UNIVERSITY
OF
JOHANNESBURG

PHYG01B/PHY1GB1 -Exam 2021

Total possible marks: 100 **Time:** 120 minutes

Examiner: Ms. CS van Niekerk **Moderator:** Prof. E Carleschi

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INSTRUCTIONS:
1) Insert units in the calculations and answer all questions (please do not write in pencil!).
2) Cell phones must be switched off in the test venue.
3) Remember that in derivations, figures and explanations carry marks.

Equations and Constants:

$\Delta L = L_0 \alpha \Delta T$ $Q = mc\Delta T$ $Q = \pm mL$ $\Delta U = Q + W$

$W = -P\Delta V$ $\frac{Q}{t} = \frac{kA\Delta T}{s}$ $v = \sqrt{\frac{B}{\rho}}$ $v = \sqrt{\frac{\tau}{\mu}}$

$y = A\sin\left(\frac{2\pi t}{T} + \phi\right)$ $y = A\sin\left(\frac{2\pi t}{T} - \frac{2\pi x}{\lambda} + \phi\right)$

$y = 2y_m\cos\left(\frac{1}{2}\phi\right)\sin\left(kx - \omega t + \frac{1}{2}\phi\right)$ $y = 2A\cos\left(\frac{2\pi t}{T}\right)\sin\left(\frac{2\pi x}{\lambda}\right)$

$q_e = 1.6 \times 10^{-19} C$ $\mu = qr$ $F_{12} = \frac{kq_1q_2}{r^2}$ $E = \frac{F}{q}$

$V = Es$ $I = \frac{q}{t}$ $V = IR$ $R = \frac{\rho L}{A}$

$F = qvB\sin\theta$ $v = \lambda f$ $n = \frac{c}{v}$ $\Delta L = d\sin\theta$

$n_1\sin\theta_1 = n_2\sin\theta_2$ $\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_i}$ $M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$ $h_i = \frac{n_2}{n_1}h_o$

$P = \sigma A T^4$ $\quad P = \frac{E}{t}$ $\quad E_n = \frac{-2.177 \times 10^{-18}}{n^2}$ $\quad \Delta E = hf = \frac{hc}{\lambda}$

$N = N_0 \exp(-0.693 \frac{t}{t_{1/2}})$ $\quad k = 9 \times 10^9 Nm^2C^{-2}$ $\quad \sigma = 5.6703 \times 10^{-8} Wm^{-2}K^{-4}$

$\lambda_{max} = \frac{2.898 \times 10^{-3}}{T}$ $\quad G = 6.67 \times 10^{-11} m^3 kg^{-1} s^{-2}$ $\quad h = 6.626 \times 10^{-34} Js^{-1}$

$c = 3 \times 10^7 ms^{-1}$ $\quad R = 1.097 \times 10^7 m^{-1}$ $\quad \Delta E(2H + 2n \rightarrow 1He) = 4.272 \times 10^{-12} J$

$P = P_0 \exp(\frac{-h}{H})$ $\quad F_s = \frac{\eta A \Delta v}{\Delta y}$ $\quad F_d = 6\pi R v \eta$

$P = P_0 + \rho g z$ $\quad A_1 v_1 = A_2 v_2$ $\quad J = -D \frac{\Delta C}{\Delta x}$

$D = \frac{kT}{6\pi\eta r}$

Question 1: **[20 Marks]**

For each of the following questions circle the appropriate option:

(I) A cube of aluminum has an edge length of 20 cm. Aluminum has a density 2.7 times that of water (1 g/cm^3) and a specific heat 0.217 times that of water (1 cal/gC°). When the internal energy of the cube increases by 47000 cal its temperature increases by: [2]

- (**a**) 5 °C
- (**b**) 10 °C
- (**c**) 20 °C
- (**d**) 100 °C
- (**e**) 200 °C

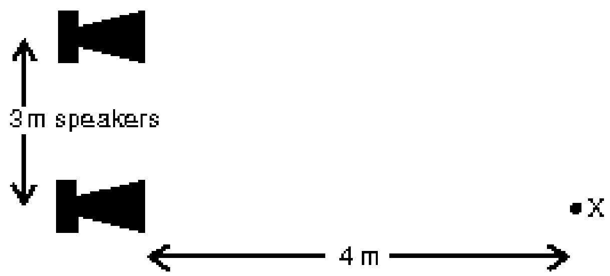
(II) Thermal energy can be transferred by convection: [2]

- (**a**) only in solids
- (**b**) only in liquids
- (**c**) only in gases
- (**d**) through a vacuum
- (**e**) in either liquids or solids

(III) Water waves in the sea are observed to have a wavelength of 300 m and a frequency of 0.07 Hz. The speed of these waves is: [2]

- (**a**) 0.00023 m/s
- (**b**) 2.1 m/s
- (**c**) 21 m/s
- (**d**) 4300 m/s
- (**e**) none of the above

(IV) Two small identical speakers are connected (in phase) to the same source. The speakers are 3 m apart and at ear level. An observer stands at X, 4 m in front of one speaker as shown. The sound she hears will be most intense if the wavelength is: [2]



- (**a**) 5 m
- (**b**) 4 m
- (**c**) 3 m
- (**d**) 2 m
- (**e**) 1 m

(V) An isolated point charged point particle produces an electric field with magnitude E at a point 2 m away from the charge. A point at which the field magnitude is E/4 is: [2]

- (**a**) 0.5 m away from the charge
- (**b**) 1 m away from the charge
- (**c**) 2 m away from the charge
- (**d**) 4 m away from the charge
- (**e**) 8 m away from the charge

(**VI**) During a lightning discharge, 30 C of charge move through a potential difference of 1.0 $\times 10^8$ V in 2.0 $\times 10^{-2}$ s. The energy released by this lightning bolt is: [2]

(**a**) 1.5×10^{11} J

(**b**) 3.0×10^{9} J

(**c**) 6.0×10^{7} J

(**d**) 3.3×10^{6} J

(**e**) 1500 J

(**VII**) The angle between a horizontal ruler and a vertical plane mirror is 30°. The angle between the ruler and its image is: [2]

(**a**) 15°

(**b**) 30°

(**c**) 60°

(**d**) 90°

(**e**) 180°

(**VIII**) A glass (n = 1.6) lens is coated with a thin film (n = 1.3) to reduce reflection of certain incident light. If λ is the wavelength of the light in the film, the least film thickness is: [2]

(**a**) less than $\lambda/4$

(**b**) $\lambda/4$

(**c**) $\lambda/2$

(**d**) λ

(**e**) more than λ

(**IX**) The surface of the Sun is at a temperature of approximately 5800 K, and radiates a peak wavelength of 500 nm. According to the Planck radiation law, calculate is its emitted intensity per unit wavelength at the peak. [2]

(**a**) 8.4 W/cm^{2}nm

(**b**) 42 W/cm^{2}nm

(**c**) 84 W/cm^{2}nm

(**d**) 8.4 $\times 10^3$ W/cm^{2}nm

(**e**) 4.2 $\times 10^7$ W/cm^{2}nm

(**X**) The half-life of radium is about 1600 years. If a rock initially contains 1 g of radium, the amount left after 8000 years will be about: [2]

(**a**) 200 mg

(**b**) 63 mg

(**c**) 31 mg

(**d**) 16 mg

(**e**) less than 1 mg

Question 2: **[15 Marks]**

2.1 Explain why countries located at the poles are colder than those at the equator. [2]

2.2 A 200 liter steel water tank is filled from a horizontal inlet pipe at the bottom. A vertical overflow pipe rises vertically from the top. Both pipes are 2.0 cm in diameter. How high does the water rise in the overflow pipe if the water is heated from 15 °C to 40 °C? (Given: $\beta_{water} = 210 \times 10^{-6}\ {}^{\circ}C^{-1}$) [4]

2.3 In order to extract the maximum flavor in the shortest amount of time, your local fast food purveyor has decided to brew its coffee at 90 °C and serve it quickly so that it has only cooled down to 85 °C. While this may be economically sensible, it is negligent and dangerous from a health and safety standpoint. Water (which is what coffee mostly is) at 85 °C is hot enough to cause third-degree burns in two to seven seconds. You decide to add ice cubes to your coffee to cool it down to a more reasonable 55 °C so you will be able to drink it sooner. How many 23.5 g ice cubes at -18.5 °C should you add to your 355 mL cup of coffee to accomplish your thermal goal? (Given: $c_{ice} = 2.06\ \ J/g°C$, $c_{water} = 4.18\ \ J/g°C$, $c_{steam} = 1.87\ \ J/g°C$ and $L_{f,water} = 334\ \ kJ/kg$, $L_{v,water} = 2260\ \ kJ/kg$) [4]

2.4 The part of a refrigerator responsible for the actual cooling is a closed system of pipes that runs both inside and outside the refrigerator. The substance in the pipes easily changes between the liquid and gaseous phases. Which phase change takes place inside the refrigerator and which takes place outside? [2]

2.5 Ice has formed on a shallow pond, and a constant temperature has been reached, with the air above the ice at -5.0 °C and the bottom of the pond at 4.0 °C. If the total depth of ice + water is 1.4 m, how thick is the ice? (Assume that the thermal conductivities of ice and water are 0.40 and 0.12 cal/m °Cs, respectively.) [3]

Question 3: **[15 Marks]**

3.1 A harmonic wave is traveling along a rope. It is observed that the oscillator that generates the wave completes 40.0 vibrations in 30.0 s. Also, a given maximum travels 425 cm along the rope in 10.0 s. What is the wavelength? [3]

3.2 Earthquakes at fault lines in Earth's crust create seismic waves, which are longitudinal (P-waves) or transverse (Swaves). The P-waves have a speed of about 7 km/s. Estimate the average bulk modulus of Earth's crust given that the density of rock is about 2 500 kg/m^3. [3]

3.3 There is evidence that elephants communicate via infrasound, generating rumbling vocalizations as low as 14 Hz that can travel up to 10 km. The intensity level of these sounds can reach 103 dB, measured a distance of 5.0 m from the source. Determine the intensity level of the infrasound 10 km from the source, assuming the sound energy radiates uniformly in all directions. [3]

3.4 A fisherman notices that his boat is moving up and down in a periodic way because of waves on the surface of the water. It takes 4.0 s for the boat to travel from its highest point to its lowest, a total distance of 3.0 m. The fisherman sees that the wave crests are spaced 8.0 m apart.

(**a**) How fast are the waves moving? [2]

(**b**) What is the amplitude, frequency, wavelength, and period of the waves? [4]

Question 4: **[18 Marks]**

4.1 A stun gun delivers 3 amperes of peak current in pulses lasting 80 microseconds. One pull of the trigger delivers 95 pulses in a 5 second cycle. A sustained 3 amps is more than enough to kill a person, but because it is delivered in such short bursts a stun gun is only capable of delivering intolerable pain. Determine the total charge delivered by the stun gun in one cycle. [4]

4.2 A standard 60 W, 120 V light bulb has a tungsten filament that is 53.3 cm long and 46 μm in diameter. Calculate the resistivity of tungsten. [4]

4.3 An alpha particle travels at a velocity of magnitude 550 m/s through a uniform magnetic field of magnitude 0.045 T. (An alpha particle has a charge of +3.2 $\times 10^{-19}$ C and a mass of 6.6 $\times 10^{-27}$ kg.) The angle between and is 52°.What is the magnitude of the force acting on the particle due to the field and the acceleration of the particle due to this force? [4]

4.4 A peanut is placed 40 cm in front of a two-lens system: lens 1 (nearer the peanut) has focal length f_1 =20 cm, lens 2 has f_2= 15 cm, and the lens separation is d = 10 cm. For the image produced by lens 2, calculate the:

(**a**) image distance [2]

(**b**) image height [2]

(**c**) image type (real or virtual) [1]

(**d**) image orientation (inverted relative to the eraser or not inverted)? [1]

Question 5: **[16 Marks]**

5.1 A star such as our Sun will eventually evolve to a “red giant” star and then to a “white dwarf” star. A typical white dwarf is approximately the size of Earth, and its surface temperature is about 2.5×10^4 K. A typical red giant has a surface temperature of 3.0×10^3 K and a radius $\approx$100,000 times larger than that of a white dwarf. What is the average radiated power per unit area and the total power radiated by each of these types of stars? How do they compare? [4]

5.2 If an all-electric home uses approximately 2 000 kWh of electric energy per month, how many fusion events described by the reaction 2H + 2n $\rightarrow$ 1 He would be required to keep this home running for one year? [4]

5.3 How much time elapses before 90.0% of the radioactivity of a sample of As disappears, as measured by its activity? The half-life of As is 26 h. [4]

5.4 A 5.00 g charcoal sample from an ancient fire pit has a ^{14}C activity of 63.0 disintegrations/min. A living tree has a ^{14}C activity of 15.3 disintegrations/min per 1.00 g.The half-life of ^{14}C is 5730 y. How old is the charcoal sample? [4]

Question 6: **[8 Marks]**

6.1 Name the two layers of the atmosphere in which the temperature increases with height. [2]

6.2 The viscosity of air is 2.0×10^{5} Pa.s. Determine the wind speed 20 cm above the ground if the air flow is caused by a shear force of 1.2×10^{-3} N per m^2 at a level of 1.0 m above the ground. [3]

6.3 Which two of the following atmospheric phenomena are caused by refraction: lightning, rainbows, halos, aurorae. [1]

6.4 List two factors determining the drag force on a spherical particle. [2]

Question 7: **[8 Marks]**

7.1 Briefly describe how water salt concentration differences can lead to the formation of ocean currents. [2]

7.2 A stone of mass 2.8 g and volume 1.20 cm^3 is placed at the surface of a 2.0 m deep pool of water ($\rho_{water} = 1000$ kgm^{-3}). How long does it take for the stone to reach the bottom of the pool? [3]

7.3 A hosepipe has a radius of 5.0 mm, and the water flows through it with a speed of 2.4 cm/s. The water exits the hosepipe through a circular nozzle with a radius of 1.0 mm. Calculate the speed that the water flow through the nozzle. [3]