UNIVERSITY OF JOHANNESBURG

# PHYG01B/PHY1GB1 - Supplementary 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.

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**Equations and Constants:**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Question 1:** **[20 Marks]**

For each of the following questions circle the appropriate option:

**(I)** Take the mechanical equivalent of heat as 4 J/cal. A 10-gram bullet moving at 2000 m/s plunges into 1 kg of paraffin wax (specific heat 0.7 cal/g°C). The wax was initially at 20°C. Assuming that all the bullet's energy heats the wax, its final temperature is: [2]

(**a**) 20.14 °C
(**b**) 23.5 °C
(**c**) 20.01 °C
(**d**) 27.1 °C
(**e**) 48.6 °C

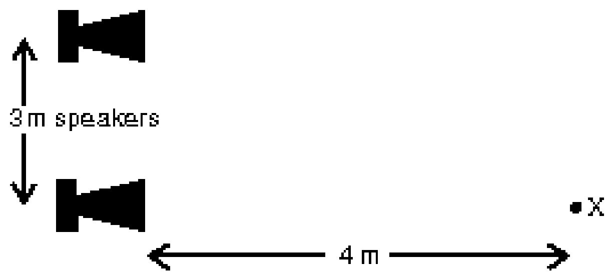
**(II)** The rate of heat flow through a slab is P. If the slab thickness is doubled, its cross-sectional area is halved, and the temperature difference across it is doubled, then the rate of heat flow becomes: [2]

(**a**) 2P
(**b**) P/2
(**c**) P
(**d**) P/8
(**e**) 8P

**(III)** Sinusoidal water waves are generated in a large ripple tank. The waves travel at 20 cm/s and their adjacent crests are 5.0 cm apart. The time required for each new whole cycle to be generated is: [2]

(**a**) 100 s
(**b**) 4 s
(**c**) 2 s
(**d**) 0.5 s
(**e**) 0.25 s

**(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. If the amplitudes are not changed, the sound he hears will be least intense if the wavelength is: [2]




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

**(V)** A 60-watt light bulb carries a current of 0.5 ampere. The total charge passing through it in one hour is: [2]

(**a**) 3600 C
(**b**) 3000 C
(**c**) 2400 C
(**d**) 1800 C
(**e**) 120 C

**(VI)** A wire has an electric field of 6.2 V/m and carries a current density of 2.4 $\times 10^8$ A/m$^2$. What is its resistivity? [2]

(**a**) $6.7 \times 10^{-10}$ $\Omega$m
(**b**) $1.5 \times 10^{-8}$ $\Omega$m
(**c**) $2.6 \times 10^{-8}$ $\Omega$m
(**d**) $3.9 \times 10^{7}$ $\Omega$m
(**e**) $1.5 \times 10^{9}$ $\Omega$m

**(VII)** A concave spherical mirror has a focal length of 12 cm. If an object is placed 18 cm in front of it the image position is: [2]

(**a**) 7.2 cm behind the mirror
(**b**) 7.2 cm in front of the mirror
(**c**) 36 cm behind the mirror
(**d**) 36 cm in front of the mirror
(**e**) None of the above

**(VIII)** In a cinema, a picture 2.5 cm wide on the film is projected to an image 3.0 m wide on a screen which is 18 m away. The focal length of the lens is about: [2]

(**a**) 7.5 cm
(**b**) 10 cm
(**c**) 12.5 cm
(**d**) 15 cm
(**e**) 20 cm

**(IX)** The wavelength of light beam B is twice the wavelength of light beam B. The energy of a photon in beam A is: [2]

(**a**) one-fourth the energy of a photon in beam B
(**b**) half the energy of photon in beam B
(**c**) equal to the energy of a photon in beam B
(**d**) twice energy of a photon in beam B
(**e**) four times the energy of a photon in beam B

**(X)** At the end of 14 min, 1/16 of a sample of radioactive polonium remains. The corresponding half-life is: [2]

(**a**) 7/8 min
(**b**) 8/7 min
(**c**) 7/4 min
(**d**) 7/2 min
(**e**) 14/3 min

**Question 2:** **[15 Marks]**

**2.1** Do two bodies with the same temperature have the same energy? Explain you answer. [2]

**2.2** A steel bridge is built in several segments, each 20 m long. The gap between segments is 4 cm at 18 °C. What is the maximum temperature that the bridge can manage before buckling? (Given: $\alpha_{steel} = 10.8 \times 10^{-6}\ {}^{\circ}C^{-1}$) [4]

**2.3** A certain diet doctor encourages people to diet by drinking ice water. His theory is that the body must burn off enough fat to raise the temperature of the water from 0.00 °C to the body temperature of 37.0 °C. How many liters of ice water would have to be consumed to burn off 454 g of fat, assuming that burning this much fat requires 3500 Cal be transferred to the ice water? Why is it not advisable to follow this diet?
Given:
1 l = $10^3$ cm$^3$, $\rho_{water} = 1.00$ g/cm$^3$
$c_{ice} = 2.06 \ J/g°C$, $c_{water} = 4.18 \ J/g°C$, $c_{steam} = 1.87 \ J/g°C$
$L_{f,water} = 334 \ kJ/kg$, $L_{v,water} = 2260 \ kJ/kg$ [6]

**2.4** Icebergs in the North Atlantic present hazards to shipping,causing the lengths of shipping routes to be increased by about 30% during the iceberg season. Attempts to destroy icebergs include planting explosives, bombing, torpedoing, shelling, ramming, and coating with black soot. Suppose that direct melting of the iceberg, by placing heat sources in the ice, is tried. How much energy as heat is required to melt 10% of an iceberg that has a mass of 200 000 metric tons? (Use 1 metric ton = 1000 kg.) [3]

**Question 3:** **[15 Marks]**

**3.1** The distance between two successive minima of a transverse wave is 2.76 m. Five crests of the wave pass a given point along the direction of travel every 14.0 s. Find the frequency of the wave and the wave speed. [4]

**3.2** Suppose you hear a clap of thunder 16.2 s after seeing the associated lightning stroke. The speed of sound waves in air is 343 m/s, and the speed of light in air is $3 \times 10^8$ m/s. How far are you from the lightning strike? Do you need to know the value of the speed of light to answer? Explain. [3]

**3.3** Provided that the amplitude is high enough, the human ears can detect sound in the range of frequencies from about 20.0 Hz to about 20,000 Hz. Compute the wavelengths corresponding to the frequencies:

(**a**) for waves in air (v = 343 m/s), [2]

(**b**) for waves in water (v = 1480 m/s). [2]

**3.4** A transverse wave on a taut string is modeled with the wave function $y(x, t) = 0.2 \sin(6.28x - 1.57t)$. Find the amplitude, wavelength, period, and speed of the wave. [4]

**Question 4:** **[18 Marks]**

**4.1** An average human brain has a power consumption of about 20 W. How much current flows within the brain as its neurons switch from resting potential (-70 mV) to action potential (+40 mV)? Hint: a watt is a joule per second, a volt is a joule per coulomb, and an ampere is a coulomb per second. [4]

**4.2** A power transmission cable is composed of 37 strands of aluminum wire, each 4.0 mm in diameter. The cable is 100 m long and is used to deliver 300 A of current to a commercial power user. Determine the total cross sectional area of the cable and the resistance of the cable. (Given: $\rho_{Al} = 1.68 \times 10^{-8}$ Ωm) [4]

**4.3** A laboratory electromagnet produces a magnetic field of magnitude 1.50 T. A proton moves through this field with a speed of 6.00 $\times 10^6$ m/s. Find the magnitude of the maximum magnetic force that could be exerted on the proton and the magnitude of the maximum acceleration of the proton? [4]

**4.4** An eraser of height 1.0 cm is placed 10.0 cm in front of a two-lens system. Lens 1 (nearer the eraser) has focal length $f_1 = 15$ cm, lens 2 has $f_2 = 12$ cm, and the lens separation is d = 12 cm. For the image produced by lens 2, calculate:

(**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** Calculate the temperature at which the peak of blackbody radiation spectrum is at 400 nm? If the temperature of a blackbody is 800 K, at calculate the wavelength it radiates the most energy at. [4]

**5.2** Assume that it is technically easy (unfortunately it is not!) to bombard the hydrogen atoms in water with neutrons and initiate a fusion reaction each time two neutrons interact with two of the protons from the hydrogen. How much energy would you in theory be able to extract from a 1 litre bottle of water (= 1 kg)? [4]

**5.3** A radioactive isotope of mercury, Hg, decays to gold, Au. The disintegration constant of gold is 0.0108 $h^{-1}$.

(**a**) Calculate the half-life of the Hg. [2]

(**b**) What fraction of a sample will remain at the end of three half-lives? [2]

**5.4** A rock recovered from far underground is found to contain 0.86 mg of U, 0.15 mg of Pb, and 1.6 mg of Ar. How much K will it likely contain? Assume that K decays to only Ar with a half-life of 1.25 $\times 10^9$ y. Also assume that U has a half-life of 4.47 $\times 10^9$y. [4]

**Question 6:** **[8 Marks]**

**6.1** How do the reflective properties of the Earth's surface affect the Earth's radiation balance? [2]

**6.2** Two round stones of the same material, A and B with $r_A = 2r_B$, are placed initially stationary in a river with water moving at speed v. Given that for equal density the mass m is proportional to $r^3$, determine the ratio of the horizontal accelerations of the stones $\frac{a_A}{a_B}$. [3]

**6.3** A beam of blue light at 440 nm enters a clean, aerosol-free atmosphere. Only 70% of the photons in this beam reach the surface (the remainder being scattered in the atmosphere). If another beam of red light at 660 nm enters the atmosphere adjacent and parallel to the blue beam, calculate the percentage of the red light reaches the surface. [3]

**Question 7:** **[8 Marks]**

**7.1** How do medium temperature, particle size and viscosity impact on diffusion? [3]

**7.2** A dam is completely filled with water. A valve of 0.05 m2 in area is opened up high up on the dam, and a jet of water rushes out of there at a speed of 2.5 m.s$^{-1}$. If the speed of the water jet is 10 m.s$^{-1}$ at the bottom of the dam, calculate the cross-sectional area of the water jet at that point. [3]

**7.3** Define the concentration gradient. [2]