**UNIVERSITY OF SWAZILAND**

**FACULTY OF SCIENCE**

**DEPARTMENT OF PHYSICS**

**MAIN EXAMINATION 2005**

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| **TITLE O F PAPER:** | INTRODUCTORY PHYSICS |
| **COURSE NUMBER:** | P100 |
| **TIME ALLOWED:** | THREE HOURS |
| **INSTRUCTIONS:** | ANSWER ANY FOUR OUT OF SIX QUESTIONS |
| | EACH QUESTION CARRIES 25 MARKS |
| | MARKS FOR EACH SECTION ARE IN THE RIGHT HAND MARGIN |
| | GIVE CLEAR EXPLANATIONS AND USE CLEAR DIAGRAMS IN YOUR SOLUTIONS. MARKS WILL BE LOST WHERE IT IS NOT CLEAR HOW THE EQUATIONS USED WERE OBTAINED |

THIS PAPER HAS EIGHT PAGES INCLUDING THE COVER PAGE

THE LAST PAGE CONTAINS DATA THAT MAY BE USEFUL IN SOME QUESTIONS

DO NOT OPEN THE PAPER UNTIL PERMISSION HAS BEEN GIVEN BY THE CHIEF INVIGILATOR

## QUESTION 1

(a) Given two vectors $\vec{A} = -\hat{i} + 2\hat{j} - 3\hat{k}$ and $\vec{B} = 2\hat{i} - 3\hat{j} + \hat{k}$, find

(i) the dot product of vectors $\vec{A}$ and $\vec{B}$, $\vec{A} \bullet \vec{B}$, **(3 marks)**

(ii) the vector $\vec{D} = \vec{A} \times \vec{B}$, and **(4 marks)**

(iii) What do you understand by the dot product of two vectors $\vec{A}$ and $\vec{B}$? Use a diagram to illustrate your answer. **(3 marks)**

(b) A boy stands at the edge roof 10 m from the ground. He kicks a ball with an initial velocity of 12 m/s at an angle of 40° with the horizontal.

(i) How high above ground does the ball rise? **(4 marks)**

(ii) How much time does the ball spend in the air before hitting the ground? **(5 marks)**

(iii) What is the range of the ball? **(2 marks)**

(iv) Write the velocity of the ball in vector form when it lands. **(2 marks)**

(v) What angle does the ball make with the horizontal when it lands? Illustrate the angle. **(2 marks)**

## QUESTION 2

(a) In Figure 1, the mass $m_1$ is 2 kg, and the mass $m_2$ is 50 kg. The system moves such that $m_1$ moves upward and $m_2$ moves down the inclined plane. Both masses have an acceleration $a$ = 0.2 m/s$^2$. The coefficient of kinetic friction between $m_2$ and the inclined plane is $\mu_k$.

(i) Make a force diagram for each body. **(4 marks)**
(ii) Find the coefficient of kinetic friction $\mu_k$ between $m_2$ and the inclined plane. **(6 marks)**

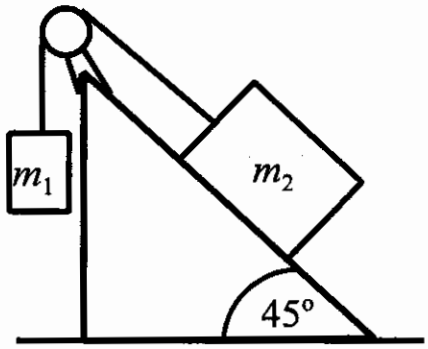


**Figure 1.**

(b) The system shown in Figure 2 is in equilibrium. The beam is uniform, 10 metres long, and weighs 500 N. The cord is attached at a distance of 5 m from the wall. The man who has a mass of $m_p$ = 85 kg stands 7 m from the wall. The hanging mass $m$ = 20 kg is at the end of the beam. Determine

(i) the tension in the cord, **(8 marks)**
(ii) the $x$- and $y$-components of the reaction force by the wall, and **(4 marks)**
(iii) the angle $\phi$ the reaction force makes with the horizontal. Illustrate it. **(3 marks)**

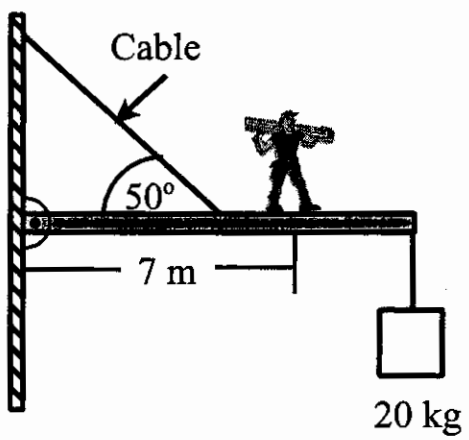


**Figure 2.**

**QUESTION 3**

(a) A body is projected upward with an initial velocity $v_0$ from the ground. When it reaches a height of 10 m its velocity is 20 m/s. Use energy methods to determine

(i) its initial velocity $v_0$, and **(5 marks)**

(ii) the maximum height $h$ reached. **(3 marks)**

(b) A body of mass $m$ = 2.5 kg with a velocity $v_0$ = 2 m/s moves on frictionless surface towards a horizontal spring of spring constant $k$ = 100 N/m. The spring is compressed a maximum distance $A$ before the mass comes to rest.

(i) Find the distance $A$. **(3 marks)**

(ii) What is the speed of the block when the spring is compressed 5 cm? **(3 marks)**

(c) A bullet of mass $m$ = 50 g moving with an initial speed $v_0$ = 300 m/s strikes a stationary metal block of mass $M$ = 2 kg. The block acquires a velocity of 10 m/s after the impact. What is the velocity of the bullet $v$ just after impact? Also state the direction of motion of the bullet after the impact. **(6 marks)**

(d) A disc with a moment of inertia $I_1$ = 150 kg.m$^2$ is rotating with angular velocity $\omega_0$ = 3000 rpm, and is brought in contact with a stationary disk of moment of inertia $I_2$ such that their axis of rotation coincide. The final angular velocity is $\omega'$ = 157 rad/s. What is the moment of inertia $I_2$ of the second disc? **(5 marks)**

**QUESTION 4**

(a) Sketch a fully labeled stress-strain diagram for a ductile material. **(6 marks)**

(b) Explain which is more important between a force and stress in causing damage to a surface. Use an example to illustrate your explanation. **(3 marks)**

(c) State Archimedes principle. **(2 marks)**

(d) A plastic sphere floats in water with 50 percent of its volume submerged. This same sphere floats in glycerine with 40 percent of its volume submerged.

(i) What is the density of the sphere? **(3 marks)**
(ii) What is the density of the glycerine? **(3 marks)**

(e) A metal block of mass 150 g at 120 °C is placed into 100 g copper cylinder containing 200 g of water at 20 °C. The final temperature of the system is 25 °C. The specific heat capacity of copper is 385 J/(kg.K). What is the specific heat capacity of the metal block? **(8 marks)**

**QUESTION 5**

(a) An industrial machine produces a sound at an average power of 100 W.

(i) At what distance from the source is the sound level at 80 dB? **(4 marks)**
(ii) If the power is doubled, what will be the sound level at the distance obtained in (i) above? **(2 marks)**

(b) A light ray enters oil of refractive index 1.48 from air at an angle $\theta$. The light ray is refracted at an angle of 20° in the oil. The oil floats on water of refractive index 1.33. Upon reaching the oil-water interface, the light ray is refracted by an angle $\theta'$. Refer to Figure 3.

(i) Find the angle $\theta$. **(3 marks)**
(ii) find the angle $\theta'$. **(3 marks)**

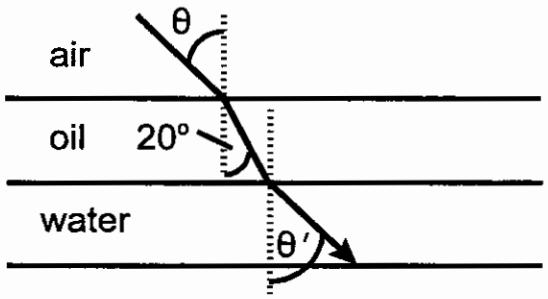


**Figure 3.**

(c) The near point of a person is 3 m. What must be the focal length of the spectacle lenses for the person to read a newspaper at a distance of 25 cm? **(4 marks)**

(d) Three charges are arranged such that $q_1$ = 2 μC is at $y$ = 10 cm, $q_2$ = 4 μC is at $x$ = 10 cm, and $q_3$ = -3 μC is at the origin. See Figure 4. Find the $x$- and $y$-components of the force on $q_3$ due to the other two charges. **(9 marks)**

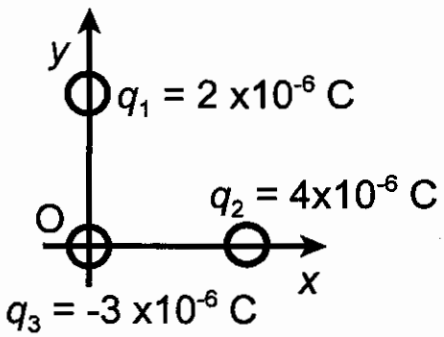


**Figure 4.**

## QUESTION 6

(a) In the circuit shown in Figure 5, use Kirchoff's laws and a diagram to set-up the equations for determining the currents $I_1$, $I_2$, $I_3$ and $I_4$. Do not solve the equations. **(8 marks)**

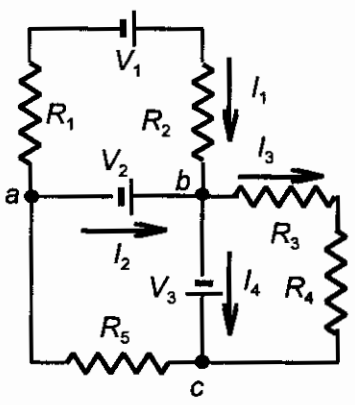


**Figure 5.**

(b) Figure 6 is a diagram of the Bainbridge mass spectrometer. The region with ***B*** and ***E*** is the velocity selector. The doted line is the path of positively charged ions of charge $q$ moving at a velocity $v$ along the negative $z$ direction. The charged particles come at a velocity of $5 \times 10^6$ m/s. The magnitude of the magnetic field ***B*** is 1 T. The particles are singly ionized xenon ions, $^{129}Xe$, $^{131}Xe$, and $^{132}Xe$.

(i) Use the cross product to determine the direction of the magnetic field ***B*** in the velocity selector. **(6 marks)**

(ii) Derive with, explanations, an expressions that relates the radius of curvature $r$ to the mass $m$, the velocity $v$, the magnetic field ***B′*** and the charge $q$ of a charged particle in the electric field free region of a mass spectrometer. **(6 marks)**

(iii) What is the electric field between the plate $P$ and $P'$? **(2 marks)**

(iv) What is the radius of motion of each magnesium isotope in the electric field free region, assuming that the magnetic field ***B′*** = 0.5 T? **(3 marks)**

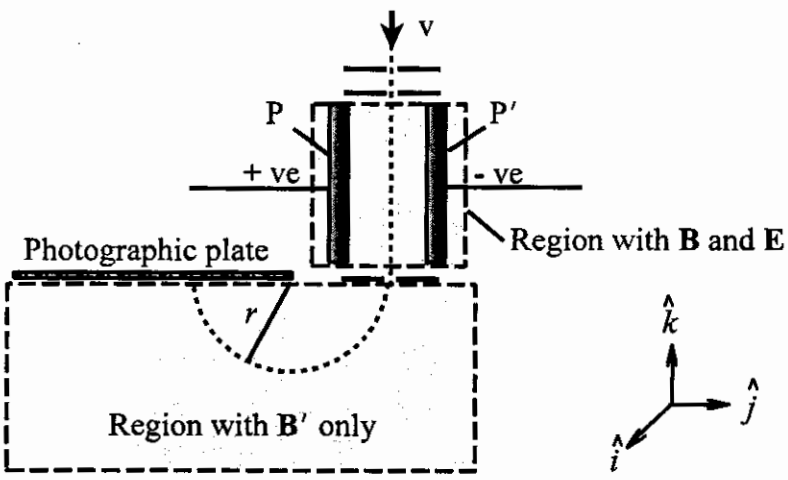


**Figure 6.**

## GENERAL DATA SHEET

Speed of light in vacuum $c = 2.9978 \times 10^8$ m/s
Speed of sound in air = 334 m/s
Gravitational acceleration = 9.80 m/s$^2$
Universal gravitational constant $G = 6.67 \times 10^{-11}$ N m$^2$/kg$^2$
Density of mercury = $1.36 \times 10^4$ kg/m$^3$
Density of water = 1000 kg/m$^3$
Standard atmospheric pressure = $1.013 \times 10^5$ Pa
Gas constant $R$ = 8.314 J/(K mol)
Avogadro's number $N_A = 6.022 \times 10^{23}$ mol$^{-1}$
$I_0 = 10^{-12}$ W/m$^2$
1 calorie = 1 c = 4.186 J
1 food calorie = 1 Calorie = 1C = $10^3$ calories = $4.186 \times 10^3$ J

c(*water*) = 4186 J/(kg K) c(*ice*) = 2090 J/(kg K) c(*steam*) = 2079 J/(kg K)
$L_f$(*ice*) = $3.33 \times 10^5$ J/kg $L_v$(*water*) = $2.260 \times 10^6$ J/kg

$$k = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \text{ Nm}^2/\text{C}^2$$

Charge of an electron = $-1.6 \times 10^{-19}$ C
Charge of a proton = $+1.6 \times 10^{-19}$ C
1 atomic mass unit = 1 amu = 1 u = $1.66 \times 10^{-27}$ kg
Electron mass, $m_e = 9.109 \times 10^{-31}$ kg
Proton mass, $m_p = 1.673 \times 10^{-27}$ kg
Neutron mass $m_n = 1.675 \times 10^{-27}$ kg