

Physics II

030

04 Nov. 2013 8.30 am – 11.30 am

REPUBLIC OF RWANDA



RWANDA EDUCATION BOARD

ADVANCED LEVEL NATIONAL EXAMINATIONS 2013

SUBJECT: PHYSICS

PAPER II: THEORY

COMBINATIONS: PHYSICS-CHEMISTRY-MATHEMATICS (PCM)
PHYSICS –CHEMISTRY- BIOLOGY (PCB)
PHYSICS – ECONOMICS- MATHEMATICS (PEM)
MATHEMATICS –PHYSICS- GEOGRAPHY (MPG)
MATHEMATICS- PHYSICS-COMPUTER SCIENCE (MPC)

DURATION: 3 HOURS

INSTRUCTIONS:

1. Do not open this question paper until you are told to do so
2. This paper consists of **two** sections **A** and **B**.

Section A: This section is compulsory. **(55 marks)**

Section B: Answer **any three** questions. **(45 marks)**

3. Non programmable scientific calculators and student geometric instruments (mathematical set) may be used.

4. Useful constants:

Avogadro's constant:	$N_A = 6.022 \times 10^{23} / \text{mol}$
Magnitude of charge of electron:	$e = 1.6 \times 10^{-19} \text{ C}$
Speed of light in vacuum:	$C = 3 \times 10^8 \text{ m/s}$
Planck's constant:	$h = 6.63 \times 10^{-34} \text{ Js}$
Permittivity of free space:	$\epsilon_0 = 8.85 \times 10^{-12} \text{ N}^{-1}\text{m}^{-2}\text{C}^2$
Acceleration due to gravity:	$g = 9.80 \text{ m/s}^2$
Permeability of free space:	$\mu_0 = 4 \pi \times 10^{-7} \text{ Hm}^{-1}$
Boltzmann's constant:	$k = 1.38 \times 10^{-23} \text{ J/K}$
Molar gas constant:	$R_g = 8.314 \text{ J/mol K}$
Faraday's constant:	$F = 96\,485 \text{ C mol}^{-1}$
Specific heat capacity of water:	$C_e = 4\,200 \text{ J/kg } ^\circ\text{C}$
Specific heat capacity of ice:	$C_i = 2\,100 \text{ J/kg } ^\circ\text{C}$
Latent heat of fusion of ice:	$L_f = 335 \text{ kJ/ kg}$

SECTION A: ATTEMPT ALL QUESTIONS (55 marks)

1. Enumerate eight policy actions taken by the Rwandan government to solve the energy problem in Rwanda. (4 marks)
2. A sinusoidal electromagnetic wave having a magnetic field of amplitude $1.50 \mu\text{T}$ and a wavelength of 400 nm is travelling in the $+z$ direction through empty space.
 - a) What is the amplitude of the associated electric field? (1.5 marks)
 - b) Determine the wave number of this electromagnetic wave. (1.5 marks)
3. a) What is meant by normal adjustment for an astronomical telescope?
Why is it used in this way? (1 mark)
 - b) An astronomical telescope in normal adjustment is required to have an angular magnification of 14. An eyepiece lens of focal length 60 mm is available.
 - i. Calculate the focal length of the objective required. (1 mark)
 - ii. Draw a ray diagram, not to scale, to show how the labelled lenses should be arranged in normal adjustment. The diagram should show two rays passing through the telescope from a non-axial point. (2 marks)
4. A hot air balloonist, rising vertically with a constant velocity of magnitude 5 m/s , releases a sandbag at an instant when the balloon is at 40m above the ground. After it is released, the sandbag is in free fall. Compute the position and the speed of the sandbag at a time equals to 0.25s (2.5 marks)
5. The energy of the ground state of the mercury atom is $E_1 = -10.4 \text{ eV}$ on a scale in which an electron completely free of the atom is at zero energy.
 - a) Determine the energy corresponding to the second excited state. (2 marks)
 - b) Calculate the ionization potential of the mercury atom. (2 marks)
6. The diagram (figure 1) shows a small block of mass 2 kg able to move on a rough plane inclined at 30° to the horizontal. The block is attached by means of a light string passing over a smooth pulley at the top of the plane to a particle of mass 4 kg hanging freely. The coefficient of friction between the block and the plane is 0.2 . The system is released from rest with the 2 kg block at the bottom of the plane.

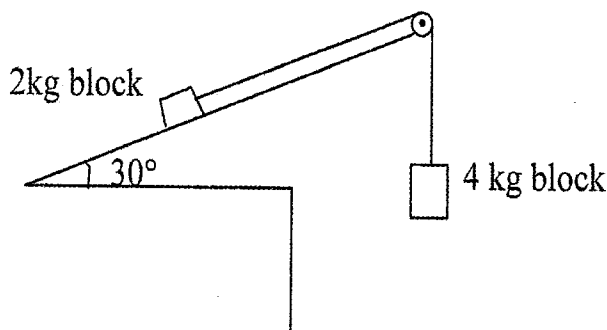


Figure 1

- Find
- a) the friction force applied to the mass of 2 kg . (1 mark)
 - b) the acceleration of the small block. (2 marks)

7. a) A projectile is launched with speed \vec{v}_0 at an angle α_0 above the horizontal. The launch point is at a height h above the ground. Show that if air resistance is ignored, the horizontal distance that the projectile travels before striking the

ground is $x = \frac{v_0 \cos \alpha_0}{g} (v_0 \sin \alpha_0 + \sqrt{v_0^2 \sin^2 \alpha_0 + 2gh})$ **(3 marks)**

- b) Determine x if h is taken to be zero. **(1 mark)**

8. a) A student asserts that a suitable unit for specific heat capacity is $1 \frac{m^2}{s^2 \text{ } ^\circ\text{C}}$.

Prove that this unit is correct or not. **(1 mark)**

- b) An insulated beaker with negligible mass contains 0.5 kg of water at a temperature of 70°C . How many kilograms of ice at a temperature of -20°C must be dropped into the water to make the final temperature of the system 30°C ? **(3 marks)**

9. An organ pipe has two successive harmonics with frequencies 1372Hz and 1764Hz.

- a) Show that this is a stopped (closed) pipe. **(2 marks)**
 b) What two harmonics are these? **(1 mark)**
 c) What is the length of the pipe? **(1 mark)**

10. A certain beam of light goes from one transparent material into another (from air into material such as a colourless glass for example). On physical grounds explain why the wavelength changes but the frequency and period do not. **(4 marks)**

11. A uniform ladder of mass m and length L leans against a smooth vertical wall making an angle θ with a horizontal floor (figure2). The coefficient of static friction between the ladder and the floor is μ .

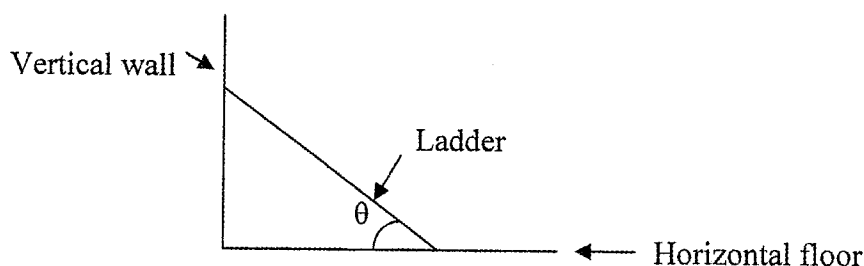


Figure 2

Find (in terms of μ) the minimum angle θ_m for which the ladder does not slip.

(3.5 marks)

12. a) State Faraday's laws of electrolysis. **(1 mark)**
 b) Calculate the mass of copper produced in 1 hour by the electrolysis of molten CuCl_2 if the electrical current is 10 amperes. The molar mass of copper is 63.5 g/mol. **(2 marks)**
13. a) State Dalton's law of partial pressure. **(1 mark)**
 b) 14 g of nitrogen gas and 10 g of helium gas are placed together in 10 litres container at 25°C. The molar mass of nitrogen is 28 g/mol and the molar mass of helium is 4 g/mol. Calculate,
 i. the total moles of the mixture of 2 gases present in the container. **(1 mark)**
 ii. the total pressure of the mixture of 2 gases. **(1 mark)**
 iii. the partial pressure of helium gas. **(1 mark)**
14. a) State Gauss's flux theorem. **(1 mark)**
 b) A point charge $q_1 = 4\text{nC}$ is located on the x-axis at $x = 2\text{ m}$, and a second point charge $q_2 = -5\text{nC}$ is on the y-axis at $y = 1\text{ m}$. The x-axis and the y-axis are perpendicular and form x-y plane. What is the total electric flux due to these two point charges through a spherical surface centred at the origin and with the radius
 i. 0.5 m ? **(1 mark)**
 ii. 2.5 m ? **(1 mark)**
 c) Comment on the sign of the calculated electric flux in 14.b (ii). **(1 mark)**
15. a) A photon with wavelength 0.1 nm collides with a free electron that is initially at rest. The wavelength of the photon after the collision is 0.11 nm.
 i. Why the wavelength of the photon after the collision is greater than the wavelength of the photon before the collision? **(1 mark)**
 ii. What is the kinetic energy of the electron after the collision? **(2 marks)**
 b) If this electron is suddenly stopped in a solid target for example, all of its kinetic energy is used to create a photon. What is the wavelength of this photon? **(1 mark)**

SECTION B: ATTEMPT ANY THREE QUESTIONS (45 marks)

16. The figure 3 shows a parallel R-L-C circuit. The instantaneous voltages and root-mean-square (r. m. s) voltages across each of the three elements are the same and each is in phase with the current through the resistor.

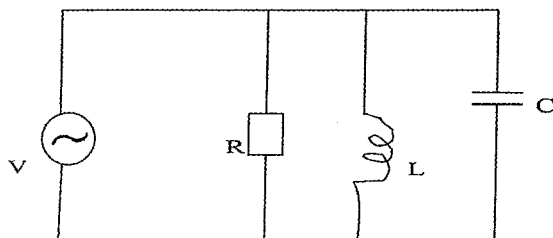


Figure 3

- a) With the aid of a phasor diagram, show that the r. m. s current delivered by the source is $I_{rms} = V_{rms} \sqrt{\frac{1}{R^2} + (\omega C - \frac{1}{\omega L})^2}$ **(7 marks)**
- b) Establish the relation of impedance Z of this circuit **(3 marks)**
- b) Show that the power factor is equal to $\frac{Z}{R}$. **(2 marks)**
- c) Deduce from the above relations the condition of the parallel resonance and the expression of resonant frequency for R-L-C parallel circuit. **(3 marks)**
17. a) A 1000 kg sports car has the same kinetic energy when it is travelling north at 40 m/s as when it is travelling northwest at 40 m/s. Is the linear momentum of the car the same in both cases? Explain. **(2 marks)**
- b) Establish the relation between the kinetic energy k and the linear momentum of magnitude p of a particle of mass m travelling along a straight line with a speed v **(3 marks)**
- c) i. A 0.04 kg stone and a 0.145 kg baseball have the same kinetic energy. Which has the greatest magnitude of momentum? **(2 marks)**
- ii. What is the ratio of the stone's magnitude of momentum to the baseball's magnitude of momentum? **(1 mark)**
- d) i. A 700 N man and a 450 N woman have the same momentum. Who has the greatest kinetic energy? **(2 marks)**
- ii. What is the ratio of the man's kinetic energy to that of the woman? **(1 mark)**
- e) i. A 40 g golf ball initially at rest is given a speed of 30 m/s when a club (a specially shaped stick for striking a ball) strikes. If the club and ball are in contact for 1.5 ms, what average force acts on the ball? **(2 marks)**
- ii. Is the effect of the ball's weight during the time of contact significant? Why or why not? **(2 marks)**

18. a) The following are three electrical components.
- A: a component which obeys Ohm's law.
 - B: a filament lamp.
 - C: a component, other than a filament lamp, which does not obey Ohm's law.
- i. For each of these components, sketch current- voltage characteristics, plotting current on vertical axis, use separate sets of axes for A, B and C. Label your graphs clearly. **(3 marks)**
 - ii. Explain the shape of the characteristic of B. **(2 marks)**
 - iii. Name the component that you have chosen for C. **(1 mark)**
- b) Distinguish between resistance and resistor. **(2 marks)**
- c) The unit of reactance and of resistance is the Ohm.
- i. Name two electrical components having reactance in alternating current. **(1 mark)**
 - ii. In what ways does a component having reactance differ from a resistor when an alternating potential difference V is applied respectively across a resistor and across a component having reactance? **(3 marks)**
- d) A battery is connected across a light bulb in series with a capacitor as shown in figure 4.

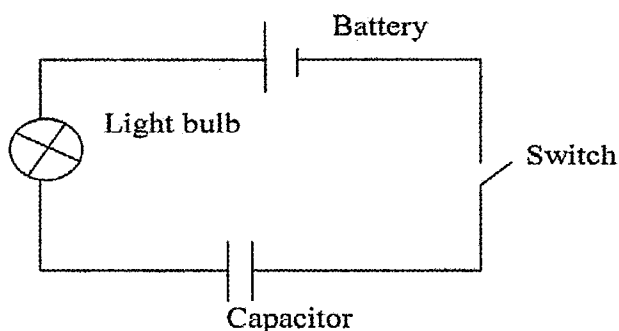


Figure 4

When the switch is closed, what happens to the brightness of the bulb?
Why?

(3 marks)

19. a) What are four assumptions made in deriving Bernoulli's equation. **(4 marks)**
- b) Show that the term $\frac{1}{2}\rho v^2$ which enters into the Bernoulli equation has the same dimensions as pressure. **(2 marks)**
- c) A fluid flows through a horizontal pipe of varying cross section (figure 5). Assuming the flow streamline and applying the Bernoulli's equation $p + \frac{1}{2}\rho v^2 = \text{constant}$, show that the pressure in the pipe is greatest where the cross-sectional area is greatest. **(5 marks)**

- d) A fluid of constant density $\rho = 960 \text{ kg/m}^3$ is flowing steadily through the following horizontal tube (figure 5).

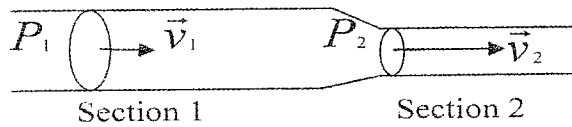


Figure 5

The diameters at the sections are $d_1 = 100 \text{ mm}$ and $d_2 = 80 \text{ mm}$ the gauge pressure at the section 1 $p_1 = 200 \text{ kN/m}^2$ and the speed here is $v_1 = 5 \text{ m/s}$.

- i. Determine the magnitude of the velocity \vec{v}_2 **(2 marks)**
 - ii. Calculate the gauge pressure at the section 2 **(2 marks)**
20. a) Can a charged particle move through a magnetic field without experiencing any force? If so why? If not, why not? **(1.5 marks)**
- b) Two long parallel wires A and B carry steady currents $I_A = 2 \text{ A}$ and $I_B = 1 \text{ A}$ respectively in the opposite directions. Figure 6 is a plan view of the arrangement of the wires. The direction of I_A is out of the page.

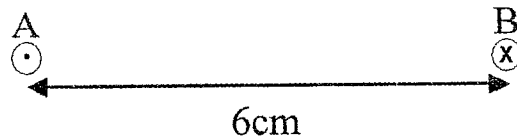


Figure 6

- i. Draw the magnetic field pattern due to the current in the wire B alone. **(1 mark)**
 - ii. Determine a point M where the magnetic flux density due to the currents I_A and I_B in the wires is zero. Mark on a second diagram the directions of the magnetic fields \vec{B}_A and \vec{B}_B due to the currents I_A and I_B respectively at M **(4 marks)**
 - iii. Calculate the magnitude of the force per unit length \vec{F}_B due to I_A acting on the length L_B of the wire B and show on the third diagram its direction. **(2.5 marks)**
- (c) A narrow vertical rectangular coil is suspended from the middle of its upper side with its plane parallel to a uniform horizontal magnetic field of 0.02 T .

The coil has 10 turns and the lengths of its vertical and horizontal sides are 0.1 m and 0.05 m respectively.

- i. Draw a sketch of this coil showing the directions of the current, magnetic field, electromagnetic force and torque. **(3 marks)**
- ii. Calculate the torque on the coil when a current of 10 is passed into it. **(2 marks)**
- iii. What would be the new value of the torque if the plane of the vertical coil was initially at 60° to the magnetic field and a current of 10A was passed into the coil? **(1 mark)**