INTERNATIONAL SECONDARY CERTIFICATE EXAMINATION
NOVEMBER 2022

FURTHER STUDIES PHYSICS

MARKING GUIDELINES

Time: 3 hours 200 marks

These marking guidelines are prepared for use by examiners and sub-examiners, all of whom are required to attend a standardisation meeting to ensure that the guidelines are consistently interpreted and applied in the marking of candidates' scripts.

The IEB will not enter into any discussions or correspondence about any marking guidelines. It is acknowledged that there may be different views about some matters of emphasis or detail in the guidelines. It is also recognised that, without the benefit of attendance at a standardisation meeting, there may be different interpretations of the application of the marking guidelines.

QUESTION 1 MULTIPLE CHOICE

1.1 B
1.2 A
1.3 B
1.4 B
1.5 C
1.6 D
1.7 A
1.8 D
1.9 A
1.10 C

QUESTION 2 THERMAL PHYSICS

2.1 2.1.1 102,0 ± 0,5 mm (range 102,0 to 103,0)

2.1.2 (a) $\Delta L = \alpha L_0 \Delta T$
$0,30 = \alpha\ (150,00)\ (107)$
$\alpha = 19 \times 10^{-6}\ K^{-1}$

(b) Steel α < Brass α
Diagram should show all the points below
The brass will expand more than the steel making the strip bend upwards
bend away from the connector
Connection with the electrical connector is lost and the alarm is triggered.

(c) Steel: $\Delta L = \alpha L_0 \Delta T$
$= (11 \times 10^{-6})\ (150)\ (107)$
$= 0,18$ cm

L brass = 150,3 ± 0,01 cm L steel = 150,2 ± 0,01 cm

Difference = (0,10 ± 0,02) cm

2.1.3 A
Due to the difference in expansion coefficients, the coil will unwind as it bends towards the steel side of the coil
The uncoiling at high temperatures means the arrow will move clockwise as the temperature increases.

2.2 2.2.1 The volume of the water will be less than the volume of the ice.

Due to the anomalous behaviour of water below 4°C, water/ice expands.
In the liquid phase the relatively strong intermolecular forces (hydrogen bonds) cause smaller distances between the molecules causing it to be more dense and have a smaller volume.

2.2.2 The amount of heat energy required to change the phase of 1 kg of the material without a change in temperature

2.2.3 $Q = m\,c_{ice}\,\Delta T + m\,L_f + m\,c_{water}\,\Delta T$

$= (0,32)(2090)(7) + (0,32)(33600) + (0,32)(4180)(38)$

$= 4681,6 + 10752 + 50828,8$

$= 6,6 \times 10^4$ J *(2 sf)*

QUESTION 3 MATTER AND NUCLEAR PHYSICS

3.1 3.1.1 No

3.1.2 Protons and neutrons both consist of quarks

3.2 3.2.1 The difference between the mass of a particular nucleus and the total mass of its constituent nucleons.

3.2.2 mass defect = 0,113 u
$= (0,113)(1,660 \times 10^{-27})$ *(calculation)*
$= 1,8758 \times 10^{-28}$ kg

$E = mc^2$
$= (1,8758 \times 10^{-28})(3,00 \times 10^8)^2$
$= 1,688 \times 10^{-11}$ J

Binding energy per nucleon = $1,6488 \times 10^{-11}$ J / 14
$= 1,2 \times 10^{-12}$ J *(2 sf)*

3.3 3.3.1 2 up quarks and 1 down quark (uud)

3.3.2 Z and W Bosons

3.3.3 very short range (10^{-18})
acts inside nucleons
change a neutron into a proton and electron during beta decay
weaker than the strong force and the electromagnetic force
play a role in nuclear fusion
allow quarks to change between up and down
(any valid 3)

3.4 3.4.1 The time taken for half of the original nuclei/radioactive particles to decay

3.4.2 $t_{1/2}$ = 5 730 years

Dead coral: 16,0 decays per second in 760 g
Living coral: 15,3 decays per minute per gram.

$A_0 = \lambda N_0 = 15,3 \div 60 \times 760$
$= 193,8$ decays per second

$\lambda = \ln 2 \ / \ t_{1/2} = 1,21 \times 10^{-4}$ decays per year

$A = A_0 e^{-\lambda t}$
$16,0 = 193,8 \ e^{-(0,00012)t}$
$t = 2,1 \times 10^4$ years *(2 sf)*

QUESTION 4 ASTROPHYSICS AND COSMOLOGY

4.1 mass more than 10 times that of the Sun
largest stars
short lifespan or high mass lost rate due to fast burning rate of hydrogen
high luminosity
low surface gravity
(any 2)

4.2 4.2.1 The total energy radiated from the surface (of a star) per second.

4.2.2 I) red giants
II) main sequence
III) white dwarfs

4.3 4.3.1 $\lambda_{max} T = 2{,}9 \times 10^{-3}$

$\lambda_{max} = 2{,}9 \times 10^{-3} / 7500$
$= 3{,}9 \times 10^{-7}$ m *(2 sf)*

4.3.2 $L_{star} / L_{sun} = (m_{star} / m_{sun})^{4{,}2}$
$3{,}9 = (m_{star} / 1{,}99 \times 10^{30})^{4{,}2}$
$M_{star} = 2{,}8 \times 10^{30}$ kg *(2 sf)*

4.3.3 The mass of Polaris is 1,38 times that of the Sun.
The Chandrasekhar limit states that any star with a mass smaller than 1,4 solar masses will become a white dwarf.
The Oppenheimer-Volkoff limits predict that between 2 and 3 solar masses will become a neutron star.
Therefore Polaris B will become a white dwarf.

4.4 The gravity of massive galaxy clusters bends and distorts the light from more distant galaxies behind them – gravitational lensing.
More lensing is observed as that can be explained using the known solar masses/seen matter
Dark matter would account for the extra lensing.

QUESTION 5 PROJECTILE MOTION AND DATA ANALYSIS

5.1 Vertical motion is independent of the horizontal motion
The vertical initial velocity is zero and gravitational acceleration is constant therefore the time is constant

5.2 Too many significant figures used.
The raw readings have a max of 2 and therefore the calculated values should have been stated to 2 significant figures as well.

5.3 Graph
Title – correct order of variables
Scale – no odd scale and more than half the given grid must be covered
Plotting – no large blobs
Accuracy – correct within one small block on the grid

5.4 All error bars correctly drawn (-1 for each mistake)

5.5 Both lines labelled and **correctly** drawn
Worst acceptable line must pass through all the error bars

5.6 5.6.1 gradient = $\Delta y \,/\, \Delta x$ values from line of best fit

= 0,92 (range 1,00 to 0,84)

5.6.2 gradient of the steepest line of fit = 1,11

$\Delta m = 1{,}11 - 0{,}92 = 0{,}19$
$\approx 0{,}2$ s coe from candidate's graph

5.6.3 The gradient represents the time.

5.7 5.7.1 at an angle of 10°: vertical initial velocity = 11 sin 10° = 1,91 $m.s^{-1}$
horizontal initial velocity = 11 cos 10° =10,83 $m.s^{-1}$

For the vertical motion: $s = ut + \frac{1}{2} at^2$
$4{,}3 = (-1{,}91)\,t + \frac{1}{2}\,(9{,}81)\,t^2$
$t = 1{,}151$ s

For the horizontal motion (range): $s = ut + 0$
$= (10{,}83)\,(1{,}151)$
= 12 m *(2 sf)*

5.7.2 Mark as per candidate's answers
Δ range / range = Δt / t
Δ range = 0,2 / 1,15 × 12 = 2,1 m

QUESTION 6 TORQUE AND FIELDS

6.1 The tendency of a force to cause a body to rotate about a fixed point or axis.
Or force x perpendicular distance
Or a twisting force that causes rotation

6.2 Clockwise torque = Anticlockwise torque

W (0,4) = F (0,15)

500 (0,4) = F (0,15)

F = 1333 N

≈ 1000 N *(1 sf)*

6.3 6.3.1 Force per unit mass.

6.3.2 Combining the given equations from the information sheet gives

$F = G\ mM / r^2$

$= (6{,}67 \times 10^{-11})(62)(6 \times 10^{24}) / (6{,}4 \times 10^{6})^2$

$= 605{,}77$ N

≈ 600 N *(1 sf)*

OR

W = Fg = mg

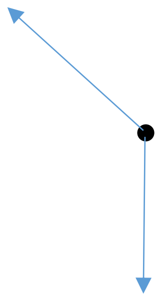
62 (9,81) = 610 N

Earth on rider and therefore according to N3 also rider on the Earth

6.3.3 According to N3 she does attract the Earth
OR
According to Newton's Law of Universal gravitation all objects with mass attracts any other object with so the rider does attract the Earth

QUESTION 7 CIRCULAR MOTION

7.1 7.1.1



7.1.2 $F_c = mv^2 / r = F_{lift} \sin\theta$ and $Fg = mg = F_{lift} \cos\theta$

$$\tan\theta = v^2 / gr$$
$$= 83^2 / (9{,}81)(900)$$
$$\theta = 38^\circ$$

7.2 7.2.1 The resultant force that acts towards the centre of the circle causing the centripetal acceleration

7.2.2 The pilot will feel as if they are being pushed back into the seat The seat pushes on the pilot to provide the centripetal force

7.2.3 (a) $Fc = 5\,Fg = 5(84 \times 9{,}81)$
$= mv^2 / r$
$v = 16\ \text{m·s}^{-1}$

(b) $T = 2\pi / \omega = 2\pi / {}^{v}/_{r}$
$= 2\pi / {}^{16}/_{5,2} = 2{,}04\ \text{s}$

Rotations per minute = 1 / 2,04 × 60 = 29 rotations

OR $v = \omega r$
$16 = \omega (5{,}2)$
$\omega = 3{,}1\ \text{rad·s}^{-1}$
$\therefore 3{,}1 \times 60 \div 2\pi = 29\ \text{rev·min}^{-1}$

7.3 $F_c = F_g$

$$mv^2 / r = GMm / r^2$$
$$v^2 = GM / r$$

and $v = 2\pi r / T$ $v^2 = 4\pi^2 r^2 / T^2 = GM / r$

$$T^2 = 4\pi^2 r^3 / GM$$

QUESTION 8 CHARGED PARTICLES IN ELECTRIC AND MAGNETIC FIELDS

8.1 8.1.1 Mark on the diagram.
Parallel lines in the centre of the plates from positive to negative.
(ignore end effects, lines should touch the plates)

8.1.2

$$F_g = F_E$$
$$mg = E\,q$$
$$mg = V / d \times q$$
$$(5{,}60 \times 10^{-15})\,(9{,}81) = (490{,}0 / 0{,}04)\,q$$
$$q = 4{,}485 \times 10^{-18}\ \text{C}$$

Number of electrons $= 4{,}485 \times 10^{-18} / 1{,}602 \times 10^{-19}$
$= 28{,}0$ *(3 sf)*

8.2 8.2.1 Out of the page.

8.2.2 The magnetic force is the resultant force that acts perpendicular to the motion.
This causes a centripetal force and therefore circular motion.

8.2.3 The force only acts perpendicular to the velocity.
The force must act in the direction of motion to affect the linear speed. (2)

8.2.4 $F_B = q\,v\,B = F_C = mv^2 / r$

$$r = mv / Bq$$
$$= (1{,}673 \times 10^{-27})\,(4{,}1 \times 10^{4}) / (8{,}7 \times 10^{-3})\,(1{,}602 \times 10^{-19})$$
$$= 0{,}049\ \text{m}$$

diameter $= 0{,}099$ m

QUESTION 9 OSCILLATIONS

9.1 The acceleration is directly proportional to the displacement and in the opposite direction.

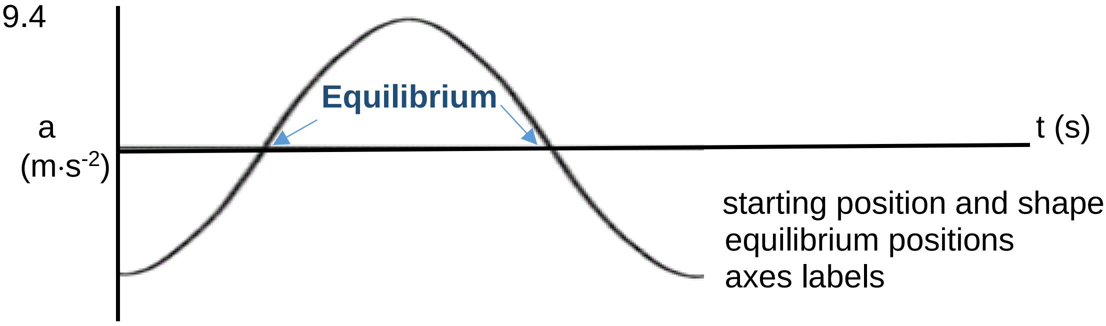
9.2 $\omega = 2\pi / T$
$8{,}4 = 2\pi / T$
$T = 0{,}75$ s

9.3 9.3.1 In an oscillation, the velocity alternates direction at $x = 0$.
(or explained in terms of movement)

9.3.2 $v = 0{,}34\ \text{m·s}^{-1}$ – from the graph

$a = v^2 / r$
$= (0{,}34^2) / 0{,}03$
$= 2\ \text{m·s}^{-2}$ *(1 sf)*

9.4



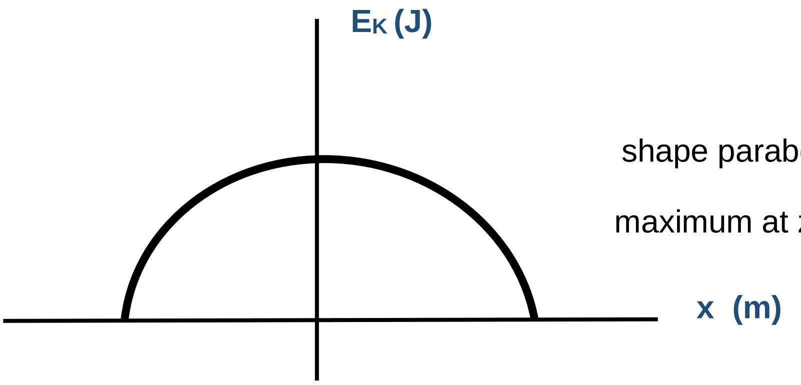
starting position and shape
equilibrium positions
axes labels

9.5 9.5.1 Mark on the graph – clear crosses at maximum displacement at $v = 0$ for both positive and negative x.

9.5.2 $E_K = \frac{1}{2} mv^2$
$= \frac{1}{2} (0{,}120)(0{,}042)^2$
$= 0{,}01$ *(1 sf)* J

or $E_k = \frac{1}{2} m\omega^2 x^2$
$= \frac{1}{2} (0{,}120)(8{,}4^2)(0{,}05^2)$
$= 0{,}01$ J *(1 sf)*

9.5.3



shape parabola

maximum at zero

Total: 200 marks