UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

PHYSICS	**AUCKLAND PARK KINGSWAY CAMPUS**

PHYG01B

SUPPLEMENTARY EXAMINATION
1 DECEMBER 2021

PHYG01B

EXAMINER:	**Ms CS van Niekerk**
INTERNAL MODERATOR:	Dr E Carleschi
TIME: 2½ HOURS	**MARKS: 100**

Please read the following instructions carefully:

ANSWER ALL QUESTIONS: 1-6

/.... page 2
/Question 1

Given equations:

$\lambda_{\max} = (2.898\times10^{-3}\ \text{m.K})/T$

$\Delta E(2\text{H} + 2\text{n} \rightarrow 1\text{He}) = 4.272\times10^{-12}$ J

$E_n = -(2.177\times10^{-18}\ \text{J})/n^2$

$N = N_0 \times \exp(-0.693 \times t/T_{1/2})$

$F_{\text{shear force}} = \eta A\Delta v/\Delta y$

$F_{\text{drag/sphere}} = 6\pi R v \eta$

Constants:

$c = 3\times10^8$ m/s $g = 9.8$ m/s^2 $G = 6.67\times10^{-11}$ N.m^2/kg^2 $h = 6.626\times10^{-34}$ J.s

$k = 9\times10^9$ N.m^2/C^2 $q_e = -1.6\times10^{-19}$ C $\sigma = 5.67\times10^{-8}$ W.m^{-2}.K^{-4}

QUESTION 1 **[18]**

a) Define the thermal expansion coefficient α. If you use a formula, define all terms in this expression. (3)

b) A 50 g cube of ice with an initial temperature of –10°C is dropped into thermally insulated water with an initial temperature of 25°C. The final temperature of the mixture is 24°C. Determine the initial mass of the water.
($c_{water} = 4186$ J.kg^{-1}.K^{-1}, $c_{ice} = 2100$ J.kg^{-1}.K^{-1}, $L_{ice/water} = 333000$ J.kg^{-1}) (5)

c) Describe how a cold front leads to rainfall. Particularly focus on the physics of the process. (5)

d) Does heat conduction depend on the dimensions of the material and how? (2)

e) Explain why glaciers move more quickly than expected. (3)

QUESTION 2 **[16]**

a) Using a diagram where necessary, define the amplitude, wavelength and period of a wave. (4)

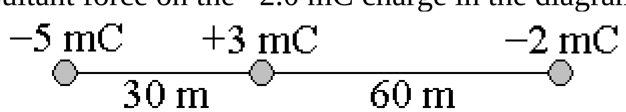
b) How is sound generated in thunder? (4)

c) A standing wave is generated through the interference of two waves moving parallel to the x-axis at 5.00 m/s in opposite directions, both with amplitude 1.20 cm and a wavelength of 1.80 m. Determine the equation describing the y-displacement as a function of x and t. (5)

d) Briefly discuss the driving mechanisms for continental drift. (3)

QUESTION 3 **[21]**

a) Determine the resultant force on the –2.0 mC charge in the diagram below. (5)



b) What is a non-ohmic conductor? (2)

c) What process does the Curie point describe, and how can this process aid in the dating of geological formations? (6)

d) A beam of blue light initially moves with a wavelength of 400 nm in a vacuum. It then moves into a medium where it travels a distance of 18.0 cm in 1 ns. Calculate the wavelength of the light inside the medium. (5)

e) How does one determine the final image of an object when there are two lenses? (3)

QUESTION 4 **[18]**

a) A star with a surface temperature of 7500 K radiates with a power of 2.40×10^{17} W.
i) At what wavelength does most of the light radiate?
ii) If the temperature of the star dropped by 800°C, what would be the power radiated by the star? (5)

b) How can one determine the composition and nature of a substance using atomic spectra? (4)

c) Where do cosmic rays originate from? (2)

d) Define the half-life of a radioactive substance. (3)

e) Given that the mass of the Sun is 2.0×10^{30} kg, determine the average speed of Jupiter if Jupiter is 7.78×10^{8} km from the Sun. (4)

QUESTION 5 **[16]**

a) Explain why the temperature increases with height in the stratosphere. (3)

b) What effect do greenhouse gases have on the Earth's incoming and outgoing radiation? (4)

c) Describe the Coriolis Effect and explain how this determines air flow around a low pressure system. (6)

d) 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)

QUESTION 6 **[11]**

a) A dam is completely filled with water. A valve of 0.05 m^2 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)

b) What is diffusion? Also briefly explain what causes it. (3)

c) 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 ($\rho_{water} = 1000$ $kg.m^{-3}$). How long does it take for the stone to reach the bottom of the pool? (5)

END

PHYG01B – 2015 – Supplementary examination – Solutions (10/50/25/15)

QUESTION 1 (nyyyyyy – 3/10/0/5)

a) Define the thermal expansion coefficient α. If you use a formula, define all terms in this expression. (3)

$\alpha = \Delta L/(L_i \Delta T)$ where ΔT is the change in temperature, ΔL is the change in length during the temperature change and L_i is the length of the body at the original temperature.

b) A 50 g cube of ice with an initial temperature of –10°C is dropped into thermally insulated water with an initial temperature of 25°C. The final temperature of the mixture is 24°C. Determine the initial mass of the water. (c_{water} = 4186 J.kg^{-1}.K^{-1}, c_{ice} = 2100 J.kg^{-1}.K^{-1}, $L_{\text{ice/water}}$ = 333000 J.kg^{-1}) (5)

$Q = m_{\text{ice}}c_{\text{ice}}\Delta T_{\text{ice}} + m_{\text{ice}}L_{\text{ice/water}} + m_{\text{ice}}c_{\text{water}}\Delta T_{(\text{cube=water})}$

$= 0.05\times2100\times(0–(–10)) + 0.05\times333000 + 0.05\times4186\times(24–0) = 1050 + 16650 + 5023 = 22723$ J

$m_{\text{wate}}\text{r}c_{\text{water}}\Delta T_{\text{water}} = –Q \Rightarrow m_{\text{water}}\times4186\times(24–25) = –22723 \Rightarrow m_{\text{water}} = 22723/4186 = 5.43$ kg

c) Describe how a cold front leads to rainfall. Particularly focus on the physics of the process. (5)

Because T is proportional to PV, a lower temperature corresponds to a smaller volume, and hence higher density. Air coming with a cold front is thus denser ('heavier') than the air it encounters, and hence cuts underneath it, at the same time forcing the warmer air upwards. As the warm air rises, the pressure decreases, and thus the temperature drops with it. This allows water vapour to condense and form raindrops

d) Does heat conduction depend on the dimensions of the material and how? (2)

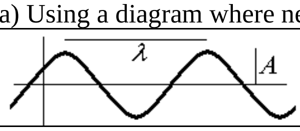
Heat conduction is proportional to the cross sectional area and inversely proportional to the thickness

e) Explain why glaciers move more quickly than expected. (3)

The ice is very heavy, so there is a strung buildup of pressure at the bottom of the glacier. Even though the temperatures there are usually below freezing, the pressure leads to melting of the ice (supercooled water). This effectively lubricates the glacier floor, and enables easier motion

QUESTION 2 (nyyyny – 4/7/5/0)

a) Using a diagram where necessary, define the amplitude, wavelength and period of a wave. (4)



wavelength λ – distance between successive peaks/troughs
amplitude A – distance from a peak/trough to the mean vertical position
period T – the time taken for the wave to cover a distance λ

b) How is sound generated in thunder? (4)

During a lightning strike an extremely strong current flows along the illuminated section for a very short time. In resisting media currents give off energy in the form of heat. The air in the immediate vicinity of the lightning beam thus suddenly becomes extremely hot. As air is a gas, this leads to a corresponding expansion of the hot air, and this disturbance is then transmitted to adjacent molecules as a sound wave

c) A standing wave is generated through the interference of two waves moving parallel to the x-axis at 5.00 m/s in opposite directions, both with amplitude 1.20 cm and a wavelength of 1.80 m. Determine the equation describing the y-displacement as a function of x and t. (5)

$k = 2\pi/\lambda = 2\pi/1.80 = 3.49$ rad/s ; $v = \omega/k \Rightarrow \omega = vk = 5.00\times3.49 = 17.5$ rad/s

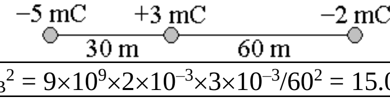
$y = 2A\times\sin(kx)\times\cos(\omega t) = 2\times1.20\times10^{-2}\times\sin(3.49x)\times\cos(17.5t) = (2.40\text{ cm})\times\sin(3.49x)\times\cos(17.5t)$

d) Briefly discuss the driving mechanism for continental drift. (3)

Continents are like floats on a 'sea' of molten material (caused by increasing temperature underground due to increasing pressure). Currents develop in this molten material due to convection and other effects. These drag the continents along with them, thereby initiating what is called continental drift

QUESTION 3 (yynyyyny – 0/11/5/5)

a) Determine the resultant force on the –2.0 mC charge in the diagram below. (5)



Force due to +3 mC: $F = kq_Aq_B/r_{AB}^2 = 9\times10^9\times2\times10^{-3}\times3\times10^{-3}/60^2 = 15.0$ N to the left

Force due to –5 mC: $F = kq_Aq_B/r_{AB}^2 = 9\times10^9\times2\times10^{-3}\times5\times10^{-3}/90^2 = 11.1$ N to the right
Resultant force = 15.0 – 11.1 = 3.9 N to the left

b) What is a non-ohmic conductor? (2)

It is a conductor in which the current strength is not proportional to the potential difference, i.e. for which Ohm's Law does not apply

c) What process does the Curie point describe, and how can this process aid in the dating of geological formations? (6)

The Curie point describes the temperature above which a ferromagnet takes on paramagnetic behaviour. If a magnetisable substance is very hot (e.g. as lava), its magnetic field aligns itself with whatever exterior field may exist, such as the Earth's magnetic field. Upon cooling down, the initially temporary magnetic field in the substance becomes permanent (ferromagnetic). A ferromagnetic rock's magnetic alignment thus records the (variable) Earth's magnetic field when the rock was formed. By comparing the intrinsic magnetisation of rocks, those with corresponding features are identified as belonging to the same era.

d) A beam of blue light initially moves with a wavelength of 400 nm in a vacuum. It then moves into a medium where it travels a distance of 18.0 cm in 1 ns. Calculate the wavelength of the light inside the medium. (5)

In the medium $v = s/t = 0.18/10^{-9} = 1.80\times10^8$ m.s^{-1}. Therefore $n = c/v = 3\times10^8/(1.80\times10^8) = 1.67$
$n = \lambda_0/\lambda \Rightarrow \lambda = \lambda_0/n = 400/1.67 = 240$ nm

e) How does one determine the final image of an object when there are two lenses? (3)

Determine the image size, position and orientation given by the first lens of the object. This image now becomes the object for the second lens. The image thus created by lens 2 is the final image.

QUESTION 4 (ynyyyyn – 3/6/9/0)

a) A star with a surface temperature of 7500 K radiates with a power of 2.40×10^{17} W.
i) At what wavelength does most of the light radiate?
ii) If the temperature of the star dropped by 800°C, what would be the power radiated by the star? (5)

i) $\lambda = (2.898\times10^{-3}$ m.K$)/T = 2.898\times10^{-3}/7500 = 3.86\times10^{-7}$ m = 386 nm
ii) $P_f/P_i = (\sigma A T_f^4)/(\sigma A T_i^4) = T_f^4/T_i^4 = (7500\text{–}800)^4/7500^4 = 0.637 \Rightarrow P_f = 0.637\times2.40\times10^{17} = 1.53\times10^{17}$ W

b) How can one determine the composition and nature of a substance using atomic spectra.. (4)

Atoms and molecules are characterised by quantised energy levels. The energy differences ΔE between the various levels are distinctive for each different type of atom or molecule. When an electron is transferred from a higher to a lower energy level, a photon is released of frequency corresponding to $\Delta E = hf$. The result is an emission line spectrum with only photons of the characteristic f showing. These are then like a fingerprint for that atom/molecule.

c) Where do cosmic rays originate from? (2)

Some cosmic rays are generated on the Sun. Others originate in deep outer space, often in the environs of black holes or other highly energetic cosmic sources

d) Define the half-life of a radioactive substance. (3)

The half-life $T_{1/2}$ is the time period required for half the particles to have undergone a radioactive decay. In other words, if there were N_0 radioactive parts at time t, there are only $N_0/2$ left at time $t+T_{1/2}$

e) Given that the mass of the Sun is 2.0×10^{30} kg, determine the average speed of Jupiter if Jupiter is 7.78×10^8 km from the Sun. (4)

$a = v^2/r$ and $a = F/m = GM/r^2 \Rightarrow v^2 = GM/r \Rightarrow v = \sqrt{(GM/r)} = \sqrt{(6.67\times10^{-11}\times2.0\times10^{30}/(7.78\times10^{11}))}$
$= \sqrt{(1.71\times10^8)} = 1.31\times10^4$ m.s^{-1}

QUESTION 5 (yynyny – 0/13/3/0)

a) Explain why the temperature increases with height in the stratosphere. (3)

The stratosphere contains the ozone layer. Solar ultraviolet light is normally absorbed in the ozone layer, and this means that the energy of those photons is transferred to the ozone molecule products, increasing T

b) What effect do greenhouse gases have on the Earth's incoming and outgoing radiation? (4)

Incoming radiation comes from the Sun. As the Sun is very hot, its radiation is mainly in the visible part of the spectrum. Greenhouse gases largely do not absorb at those wavelengths, and hence the incoming solar radiation is not dampened by greenhouse gases. The outgoing radiation is thermal radiation from the Earth, which is largely in the infrared. Here greenhouse gases absorb radiation strongly. Hence the outgoing radiation is partly trapped and weaker than without greenhouse gases

c) Describe the Coriolis Effect and explain how this determines air flow around a low pressure system. (6)

The Coriolis Effect is linked to the conservation of angular momentum. To do so a body in circular motion needs to speed up if the circle gets smaller and slow down if the circle grows. In the southern hemisphere, air to the north of a low pressure will be drawn towards it, but the moment it moves south its radius around the Earth axis decreases, and hence it will speed up, i.e. move eastward. Conversely, air to the south of this low pressure ends up moving westward. The result is clockwise motion. In the northern hemisphere the argument is similar bur inverted, resulting in anticlockwise motion around the low pressure

d) 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)

$F/A = \eta\, \Delta v/\Delta y \Rightarrow \Delta v = (F/A)\Delta y/\eta = 1.2\times10^{-3}\times0.20/(2\times10^{-5}) = 12$ m/s

QUESTION 6 (ynyy – 0/3/3/5)

a) A dam is completely filled with water. A valve of 0.05 m^2 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)

$A_1v_1 = A_2v_2 \Rightarrow A_2 = (v_1/v_2)A_1 = (2.5/10)\times0.05 = 0.0125\ m^2$

b) What is diffusion? Also briefly explain what causes it. (3)

Diffusion is the progressive spread of an initially localised fluid inside another medium. It is caused by the random motion of the particles of the fluid. This results in a gradual increased distancing of fluid particles

c) 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 (ρ_{water} = 1000 $kg.m^{-3}$). How long does it take for the stone to reach the bottom of the pool? (5)

$B = \rho g V = 1000\times9.8\times1.20\times10^{-6} = 0.0118$ N. $F_{res} = mg - B = 2.8\times10^{-3}\times9.8 - 0.0118 = 0.0157$ N

$a = F_{res}/m = 0.0157/0.0028 = 5.6\ m.s^{-2}$. $s = ut + ½at^2 \Rightarrow 2.0 = 0 + 0.5\times5.6\times t^2 \Rightarrow t = \sqrt{(2/2.8)} = 0.85$ s