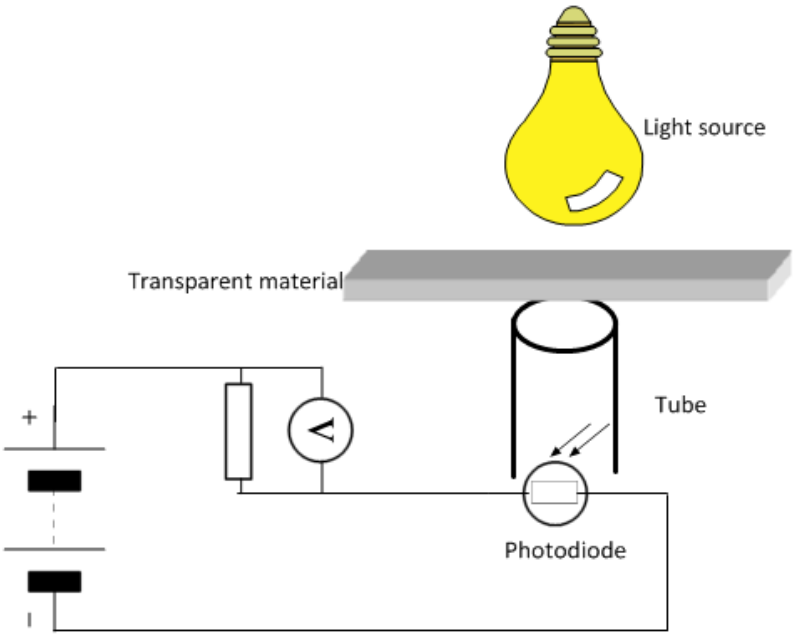
4.2 Explain why the photodiode does not respond to infra-red photons, regardless of the intensity of the infra red source. (4)

A battery can be used to pull the photoelectrons which are released from the photodiode through an electric circuit. When visible light is incident on the photodiode a very small electric current is produced. The strength of this current is calculated (from measurements of the voltage across the resistor).



This kind of circuit can be used to test the transparency of various materials. A tube with a fixed diameter is placed directly over the top of the photodiode to prevent other light from reaching it. Various materials are placed one by one over the tube, and the photocurrent is calculated and recorded.

The experiment set up is shown below.



The following results were obtained when various materials were placed in turn across the top of the photodiode tube.

Material	% Transparency	Photocurrent (nA)
Black paper	0	0
Brown paper	7	30
Tracing paper	23	100
Green cellophane	68	310
Clear glass	100	460

4.3 List two variables which must be controlled in this experiment. (2)

4.4 Plot a graph of these results on graph paper. (8)

4.5 Describe how the photocurrent is related to the percentage transparency of the different types of materials. (1)

4.6 Explain why the photocurrent increases when the percentage transparency increases. (2)

4.7 Explain how this experiment could be adapted to measure the transparency for UV light only and not visible light. (4)

The transparency of some sunglasses is tested using the apparatus shown. A dark sunglass lens produces a current of 70 nA and a light polariod lens produces a current of 200 nA. Polaroid lenses cut out the glare reflected from smooth surfaces.

4.8 Determine the transparency of each lens:

4.8.1 Normal sunglass lens (2)

4.8.2 Polaroid sunglass lens (2)

4.9 Discuss the advantages and disadvantages of each of these types of lenses when worn by the driver of a motor vehicle at sunset. (6)

34 marks

