INTERNATIONAL SECONDARY CERTIFICATE EXAMINATION
MAY 2024

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

2 × 10 = 20 marks
[20]

QUESTION 2 THERMAL PHYSICS

2.1 2.1.1 When the railway lines heat up, the increase in temperature causes an increase in the average kinetic energy of the particles / move faster ✓ leading to an increase in the length of the railway lines ✓ that might cause the lines to bend if there is no space left for expansion. ✓ (3)

2.1.2
$$\Delta L = \alpha L_0 \Delta T$$
$$1{,}6 \times 10^{-2} = (1{,}2 \times 10^{-5})(12{,}8)\ \Delta T$$
$$\Delta T = 104{,}167$$
$$T - 18 = 104{,}167 \quad \text{(could start with } \Delta T \text{ as } T - 18)$$
$$\mathbf{T = 122{,}17\ °C}$$ (3)

2.2 2.2.1 The amount of heat (energy) required to change the phase of 1 kg of the material ✓ without a change in the temperature or at a constant temperature. ✓ (2)

2.2.2 $\Delta T = 18 - (-3)$ ✓ = 21 °C which is equal to 21 K ✓ (2)

2.2.3 The coefficient of linear expansion of brass is larger than that of steel ✓ When increasing the temperature brass expand more and the track will bend ✓ When decreasing the temperature brass contracts more which will have no effect ✓ (3)

2.3 2.3.1 All regions/substances are at the same temperature.✓✓ (2)

2.3.2 Q lost by brass = Q gained by ice heating to 0 + Q gained by ice melting + Q gained by water heating to 27,4 ✓

$$mc_{brass}\Delta T = mc_{ice}\Delta T + mL_f + mc_{water}\Delta T$$ ✓

$1{,}88(380)(98{,}0 - 17{,}4)$ ✓ $= (m)(2110)(1{,}6) + (m)(336 \times 10^3) + (m)(4190)(17{,}4)$ ✓

$57\,580{,}64 = 3376\ m + 336000\ m$

$m = 7{,}16\ kg$

$\mathbf{m \approx 7{,}2\ kg}$ ✓ (5)

[20]

QUESTION 3 NUCLEAR STRUCTURE, REACTIONS AND DECAY

3.1 3.1.1 55 protons: uud ✓= 110 u and 55 d total up = 192 ✓
82 neutrons: udd ✓= 82 u and 164 d total down = 219 ✓ adding (4)

3.1.2 Beta (minus) decay ✓ (1)

3.1.3 (2)

antineutrino ✓	lepton ✓

3.1.4 $^{137}_{56}Y$ ✓ (1)

3.1.5 Fundamental force: Weak nuclear force ✓
Exchange particle: (W^+ / gauge) W boson ✓ (2)

3.2 3.2.1 Th-232 – ratio of proton:neutron closer to the optimal number. ✓
Th-233 – more neutrons – more internal energy needed to be emitted. ✓(2)

3.2.2 It undergoes fission easily. ✓ (1)

3.2.3 (a) Calculate the percentage uncertainty in the mass of a neutron. (2)
% uncertainty = $^{0,000001529}/_{233,041580208} \times 100$ ✓
= 0,0000006561 % ✓
Or **$6{,}56 \times 10^{-7}$ %**

(b) The difference between the mass of a particular nucleus and the total mass of its constituent parts ✓✓ (2)

(c) 90 protons + 142 neutrons = $90(1{,}673 \times 10^{-27})$
$+ \ 142 \ (1{,}675 \times 10^{-27})$
$= 3{,}8842 \times 10^{-25}$ kg✓

Mass of Th-233 nucleus in kg = $233{,}041580208 \times 1{,}660 \times 10^{-27}$ ✓
$= 3{,}8685 \times 10^{-25}$ kg

∴ mass defect = $3{,}8842 \times 10^{-25} - 3{,}8685 \times 10^{-25}$ ✓
= **$0{,}0157 \times 10^{-25}$ kg** ✓ (4)
mass defect = $1{,}57 \times 10^{-27}$ kg

3.2.4 (a) $\lambda = -\frac{\ln 2}{t_{1/2}}$ ✓ $= -\frac{\ln 2}{21{,}83}$ ✓
= **– $3{,}175 \times 10^{-2}$ min^{-1}** (4sf) ✓ (can leave out -) (3)

(b) $x = x_0 e^{-\lambda t}$ ✓

$fraction = \frac{x}{x_0} = e^{-0{,}0318(2\times60)}$ ✓

= **$2{,}202 \times 10^{-2}$** ✓ (3)

(c) $t = \dfrac{-\ln\left(\dfrac{A}{A_0}\right)}{\lambda}$ ✓

$t = \dfrac{-\ln\left(\dfrac{12}{100}\right)}{-0{,}0318}$ ✓ = **66,67 min** ✓

t = **66,67 min** ✓ (3)

[30]

QUESTION 4 ASTROPHYSICS AND COSMOLOGY

4.1 4.1.1 The luminosity of a star is a measure of the total amount of energy emitted by the star. ✓✓ (2)

4.1.2 The luminosity of a star is determined by the brightness detected and the distance to the star. ✓✓
OR by the size and the surface temperature of a star. (2)

4.1.3 $\lambda_{max} T = 2{,}9 \times 10^{-3}$ ✓
$\lambda_{max}(3763 - 273{,}15) = 2{,}9 \times 10^{-3}$ ✓
$\lambda_{max} = \mathbf{8{,}310 \times 10^{-7}\, m}$ ✓ (3)

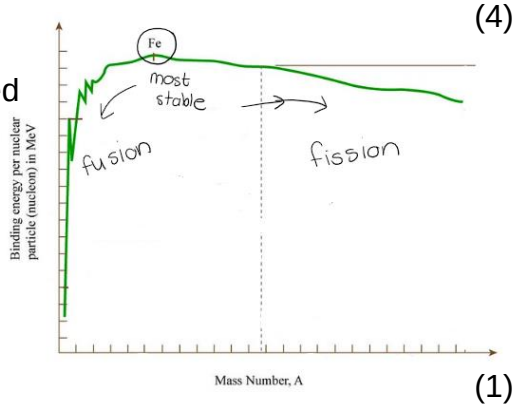
4.1.4 Fusion is the process during which two light nuclei join together to form a heavier nucleus. ✓✓ (2)

4.1.5 Gravitational pressure pulling matter inwards is opposed by the radiation pressure caused by fusion. ✓
When an equilibrium is reached ✓– a stable star is formed. (2)

4.1.6 The mass of the star or the luminosity and temperature ✓ ✓ (2)

4.1.7 Hydrogen for fusion is depleted – less fusion – less radiation pressure. ✓
Gravitation pressure now > radiation pressure – matter falls inward causing heat in outer layer where hydrogen can fuse again. ✓
Outward energy causes the star to expand causing it to become more ✓ luminous and outer layers cool down causing it to become more red ✓ (4)

4.1.8 Graph shape ✓ Graph labels ✓ (4)
Iron shown in the correct position. ✓
After iron no more energy will be released by fusion since the binding energy per nucleon decreases. ✓



4.2 4.2.1 ± 26 %✓ (1)

4.2.2 Gravitational lensing ✓✓ (2)
[24]

QUESTION 5 PROJECTILE MOTION AND LEVERS

5.1 5.1.1 For the vertical motion v = 0 and u = 50 sin 30°

$v^2 = u^2 + 2as$

$0 = 50^2 \sin^2 30° - 2gs$ ✓

$2gh = 50^2 \frac{1}{4}$ ✓ $= \frac{50^2}{8g}$ (3)

5.1.2 Vertical motion Horizontal motion (6)

$s = ut + \frac{1}{2}at^2$

$-60 = (50\sin 30°)t + \frac{1}{2}(-9{,}8)t^2$ ✓

t = 6,876 s ✓

$s = ut + \frac{1}{2}at^2$ and $a = 0$ ✓

$S_H = (50\sin 30°)t$ ✓ $t_V = t_H$ ✓

$S_H = (50\sin 30°)(6{,}876)$

$S_H = 297{,}74m$ = **3,0 × 10²m** ✓

5.2 5.2.1 Distance **a**: 40,0 ± 0,1 cm ✓ (3)

Distance **b**: 30,0 ± 0,1 cm ✓ uncertainties ✓

5.2.2 CW = F × ⊥distance ✓

= 60,0 × 0,3 = 18,0 N·m ✓

ACW = F × ⊥distance

= 30,0 × 0,40 = 12 N·m ✓

Turning force = 18 – 12 = 6 N·m ✓

Δ Turning force = 0,09 ✓

= 6,00 ± 0,09 N·m ✓ clockwise ✓ (7)

(coe from uncertainties in 5.2 above)

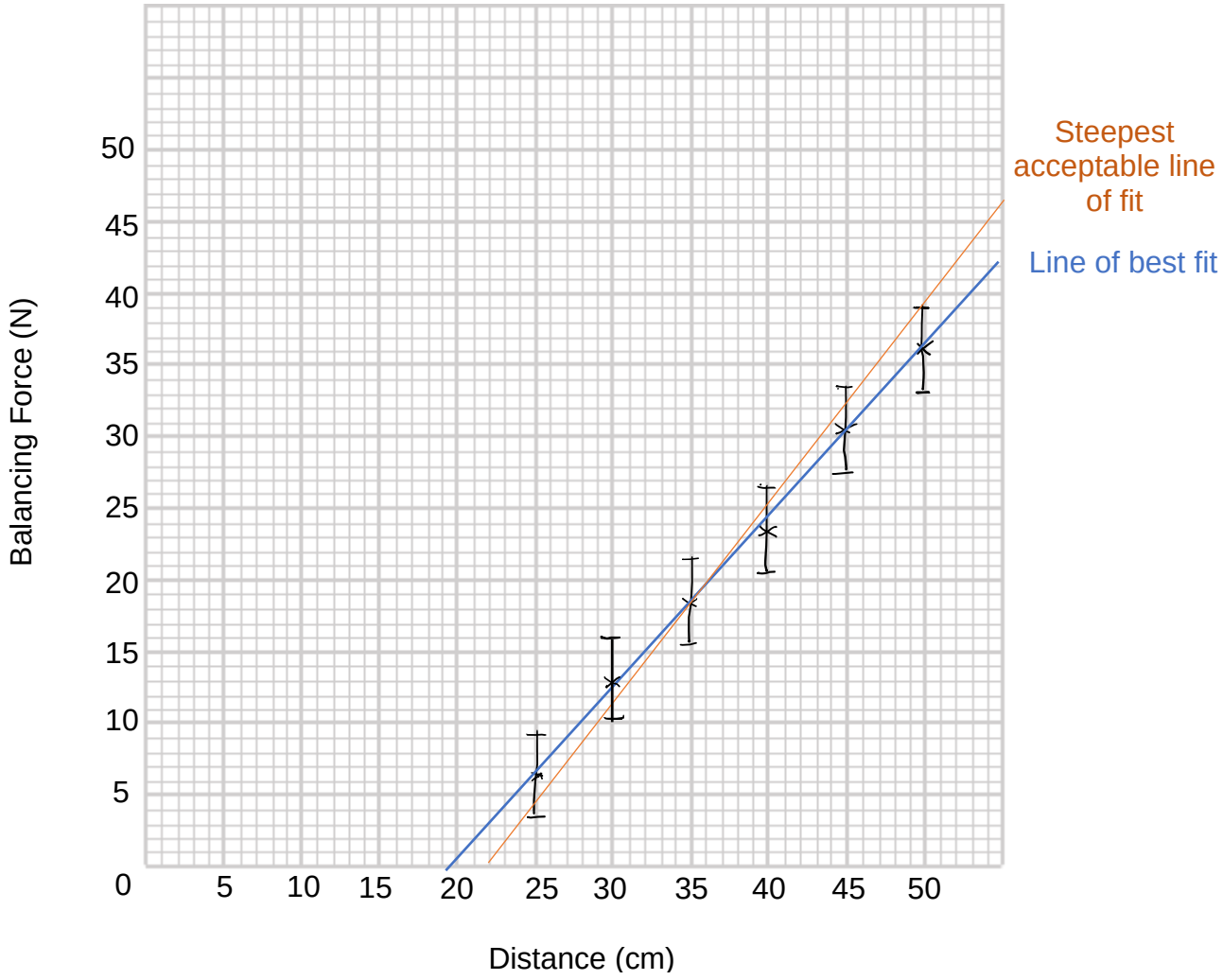
5.2.3 12 N ✓✓ (2)

5.2.4 Error of parallax ✓ – wrong distance readings. ✓

OR Moving Newton meter ✓– wrong force ✓ (2)

5.2.5 Graph – see next page (4)

Graph of balancing force vs distance



5.2.6 Error bars drawn correctly ✓✓ (2)

5.2.7 Lines drawn correctly and labelled ✓✓ (2)

5.2.8 gradient = $\Delta y/\Delta x$ ✓ = 1,20 ✓ (within the range 1,15 to 1,25 ✓)
∴ gradient = 1,20 N·cm^{-1} ✓ (could have used meters) (4)

5.2.9 use y = mx + c with the x value as zero
Sub gradient calculated and point from line of best fit ✓
Calculate the y intercept within the range –22 to –26 ✓
The y intercept represents the force required when B is removed or at the pivot. ✓ (3)

[38]

QUESTION 6 CIRCULAR ORBITS

6.1 6.1.1 LHS: Energy = W = F × s = mas ✓

$\Rightarrow$ kg·m·s^{-2}·m = kg ·m^2· s^{-2} ✓

RHS: ½ mv^2 $\Rightarrow$ kg(m·s^{-1})^2 = m^2·kg·s^{-2} ✓

Same base units for each term ∴ the equation is homogenous. (3)

6.1.2 $\omega = {}^{2\pi}/_{T}$ ✓ $= {}^{2\pi}/_{3,5} = 1,795$ ✓ = 1,8 rad·s^{-1}

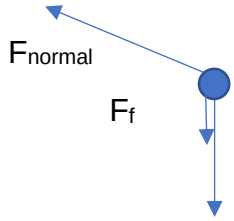
a = ω^2 r = $({}^{4}/_{7}\,\pi)^2$ $({}^{0,65}/_{2})$ ✓ **= 1,05 m·s^{-2}** ✓ (4)

6.1.3 The resultant or net force that acts towards the centre of the circle ✓
Causing the centripetal acceleration. ✓ (2)

6.1.4 $F_N - mg$ ✓ $= F_c = \frac{mv^2}{r}$ ✓

$F_N = \frac{(0,038)2,1^2}{0,325}$ ✓ + (0,038)(9,81)

F_N = 0,88 N ✓ upwards or towards the centre of the loop ✓ (5)

6.1.5 

✓✓✓ one for each force and -1 for each extra (3)

6.1.6 $F_C = \frac{mv^2}{r} = mg$ ✓ $F_{normal} = 0$ ✓

$v^2 = rg = (0,035)(9,81)$ ✓

v = 1,786 m·s^{-1} ✓ (4)

6.2 6.2.1 $\omega = \frac{2\pi}{T} = \frac{2\pi}{27,3 \times 24 \times 60 \times 60}$ ✓

ω = 2,66 × 10^{-6} rad·s^{-1} ✓ (2)

6.2.2 The moon does not have a period of 24 h. ✓ (1)

6.2.3 $F_g = F_C$

$$\frac{GMm}{r^2} = \frac{mv^2}{r} \quad \checkmark$$

$$v^2 = \frac{GM}{r} \quad \therefore v = \sqrt{\frac{GM}{r}} = \frac{2\pi r}{T} \quad \checkmark \qquad \text{2 marks for equations}$$

$$\frac{GM}{r} = \frac{2^2\pi^2 r^2}{T^2} \qquad \text{from here } T^2 = \frac{4\pi^2}{GM} r^3 \quad \checkmark \text{ (Kepler)}$$

$$r^3 = \frac{(24 \times 60 \times 60)^2}{\left(\frac{4\pi^2}{6{,}67 \times 10^{-11} \times 5{,}972 \times 10^{24}}\right)} \quad \checkmark \qquad = 7{,}53 \times 10^{22}$$

$\therefore$ **r = 4,22 × 10^7 m** ✓ (5)

[29]

QUESTION 7 CHARGED PARTICLES IN ELECTRIC AND MAGNETIC FIELDS

7.1 7.1.1 Electrostatic force. ✓✓ (2)

7.1.2 $F_E = F_B$ ✓
Eq = qvB sin θ at 90° sin θ = 1
$^{V}/_{d}$ = vB ✓equations
$^{125}/_{0,015}$ = v (0,500) ✓
v = 1,667 × 10⁴ m·s⁻¹ ✓ (4)

7.1.3 The curve would be upwards ✓✓ (2)

7.1.4 (a) $F_B = F_C$

$$qvB = \frac{mv^2}{r} \checkmark$$

$$qB = \frac{mv}{r}$$

$$q(0,5) = \frac{(1,2\times10^{-26})(3,20\times10^{4})}{(0,075\times10^{-3})} \checkmark\checkmark$$

$$\boldsymbol{q = 1,024\times10^{-17}C} \checkmark$$ (4)

(b) A heavier particle. ✓
According to the equation qB = mv/r ✓ the mass and the radius of the circular path is directly proportional if the magnetic field and the charge remains constant. ✓ So, the larger radius will be from the larger mass. (3)

7.2 7.2.1 High frequency voltage
The electric field must alternate ✓ at the correct frequency to accelerate the charged particles across the gaps. ✓ (2)

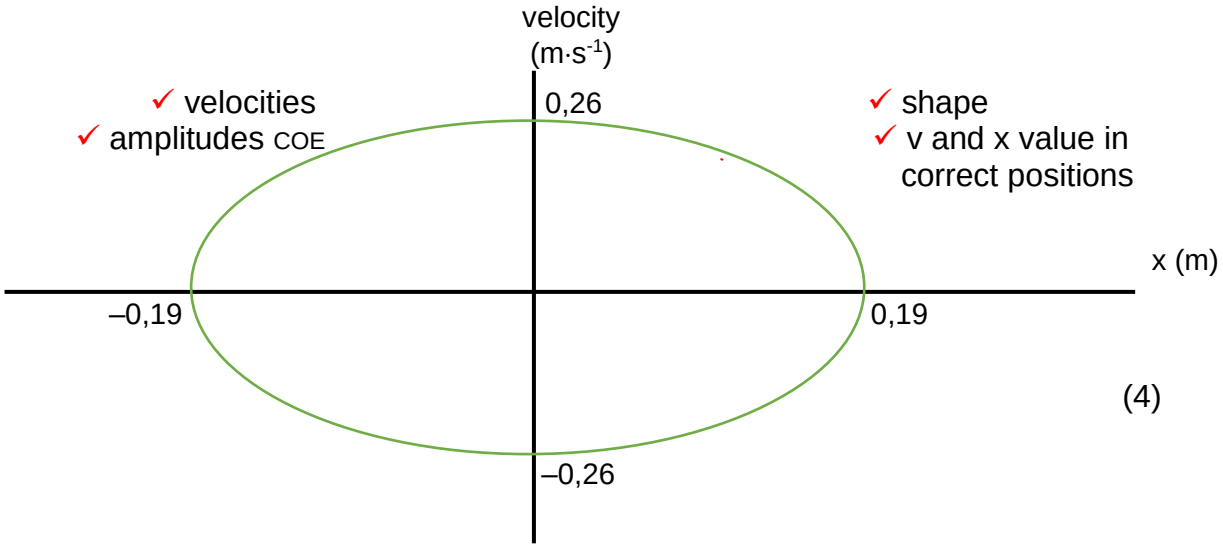
7.2.2 Drift tubes
No electric field is present in the tubes to keep the particles moving at a constant speed. ✓ Since the speed increases between each tube, the length must increase to match the time inside the tube with the period of the electric field. ✓ (2)
[19]

QUESTION 8 OSCILLATIONS

8.1 The motion repeats itself ✓ at regular time intervals. ✓ (2)

8.2 ½ (49 – 11) ✓ = **19 cm** ✓ (2)

8.3



(4)

8.4 $v = w\sqrt{x_0^2 - x^2}$ ✓ or $v = wr$ ✓

$0,26 = w\sqrt{0,19^2 - 0}$ ✓✓ $0,26 = w(0,19)$ ✓✓

$\boldsymbol{w = 1,37 rad \cdot s^{-1}}$ ✓ $\boldsymbol{w = 1,37 rad \cdot s^{-1}}$ ✓ (4)

8.5 $E = \frac{1}{2}mw^2x_0^2$ ✓

$0,07 = \frac{1}{2}m(1,37)^2(0,19)^2$ ✓ ✓ (4)

m = 2,07 kg ✓

8.6 Spring compressed ✓✓ (2)

8.7 Use water or anything that causes friction. ✓✓ (2)

[20]

Total: 200 marks