UNIVERSITY OF JOHANNESBURG

# FACULTY OF SCIENCE

**DEPARTMENT OF APPLIED PHYSICS & ENGINEERING MATHEMATICS**

NATIONAL DIPLOMA IN CHEMICAL ENGINEERING
ENGINEERING METALLURY
EXTRACTION METALLURGY

**MODULE** PHY1ABT
PHYSICS I (Theory)

**CAMPUS** **DFC**

**JUNE EXAMINATION**

**DATE: 08 June 2016** **SESSION: 12:30 – 15:30**

**ASSESSOR:** **MR. T.G. MATHE**

**INTERNAL MODERATOR:** **DR. L. REDDY**

**DURATION: 3 HOURS** **MARKS: 140**

---

**NUMBER OF PAGES: 13 PAGES, INCLUDING 2 INFORMATION SHEETS**

**<u>INSTRUCTIONS</u>:**

**SCIENTIFIC CALCULATORS ARE PERMITTED (ONLY ONE PER STUDENT).**

**<u>REQUIREMENTS</u>:**

- **ONE EXAMINATION ANSWER SCRIPT PER STUDENT**
- **ONE UJ MULTIPLE CHOICE ANSWER SHEET**

**INSTRUCTIONS TO CANDIDATES:**

1. **Answer ALL the questions.**
2. **Answer SECTION A on the provided examination answer script.**
3. **Answer SECTION B on the UJ multiple choice answer sheet.**
   **FOLLOW THE INSTRUCTIONS ON THE SHEET CAREFULLY.**
   **DO NOT MARK MORE THAN ONE ANSWER PER ROW.**
   **DO NOT FOLD OR CREASE THE SHEET.**
4. **Place the multiple choice answer sheet inside the answer script when handing in.**
5. **An information sheet is attached at the end of the question paper.**
6. **Work written in pencil will not be marked. However, drawings may be done in pencil.**
7. **You may start with any question but all sub-questions must be kept together.**
8. **In Section A, start each question on a new page.**
9. **In all calculations, significant figures must be observed.**

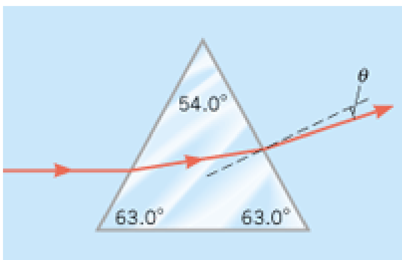
## SECTION A [96 marks]

## QUESTION 1 [25 marks]

1.1 A candle is placed 15.0 cm in front of a convex mirror. When the convex mirror is replaced with a plane mirror, the image moves 7.0 cm farther away from the mirror. Find the focal length of the convex mirror. (5)

1.2 Two converging lenses are separated by 24.00 cm. The focal length of each lens is 12.00 cm. An object is placed 36.00 cm to the left of the lens that is on the left. Determine the final image distance relative to the lens on the right. (6)

1.3 The drawing shows a horizontal beam of light that is incident on a prism made from ice. The base of the prism is also horizontal. The prism ($n$ = 1.31) is surrounded by water whose index of refraction is 1.33. Determine the angle θ that the exiting light makes with the normal to the right face of the prism. (6)



1.4 In a Young's double-slit experiment, the wavelength of the light used is 520 nm (in vacuum), and the separation between the slits is $1.4\times 10^{-6}$ m Determine the angle that locates

(a) the dark fringe for which $m$ = 1, and (2)
(b) the bright fringe for which $m$ = 2. (2)

1.5 Light shines through a single slit whose width is $5.6 \times 10^{-4}$ m. A diffraction pattern is formed on a flat screen located 4.0 m away. The distance between the middle of the central bright fringe and the first dark fringe is 3.5 mm. What is the wavelength of the light? (4)

---

**<u>QUESTION 2 [16 marks]</u> Start on a new page**

2.1 A container which is 1.00 m tall, is completely filled, partway with mercury and the rest of the way with water. The container is open to the atmosphere. What must be the depth of the mercury so that the absolute pressure at the bottom of the container is **twice** the atmospheric pressure?
$[\boldsymbol{\rho_{\text{mercury}} = 13.6 \times 10^3\ \text{kg.m}^{-3}};\ \boldsymbol{\rho_{\text{water}} = 1.00 \times 10^3\ \text{kg.m}^{-3}};$
$\boldsymbol{g = 9.80\ \text{m.s}^{-2}};\ \boldsymbol{P_{\text{atm}} = 1.01 \times 10^5\ \text{Pa}}]$ (6)

2.2 A dentist's chair with a patient in it weighs 2100 N. The output plunger of a hydraulic system begins to lift the chair when the dentist's foot applies a force of 55 N to the input piston. Neglect any height difference between the plunger and the piston. What is the ratio of the radius of the plunger to the radius of the piston? (5)

2.3 A 58 kg skier is going down a slope inclined at 35° above the horizontal. The area of each ski in contact with the snow is 0.13 $m^2$. Determine the pressure that each ski exerts on the snow. (4)

---

**<u>QUESTION 3 [25 marks]</u> Start on a new page**

3.1 A 325 kg boat is sailing 15.0° north of east at a speed of 2.00 $m.s^{-1}$. Twenty seconds (20.0 s) later, it is sailing 35.0° north of east at a speed of 4.00 $m.s^{-1}$. During this time, **three** forces act on the boat:

- a 31.0 N force directed 15.0° north of east (due to an auxiliary engine),
- a 23.0 N force directed 15.0° south of west (resistance due to the water),
- $\vec{F}_W$ (due to the wind).

Calculate the magnitude **and** direction of the force $F_W$.
**Express the directional angle in a bearing method and in a cardinal point method.** (11)

3.2 The drawing shows three objects. They are connected by strings that pass over massless and frictionless pulleys. The objects move, and the coefficient of kinetic friction between the middle object and the surface of the table is 0.100.

(a) What is the acceleration of the three objects? (4)
(b) Find the tension in each of the two strings. (3)


3.3 A 1200 kg car is being driven up a 5.0° hill. The frictional force is directed opposite to the motion of the car and has a magnitude of $f$ = 524 N. A force $\vec{F}$ is applied to the car by the road and propels the car forward. In addition to these two forces, two other forces act on the car: its weight $\vec{W}$ and the normal force $\vec{F_N}$ directed perpendicular to the road surface. The length of the road up the hill is 290 m. What should be the magnitude of $\vec{F}$, so that the net work done by all the forces acting on the car is +150 kJ? (7)

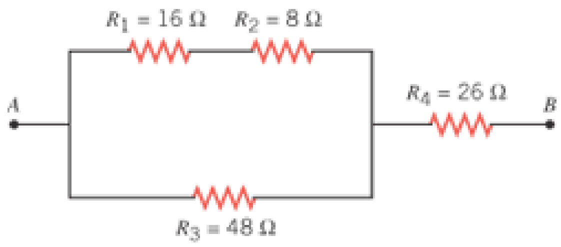
**<u>QUESTION 4 [15 marks]</u> Start on a new page**

4.1 A car battery has a rating of 220 ampere·hours (A·h). This rating is one indication of the *total charge* that the battery can provide to a circuit before failing.

(a) What is the total charge (in coulombs) that this battery can provide? (3)
(b) Determine the maximum current that the battery can provide for 38 minutes. (2)

4.2 Tungsten has a temperature coefficient of resistivity of 0.0045 $(^{o}C)^{-1}$. A tungsten wire is connected to a source of constant voltage via a switch. At the instant the switch is closed, the temperature of the wire is 28°C, and the initial electric power delivered to the wire is $P_0$. At what wire temperature will the power that is delivered to the wire be decreased to $\frac{1}{2}P_o$? (5)

4.3 Find the equivalent resistance between the points *A* and *B* in the drawing.




(5)

**<u>QUESTION 5 [15 marks]</u> Start on a new page**

5.1 Suppose that the steel petrol tank in your car is completely filled when the temperature is 17 °C. How many gallons will spill out of the twenty-gallon tank when the temperature rises to 35 °C? (4)
[**1 gal = 3.785** × **10$^{-3}$ m$^{3}$**; $\boldsymbol{\beta_{steel} = 3.6 \times 10^{-5}\,°C^{-1}}$; $\boldsymbol{\alpha_{petrol} = 3.2 \times 10^{-4}\,°C^{-1}}$]

5.2 An ideal gas at 15.5 °C and a pressure of 1.72 × 10$^{5}$ Pa occupies a volume of 2.81 m$^{3}$.

(a) How many moles of gas are present? (2)
(b) If the volume is raised to 4.16 m$^{3}$ and the temperature raised to 28.2 °C, what will be the pressure of the gas? (2)
**[R = 8.31 J.mol$^{-1}$.K$^{-1}$]**

5.3 An unknown material has a normal melting/freezing point of –25.0 °C, and the liquid phase has a specific heat capacity of 160 $J.kg^{-1}\cdot(^{o}C)^{-1}$. One-tenth of a kilogram of the solid at –25.0 °C is put into a 0.150 kg aluminium calorimeter cup that contains 0.100 kg of glycerine. The temperature of the cup and the glycerine is initially 27.0 °C. All the unknown material melts, and the final temperature at equilibrium is 20.0 °C. The calorimeter neither loses energy to nor gains energy from the external environment. What is the latent heat of fusion of the unknown material?

**Specific heat capacity of aluminium = 900 $J.kg^{-1}.^{o}C^{-1}$**
**Specific heat capacity of glycerine = 2410 $J.\ kg^{-1}.^{o}C^{-1}$** (7)

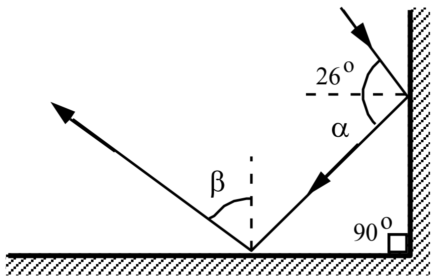
## SECTION B – MULTIPLE CHOICE QUESTIONS [44 marks]

1. Complete the following sentence: The term *coherence* relates to

A. The phase relationship between two waves.
B. The amplitude of two waves.
C. The speed of two waves.
D. The frequency of two waves.
E. The diffraction of two waves.

2. A ray of light is reflected from two plane mirror surfaces as shown in the figure. What are the correct values of α and β?

| | *Value of* α | *Value of* β |
|---|---|---|
| A. | 26° | 26° |
| B. | 26° | 64° |
| C. | 38° | 52° |
| D. | 52° | 26° |
| E. | 64° | 26° |



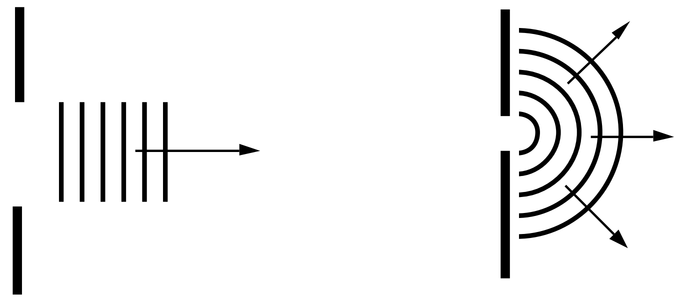

3. Which one of the following statements concerning the index of refraction for a given material is true?

A. The index of refraction may be less than 1.
B. The index of refraction may be measured in nanometers.
C. The index of refraction does not depend on the frequency of the incident light.
D. For a given frequency, the index of refraction is inversely proportional to the wavelength of light in vacuum.
E. For a given frequency, the index of refraction is inversely proportional to the wavelength of light in the material.

4. Which physical phenomenon is illustrated by the fact that the emerging rays are spread into the component colors of the beam?

A. refraction
B. dispersion
C. diffraction
D. total internal reflection
E. interference

5. Water waves approach a slit. The resulting patterns are shown for two different cases, **A** and **B**, in which the wavelength and slit size are varied.



A B

Which one of the following statements concerning these cases is **true**?

A. Neither figure shows diffraction. In both cases, the wavelength is much smaller than the slit.
B. Diffraction occurs in **A**, but not in **B** because the wavelength in **A** is much smaller than the slit.
C. Diffraction occurs in **B**, but not in **A** because the wavelength in **B** is much smaller than the slit.
D. Both figures show diffraction. In both cases, the wavelengths are approximately the same size as the slit.
E. Diffraction occurs in **B**, but not in **A** because the wavelength in **B** is approximately the same size as the slit.

6. Complete the following sentence: The operation of a hydraulic jack is an application of

A. Pascal's principle.
B. Newton’s third law of motion.
C. Law of hydraulics.
D. Huygen’s principle.
E. Hydrostatic pressure.

7. Which one of the following statements concerning a completely enclosed fluid is true?

A. Any change in the applied pressure of the fluid produces a change in pressure that depends on direction.
B. The pressure at all points within the fluid is independent of any pressure applied to it.
C. Any change in applied pressure produces an equal change in pressure at all points within the fluid.
D. An increase in pressure in one part of the fluid results in an equal decrease in pressure in another part.
E. The pressure in the fluid is the same at all points within the fluid.

8. The two dams are identical with the exception that the water reservoir behind dam **A** extends twice the horizontal distance behind it as that of dam **B**. Which one of the following statements regarding these dams is correct?

A. The force exerted by the water on dam **A** is greater than that on dam **B**.
B. The force exerted by the water on dam **B** is greater than that on dam **A**.
C. Dam **A** is more likely to collapse than dam **B** if the water level rises.
D. Dam **B** is more likely to collapse than dam **A** if the water level rises.
E. The horizontal distance of the water behind the two dams does not determine the force on them.

9. During the first 18 minutes of a 1.0-hour trip, a car has an average speed of 11 m.s$^{-1}$. What must the average speed of the car be during the last 42 minutes of the trip be if the car is to have an average speed of 21 m.s$^{-1}$ for the entire trip?

A. 21 m.s$^{-1}$
B. 23 m.s$^{-1}$
C. 25 m.s$^{-1}$
D. 27 m.s$^{-1}$
E. 29 m.s$^{-1}$

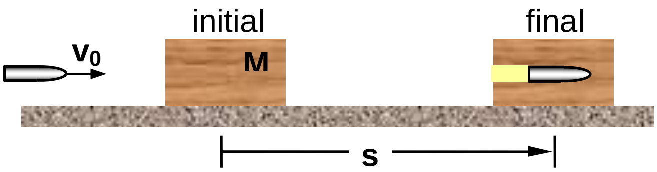
10. An elevator is moving upward with a speed of 11 m.s$^{-1}$. Three seconds later, the elevator is still moving upward, but its speed has been reduced to 5.0 m.s$^{-1}$. What is the average acceleration of the elevator during the 3.0 s interval?

A. 2.0 m.s$^{-2}$, upward
B. 5.3 m.s$^{-2}$, upward
C. 2.7 m.s$^{-2}$, downward
D. 2.0 m.s$^{-2}$, downward
E. 5.3 m.s$^{-2}$, downward

11. A ball is dropped from rest from a tower and strikes the ground 125 m below. Approximately how many seconds does it take the ball to strike the ground after being dropped? Neglect air resistance.

A. 2.50 s
B. 3.50 s
C. 5.05 s
D. 12.5 s
E. 16.0 s

12. A bullet of mass *m* is fired at speed $v_0$ into a wooden block of mass *M*. The bullet instantaneously comes to rest in the block. The block with the embedded bullet slides along a horizontal surface with a coefficient of kinetic friction $\mu$.




Which one of the following expressions determines how far the block slides before it comes to rest (i.e. the magnitude of displacement **s** in the figure)?

A. $s = \dfrac{mv_0^2}{M\mu g}$
B. $s = \dfrac{m}{m+M}\left(\dfrac{v_0^2}{\mu g}\right)$
C. $s = \left(\dfrac{m}{m+M}\right)^2 \dfrac{v_0^2}{2\mu g}$
D. $s = \left(\dfrac{m}{m+M}\right)^2 \sqrt{\dfrac{v_0^2}{2\mu g}}$
E. $s = \dfrac{v_0^2}{\mu g}$

13. Complete the following statement: A collision is *elastic* if

A. the final velocities are zero.
B. the final momentum is zero.
C. the objects stick together.
D. the total kinetic energy is conserved.
E. the final kinetic energy is zero.

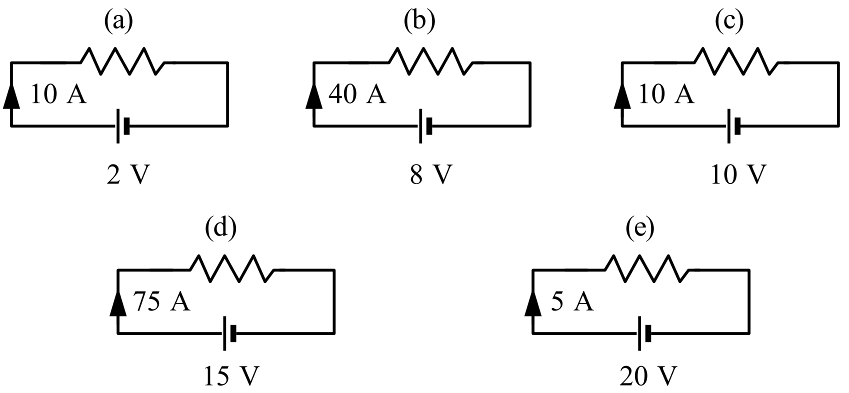
14. How much power is needed to lift a 75 kg student vertically upward at a constant speed of 0.33 m.s$^{-1}$?

A. 12.5 W
B. 115 W
C. 243 W
D. 25 W
E. 230 W

15. The potential difference across the ends of a wire is doubled in magnitude. If Ohm's law is obeyed, which one of the following statements concerning the resistance of the wire is **true**?

A. The resistance is one-half of its original value.
B. The resistance is twice its original value.
C. The resistance is not changed.
D. The resistance increases by a factor of four.
E. The resistance decreases by a factor of four.

16. Which one of the following circuits has the **largest** resistance?




17. Which one of the following statements concerning resistance is **true**?

A. The resistance of a semiconductor increases with temperature.
B. Resistance is a property of resistors, but not conductors.
C. The resistance of a metal wire changes with temperature.
D. The resistance is the same for all samples of the same material.
E. The resistance of a wire is inversely proportional to the length of the wire.

18. A non-ideal battery has a 6.0 V *emf* and an internal resistance of 0.6 Ω. Determine the terminal voltage when the current drawn from the battery is 1.0 A.

A. 5.0 V
B. 6.0 V
C. 5.4 V
D. 6.6 V
E. 5.8 V

19. Absolute zero on the Celsius temperature scale is –273.15 °C. What is absolute zero on the Fahrenheit temperature scale?

A. –331.67 °F
B. –363.67 °F
C. –395.67 °F
D. –427.67 °F
E. –459.67 °F

11/…

20. Which one of the following statements is the best explanation for the fact that metal pipes that carry water often burst during cold winter months?

    A. Water contracts upon freezing while the metal expands at lower temperatures.
    B. The metal contracts to a greater extent than the water.
    C. The interior of the pipe contracts less than the outside of the pipe.
    D. Water expands upon freezing while the metal contracts at lower temperatures.
    E. Both the metal and the water expand, but the water expands to a greater extent.

21. Which one of the following statements explains why it is difficult to measure the coefficient of volume expansion for a liquid?

    A. Liquids are more compact than solids.
    B. Liquids are more compact than gases.
    C. Liquids tend to expand more slowly than solids.
    D. The liquid will lose heat to the containing vessel.
    E. The volume of the containing vessel will also increase.

22. Under which of the following conditions would you expect real gases to approach ideal gas behaviour?

    A. Low temperature and low pressure
    B. High temperature and high pressure
    C. High temperature and low pressure
    D. High temperature and high density
    E. Low temperature and high pressure

**END OF EXAMINATION**

---

**TOTAL MARKS = 140**
**100% = 140**