The University of Zambia
Physics Department
University Examinations 2018-19
PHY 1010: Introductory Physics

All questions carry equal marks. The marks are shown in brackets. Question 1 is compulsory. Attempt four (4) more questions. Clearly indicate on the answer script left column on the cover page the questions you have answered. Some useful equations are given at the back of the question paper.

Time : Three hours. **Maximum marks = 100.**

Do not forget to write your computer number clearly on the answer book as well as on the answer sheet for Question 1. Tie them together.

==

Wherever necessary use:

$g = 9.8 \text{ m/s}^2$

$P_A = 1.01 \times 10^5 \text{ N/m}^2$

1 cal. = 4.18 J

$C_{water} = 4184$ J/kg.°C

$R = 8314$ J/kmol.K

$K_B = 1.381 \times 10^{-23}$ J/K (Bolzmann's constant)

$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{Nm}^2$

$c = 3 \times 10^8$ m/s

$h = 6.63 \times 10^{-34}$ J-s

1 pascal = 1 N/m^2

$1\text{eV} = 1.6 \times 10^{-19}$ J

$e = 1.6 \times 10^{-19}$ C

$m_e = 9.11 \times 10^{-31}$ kg

$k = 9 \times 10^9\ \text{Nm}^2/\text{C}^2$

$\mu_0 = 4\pi \times 10^{-7}\ \text{N/A}^2$

$\rho_{water} = 1000\ \text{kg/m}^3$

$G = 6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2$

1 metric ton = 1000 kg

H_f = 80 cal/g-water

H_v = 539 cal/g-steam

1 litre = $1 \times 10^{-3}\ \text{m}^3$

Vol. sphere = $\frac{4}{3}\pi r^3$

N.B. Useful equations are on pages 7 and 8

Question 1: For each correct answer, 2 marks will be given. For each wrong answer, 0.67 will be deducted. For no answer, zero mark will be given. The minimum total mark for Question 1 is zero.

(A) In natural convection a heated portion of fluid moves because:

a) of molecular vibrations about the equilibrium
b) its density is less than that of the surrounding fluid.
c) of molecular collisions within it.
d) its molecular motions become aligned.

(B) A Carnot engine that operates between the absolute temperatures T_1 and T_2:

a) Has an efficiency of T_1/T_2.
b) Is 100% efficient.
c) Has an efficiency of a non-reversible engine.
d) Has the maximum efficiency possible for the given temperatures.

(C) Sound travels fastest in:

a) water
b) a vacuum
c) solids
d) air

(D) The stress on a wire supporting a load does not depend on:

a) wire's length
b) wire's diameter
c) the mass of the load
d) the acceleration of gravity

(E) Objects may acquire an excess or deficiency of charge electrostatically by:

a) grounding them
b) rubbing them together
c) shielding them
d) putting them together

(F) The rotational corresponding term to force in linear motion is:

a) angular momentum
b) moment of inertia
c) angular velocity
d) torque

(G) The amplitude of the motion of an object undergoing SHM is:

a) its minimum displacement on either side of the equilibrium position

b) its the maximum displacement on either side of the equilibrium position

c) its total range of motion

d) the number of cycles per second it undergoes

(H) In a perfectly elastic collision between two objects, their relative velocity after the collision is:

a) zero

b) less than their relative velocity before the collision

c) more than their relative velocity before the collision

d) equal to their relative speed before collision

(I) A tablet of soap placed in water filled bathtub sinks. The buoyant force on the soap is:

a) more than its weight

b) equal to its weight

c) less than its weight

d) negligible

(J) Which of the following formulas expresses the relationship between the pressure and absolute temperature of a gas whose volume is fixed?

a) $\frac{P_1}{T_2} = \frac{P_2}{T_1}$

b) $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

c) $\frac{P_1}{P_2} = \frac{T_2}{T_1}$

d) $\frac{P_1}{T_1} = \frac{T_2}{P_2}$

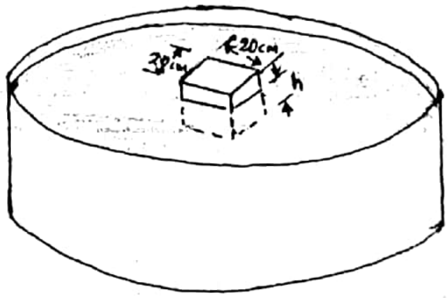
Attempt any four questions from the following:

Q2 (a) What is the minimum amount of ice at -15 °C that must be added to 0.60 kg water at 20 °C in order to bring the temperature of water down to 0 °C? Given c_{ice} = 2.09 kJ/kg °C, H_f = 335 kJ/kg, and c_{water} = 4.184 kJ/kg°C. [11]

(b) A cube of wood with edge dimension 20 cm and density 650 kg floats on water as shown in the figure below.

i) What is the distance from the horizontal top surface of the cube to the water level? [6]

ii) What additional weight must be placed on the cube so that the top surface of the cube will be just level with the water surface? [3]

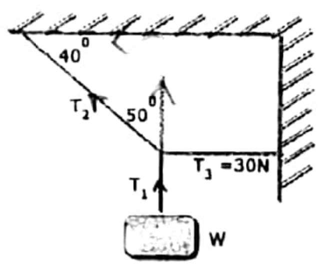


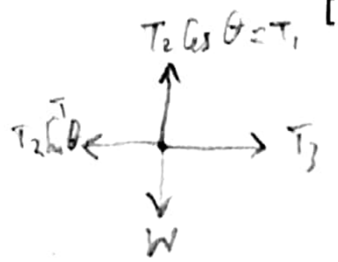
Q.3 (a) A sealed glass bulb is filled with pure nitrogen gas at a pressure of 2.0 atm. The volume of the container is 500 cm³ and the temperature is 22 °C.

i) Calculate the number of moles and mass of the nitrogen gas (1 mole N_2 = 28 g) within the bulb. [5]

ii) If the nitrogen gas is heated to 100 °C, what will be the pressure? [5]

(b) In the figure below, the tension in the horizontal cord is 30N. Find the weight of W of the hanging object. [10]





Q.4 (a) An ideal refrigerator, which is a Carnot engine operating in reverse, operates between inside temperature of -4 °C and a room temperature of 27 °C. In a certain period, it absorbs 115 J from the interior. How much heat is rejected to the room? [9]

(b) A uniform disk released from the top of an inclined plane reaches the bottom with a velocity of 15 m/s. How high is the upper end of the inclined plane in relation to the horizontal level? Assume that the disk rolls without slipping and that there is no friction loss. (I_{disk} = ½mr^2) [7]

(c) A certain amount of heat is added to a mass of aluminium (c = 0.12 cal/g.^{0}C), and its temperature is raised to 70 ^{0}C. If the same amount of heat is added to the same mass of copper (c = 0.093 cal/g.^{0}C). How does the temperature of the copper rise? [4]

Q.5 (a) The sound level measured 50 m from a jumbo jet is 120 dB. What is the intensity sound level at 250 m? (treat the source as a point source) [10]

(b) A marble moving at 5.00 m/s east strikes a stationary marble of the same mass. After the collision the first marble moves at 4.33 m/s at angle of 30^0 with respect to the original direction (i.e. above the original line of motion). Find:

i) the velocity of the second ball, and [8]

ii) its direction. [2]

(10)

Q.6 (a) A stone is thrown upward from the top of a building at angle of 25^0 to the horizontal and with an initial velocity of 15 m/s. If the stone is in flight for 3.0 seconds, how tall is the building? [10]

(10)

(b) A boy stands at the platform of train station. He blows a whistle of frequency 700 Hz. A train passes at 72 km/h. What does the frequency of the whistle appear to a man sitting in the train as the train

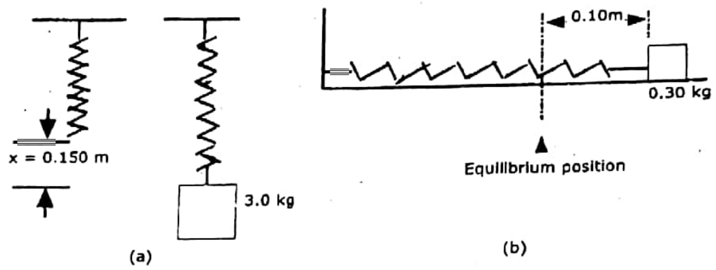
i) approaches the boy? [5]

ii) moves away from the boy the boy (velocity of sound as 340 m/s)? [3]

iii) Comment on the frequencies heard by the listener on the train. [2]

Q.7 (a) A spring stretches 0.150 m when a 3 kg mass is gently hung on it as shown in figure (a) below. The spring is then setup horizontally with 0.30 kg mass resting on frictionless table as in figure (b) below. The mass is pulled so that the spring is stretched 0.100 m from equilibrium point, and released from rest. Determine the:

i) spring constant of the spring; [1]
ii) amplitude of the horizontal oscillation of the 0.30 kg mass; [1]
iii) magnitude of the maximum velocity; [4]
iv) magnitude of the velocity when the mass is 0.05 m from equilibrium; and [2]
v) the maximum acceleration of the mass. [2]

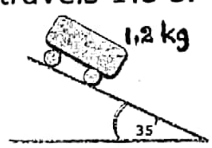


(a) (b)

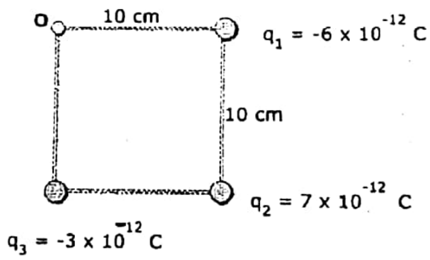
(b) A wagon with small wheels and well lubricated bearings (frictionless) is released from rest on an inclined plane which makes an angle of 35⁰ with the horizontal. If the mass of the wagon is 1.2 kg. Determine the:

i) magnitude of the force exerted by the surface on the wagon [3]
ii) acceleration of the cart [3]
iii) speed of the wagon after a time of 1.5 s [2]
iv) distance the wagon travels 1.5 s. [2]

10

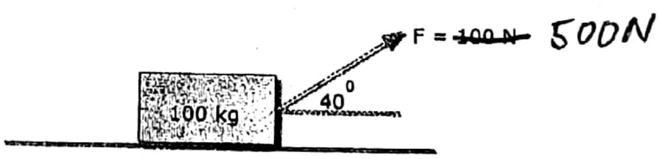


Q.8 (a) Three charges $Q_1 = -6 \times 10^{-12}$ C, $Q_2 = 7 \times 10^{-12}$ C, and $Q_3 = -3 \times 10^{-12}$ C are placed at three corners of a square 10 cm on a side, as shown. Find the magnitude and direction of the total electric field at point *O*. [11]



(b) A 100 kg box shown below is pulled by a 500 N force at an angle of 40⁰ with respect to the horizontal. The coefficient of kinetic friction between the box and the surface is 0.5. Find the acceleration of the box. [9]

9



END OF EXAMINATION

Thermal Properties of matter:

$PV = nRT$: $\Delta Q = mc\Delta T = nC\Delta T$: $\Delta L = \alpha L \Delta T$: $L_t = L_0(1+\alpha t)$: $\Delta V = \gamma V \Delta T$:

$W = P\Delta V$ $(\Delta Q / \Delta t) = (kA\Delta T)/\Delta L$: $m = V \times \rho$ $\frac{Q}{t} = eA\sigma T^4$ $C_P = C_V + R$

$Q = n.C.\Delta T = \frac{3}{2} n.R.\Delta T$ for isobaric and iso-volumetric processes

Thermodynamics:

abaitic

$\Delta Q = \Delta U + \Delta W$: $W = p.\Delta V$ $PV = nRT$ $n = \frac{m}{M}$ $P_1V_1^{\gamma} = P_2V_2^{\gamma}$ $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$COP_{ref} = \frac{Q_C}{W}$ $COP_{heat\ pump} = \frac{Q_H}{W}$ $W_{isothermal} = nRT \ln \frac{V_2}{V_1}$

$W_{adiabatic} = \frac{1}{\gamma - 1}(P_1V_1 - P_2V_2)$: $COP_{max-refr} = \frac{T_C}{W}$ $COP_{max-heat\ pump} = \frac{T_H}{W}$

$e = 1 - \frac{T_c}{T_h} = \frac{\text{work done}}{\text{input heat at high temp}}$

Waves and Sound:

$f = \frac{1}{\tau}$ $v = \pm\sqrt{\frac{k}{m}(x_0^2 - x^2)}$ $v = \sqrt{\frac{T}{m/L}}$ $\tau = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}}$ $a = -\left(\frac{k}{m}\right)x$ $v = \sqrt{\frac{Y}{\rho}}$

$v = \sqrt{\frac{B}{\rho}}$ $f' = f\frac{v \pm v_L}{v \mp v_S}$ $(dB) = 10.\log\frac{I}{I_0}$

$\tau = \frac{2\pi x_0}{v_0} = 2\pi\left(\frac{x_0}{v_0}\right) = \frac{2\pi}{\omega}$ $f = \frac{1}{2L}\sqrt{\frac{T}{m}}$ $x = x_0\cos(\omega t)$ $I_0 = 10^{-12}\ W/m^2$

Electric Field:

$\boldsymbol{F} \propto \frac{q_1 q_2}{r^2}$ or $F = k.\frac{q_1 q_2}{r^2}$; $k = 8.9874 \times 10^9$ N.m^2.C^{-2} or $k = (1/(4\pi\varepsilon_0))$ where ε_0 is the permittivity constant $= 8.85 \times 10^{-12}$ C^2.(N.m^2)$^{-1}$.

Some Useful Equations

Uniformly accelerated motion:

$x = \bar{v}t$ $\quad \bar{v} = \frac{1}{2}(v_f + v_i)$ $\quad v_f = v_i + at$ $\quad v_f^2 = v_i^2 + 2ax$ $\quad x = v_i t + \frac{1}{2}at^2$

Projectile motion:

$v_x = v_i \cos\theta_i$ = constant $\quad v_y = v_i \sin\theta_i - gt$ $\quad y = (v_i \sin\theta_i)t - \frac{1}{2}gt^2$

$y = (\tan\theta_i)x - \left[\frac{g}{2v_i^2(\cos^2\theta_i)}\right]x^2$ $\quad R = \frac{v_i^2}{g}\sin 2\theta$ $\quad t = \frac{2v_i \sin\theta}{g}$

Force and motion:

$F = ma$ $\quad w = mg$ $\quad F_{AB} = -F_{BA}$ $\quad F_f = \mu F_N$

Work and Energy:

$PE = wh = mgh$ $\quad KE = \frac{1}{2}mv^2$ $\quad W = Fx\cos\theta$ $\quad P = \frac{W}{t} = Fv\cos\theta$

Linear momentum: $\quad p = mv$ $\quad F\Delta t = \Delta mv = m\ v_f - v_0$

Circular motion and gravitation:

$T = \frac{2\pi r}{v}$ $\quad a_c = \frac{v^2}{r}$ $\quad F_c = \frac{mv^2}{r}$ $\quad F_{grav} = -G\frac{m_a m_b}{r^2}$ $\quad 1rev = 360^0 = 2\pi\, rad$

$v_T = \frac{(2\pi r)}{T}$: $\quad \tan\theta = \frac{v^2}{rg}$:

Rotational motion and angular momentum:

$\theta = \frac{s}{r} = \left(\frac{\omega_i + \omega_f}{2}\right)t$ $\quad \omega = \frac{\theta}{t}$ $\quad \theta = \omega_i t + \frac{1}{2}\alpha t^2$ $\quad \omega_f = \omega_i + \alpha t$ $\quad v = \omega r$

$I = mk^2$ $\quad \omega_f^2 = \omega_i^2 + 2\alpha\theta$ $\quad \alpha = \frac{\Delta\omega}{\Delta t} = \frac{a_T}{r}$ $\quad I = \sum mr^2$ $\quad KE_{rot} = \frac{1}{2}I\omega^2$

$\tau = FL = I\alpha$ $\quad W = \tau\theta$ $\quad P = \tau\omega$ $\quad L = I\omega$ $\quad KE_{total} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

Properties of matter:

$\rho = \frac{m}{V}$ $\quad F = -kx$ $\quad \frac{\Delta L}{L_i} = \frac{1}{Y}\frac{F}{A}$ $\quad \phi = \frac{s}{d} = \frac{1}{s}\frac{F}{A}$ $\quad B = -\frac{\Delta P}{\Delta V / V_0}$

$W_{app} = W\left(1 - \frac{\rho_{fluid}}{\rho}\right)$ $\quad F_B = \rho V g$, (submerged object) $\quad F_B = Mg$ (floating M)