GRADE 12 EXAMINATION
NOVEMBER 2021

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

QUESTION 2 THERMAL PHYSICS

2.1. 2.1.1 968 ± 1 mm OR 968,0 ± 0,5 mm

2.1.2 971 ± 1 mm OR 971,0 ± 0,5 mm

2.1.3 $\Delta L = 3 \pm 2$ mm OR 3,0 ± 1,0 mm readings uncertainties
ΔL uncertainty in ΔL

2.2 $\Delta L = \alpha L_0 \Delta T$ $\Delta T = (78 - 25) \pm 2$ °C
$3 = \alpha (968)(53)$
$\alpha = 5{,}85 \times 10^{-5}$ °C^{-1}

$$\frac{\Delta\alpha}{\alpha} = \frac{\Delta(\Delta L)}{\Delta L} + \frac{\Delta L_0}{L_0} + \frac{\Delta(\Delta T)}{\Delta T}$$

$$= \frac{2}{3} + \frac{1}{968} + \frac{2}{53} \text{ OR } \frac{1}{3} + \frac{0{,}5}{968} + \frac{2}{53}$$

$\Delta\alpha = 4{,}13 \times 10^{-5}$ °C^{-1} or K^{-1} OR $2{,}17 \times 10^{-5}$ °C^{-1} OR K^{-1}

Could also use (max – min) ÷ 2

Answer: $\alpha = (5{,}9 \pm 4{,}1) \times 10^{-5}$ °C^{-1} or K^{-1} combined answer with unit
OR $\alpha = (5{,}9 \pm 2{,}2) \times 10^{-5}$ °C^{-1} or K^{-1}

2.3 In sections B and D, the water is changing phas
and heat energy added is used to overcome the intermolecular forces or only an increase in potential energy.
There is no increase in kinetic energy and therefore no increase in temperature.

2.4 2.4.1 The amount of heat required to change the temperature of 1 kg of the material by 1 °C

2.4.2 271,15 K

2.4.3 $Q = mc\Delta T + mL$
$= (0{,}010)(5)(2050)(2) + (0{,}010)(5)(334 \times 10^3)$
$= 1{,}69 \times 10^4$ J OR 16,9 kJ

2.4.4 Q gained by the ice + Q gained by molten ice = Q lost by the coffee
$1{,}69 \times 10^4 + mc\Delta T = mc\Delta T$
coe $1{,}69 \times 10^4 + (0{,}05)(4190)(T_f - 0) = (0{,}20)(4190)(75 - T_f)$
$1{,}0475 \times 10^3\ T_f = 4{,}595 \times 10^4$
$T_f = 43{,}9\ °C$
(accept 2 or 3 significant figures)

2.4.5 The coffee loses heat to the ice and the environment, the calculation did not take into account the heat loss to the environment. The coffee lost more energy as calculated in Question 2.4.4 resulting in the lower temperature.

QUESTION 3 MATTER AND NUCLEAR PHYSICS

3.1 Plutonium-239 $\left({}^{239}_{94}Pu\right)$

3.1.1 94 protons $\rightarrow$ 94 down quarks (Proton – 1 down)
145 neutrons $\rightarrow$ 290 down quarks (Neutron – 2 down)
Total down quarks = 384

3.1.2 $${}^{239}_{94}Pu \rightarrow {}^{4}_{2}\alpha + {}^{235}_{92}U$$

nucleons balanced
protons balanced

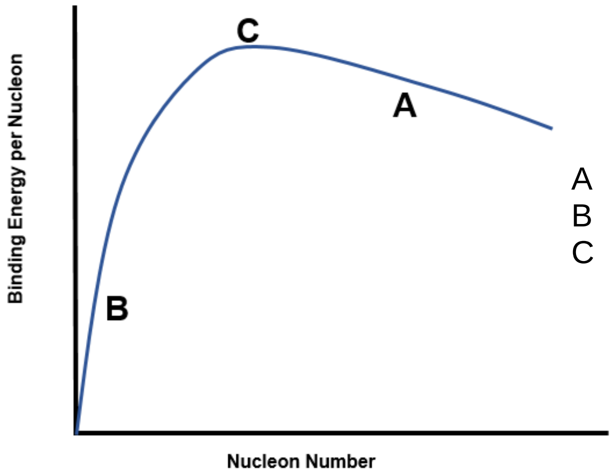
3.1.3 (a)
- The strongest of the fundamental forces.
- An attractive force that holds the nucleus (protons and neutrons as well as quarks) together.
- Acts the same on all nucleons.
- Acts over small ranges but does not diminish with distance.
- At extremely small distances the strong nuclear force is repulsive to prevent the nucleus from collapsing.

2 relevant points.

(b) Gluons

3.2 3.2.1 The **average** energy required to remove an individual nucleon from a nucleus.

3.2.2



A
B
C

3.3 3.3.1 In a stable nucleus the ratio of protons to neutrons are specific.
In an unstable nucleus there are too many neutrons.

3.3.2 $\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

$= \dfrac{\ln 2}{25000}$

$= 2{,}8 \times 10^{-5}$ years^{-1}

3.3.3 (a) The number of disintegrations per unit time (also known as the decay rate).

(b) $\frac{N}{N_A} = \frac{m}{M} \quad \therefore \quad N = \frac{m}{M} \times N_A$

For Pu: $N = \frac{m}{M} \times N_A$

$$N = \frac{3 \times 10^{-3}}{239} \times 6,022 \times 10^{23}$$
$$= 7,55 \times 10^{18}$$

For U: $N = \frac{m}{M} \times N_A$

$$N = \frac{9 \times 10^{-3}}{235} \times 6,022 \times 10^{23}$$
$$= 2,31 \times 10^{19}$$

Total number of atoms in original sample = $3,06 \times 10^{19}$

Fraction $\left(\frac{x}{x_o}\right)$ = $(7,55 \times 10^{18}) \div (3,06 \times 10^{19})$ = 151/612 = 0,25

Fraction of ¼ can be given if rounded values are used throughout.

(c) $$t = -\frac{\ln\left(\frac{x}{x_o}\right)}{\lambda}$$
$$= -\frac{\ln 0,25}{2,8 \times 10^{-5}}$$ *coe from (b) and 3.3.2*
$$= 49\ 500$$
$\approx$ 50 000 years from 2021

OR use $x = x_0 e^{-\lambda t}$

QUESTION 4 ASTROPHYSICS AND COSMOLOGY

4.1 (Nuclear) Fusion

4.2 Surface temperature of Eta Carinae = $5\,800 \times \frac{20}{3} = 38\,667$ K

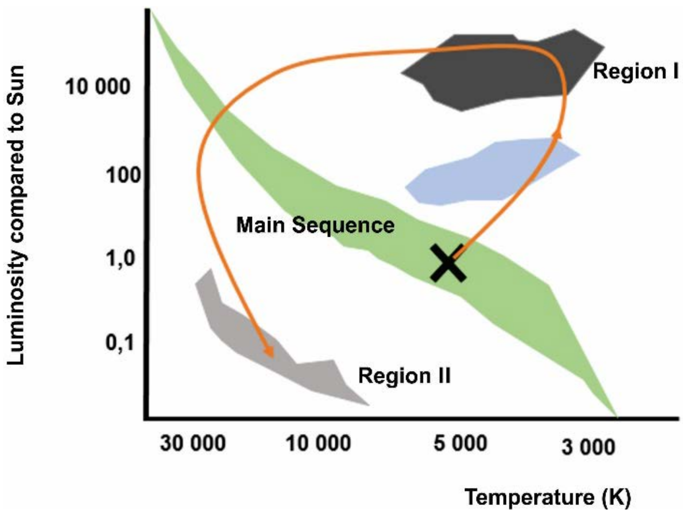
OR $\frac{3}{20} T_{Eta} = 5\,800$

$$\lambda_{max} T = 2{,}9 \times 10^{-3}$$
$$\lambda_{max} (5\,800 \times \frac{20}{3}) = 2{,}9 \times 10^{-3}$$
$$\lambda_{max} = 7{,}5 \times 10^{-8} \text{ m}$$

4.3 4.3.1 (a) Super Giants

(b) White Dwarfs

4.3.2 Position of the Sun show correctly using a cross.



4.3.3 On the diagram show the evolutionary path of the Sun.
First towards region I and then towards region II.
Path shown as on diagram

4.4
- Expectation according to Kepler's laws is that the further objects are from the centre of a galaxy, the slower they should rotate.
- Rotation curves show that galaxies are rotating at large speeds.
- Using the mass of visible matter, it is predicted that galaxies should not stay in their orbits but fly apart at speeds measured.
- However, galaxies do not fly apart so there must be invisible mass providing extra gravitational force to support the faster rotation.
- This mass is called DARK MATTER.

QUESTION 5 PROJECTILE MOTION

5.1 **Vertical motion:**

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

$0 = (21 \sin 32°)^2 + 2\,(-9{,}81)s$

$s = 6{,}31$ m

$\therefore$ the max height above the landing platform $= 6{,}31 + 4{,}20$ *addition*

$= 10{,}51$ m

OR use $v = u + at$ to calculate t and then $s = ut + ½\,at^2$ to get s.

5.2 **For the vertical motion:**

$s = ut + ½\,at^2$

$-4{,}2 = (21 \sin 32°)\,t + ½\,(-9{,}81)\,t^2$ *correct substitution and signs*

$4{,}905\,t^2 - 11{,}1283\,t - 4{,}2 = 0$ *(step not needed)*

$t = 2{,}598$ s

time for vertical motion = time for horizontal motion = 2,598 s

For the horizontal motion:

$s = ut + ½\,at^2$

$s = ut = (21 \cos 32°)(2{,}598)$

Range = 46,3 m

5.3 **For the vertical motion:**

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

$= (21 \sin 32°)^2 + 2(-9{,}81)(-4{,}2)$ *correct substitution and signs*

$v = -14{,}361\ \text{m}\cdot\text{s}^{-1}$

Or use $v = u + at$ and the time calculated above.

For the horizontal motion:

No acceleration $\therefore$ $u = v = 21 \cos 32°$

$= 17{,}809\ \text{m}\cdot\text{s}^{-1}$

$(\text{Resultant velocity})^2 = 14{,}361^2 + 17{,}809^2$

$v = 22{,}9\ \text{m}\cdot\text{s}^{-1}$

Angle: $\tan\theta = {}^{14{,}361}\!/_{17{,}809}$

$\theta = 38{,}88°$

$\therefore$ the velocity that it hits the ground at:

$22{,}9\ \text{m}\cdot\text{s}^{-1}$ at an angle of 38,9° with the horizontal.

(51,1° with the vertical) accept 2 or 3 significant figures.

QUESTION 6 FISHING AND TORQUE

6.1 6.1.1 LHS: $W = mg$
$\rightarrow \text{kg}\cdot\text{m}\cdot\text{s}^{-2}$

RHS: $\rho Vg \rightarrow \text{kg}\cdot\text{m}^{-3}\text{m}^{3}\text{m}\cdot\text{s}^{-2}$
$= \text{kg}\cdot\text{m}\cdot\text{s}^{-2}$

$\therefore$ the equation is homogeneous

6.1.2 $W = \rho Vg$
$5{,}6 = \rho ALg = 780 \times A \times 2{,}4 \times 9{,}81$

$A = 3{,}049 \times 10^{-4}\ \text{m}^2$
$= 3{,}0 \times 10^{2}\ \text{mm}^2$

6.2 6.2.1 There is no linear acceleration OR sum of all forces = 0.
There is no angular acceleration OR sum of all torques = 0.

6.2.2 $W_{\perp \text{ to rod}} = 5{,}6$ (sin 59°
$= 4{,}8$ N

6.2.3 Taking moments about point A:

$$\text{ACW} = \text{CW}$$
$$(T)(2{,}4) + (4{,}8)(1{,}2) = (4{,}5)(1{,}8)$$
$$T = 0{,}98\ \text{N}$$

QUESTION 7 CIRCULAR MOTION AND DATA ANALYSIS

7.1 7.1.1 $s = \theta r$

$= (0{,}60)\,(^{55}/_{2})$

$= 16{,}5$ m

≈ 17 m

7.1.2 The direction of the gondola is constantly changing. Therefore, there is a change in the velocity and $\therefore$ acceleration. OR There is a net force that acts towards the centre of the circle perpendicular to the velocity causing a change in the direction of the velocity although the speed remains constant.

7.1.3 Show an arrow that points from P to the centre of a circle.

7.1.4 $T = \dfrac{2\pi}{\omega}$ *(for both formulae)*

$(8 \times 60) = \dfrac{2\pi}{\omega}$ $\quad\therefore\ \omega = 0{,}013\ \text{rad}\cdot\text{s}^{-1}$

$a = \omega^2 r$

$= (0{,}013)^2\,(^{55}/_{2})$

$= 4{,}7 \times 10^{-3}\ \text{m}\cdot\text{s}^{-1}$

7.2 7.2.1
- The satellite is placed in an orbit with a period of exactly one day.
- The rotation is in the same direction as the Earth which makes it seem (from Earth) as if the satellite is motionless.
- Remains above the equator.

(Any two)

7.2.2 $F_g = \dfrac{GMm}{r^2}$ and $F_c = m\omega^2 r = m(^{v}/_{r})^2 r$

These forces are the same and causing the circular motion of the satellite.

$m(^{v}/_{r})^2 r = \dfrac{GMm}{r^2}$ *for showing $F_c = F_g$ OR $g = a$*

$\therefore\ v^2 = \dfrac{GM}{r}$

7.2.3 See graph on page 11.

(a) Correct title stating 'graph of v^2 vs $^1/r$'.
Quantities with units on *x* and *y*-axis.
Correct scale. > ½ the grid and no odd scale.
Accurate plotting.

(b) Error bars all correctly plotted and labelled.

(c) Line of best fit.
Least acceptable line (steepest).
Both lines must be labelled.

(d) v^2 is directly proportional to $^1/r$
OR v^2 is inversely proportional to r.
The graph forms a straight line through the origin.

7.2.4 Gradient of line of best fit $= \dfrac{y_2 - y_1}{x_2 - x_1}$

$$= \frac{(6{,}5 - 1{,}6) \times 10^7}{(1{,}6 - 0{,}4) \times 10^{-7}}$$

$= 4{,}08 \times 10^{14}$
all shown on graph

Gradient of steepest acceptable line $= \dfrac{y_2 - y_1}{x_2 - x_1}$

$$= \frac{(7{,}0 - 1{,}5) \times 10^7}{(1{,}56 - 0{,}4) \times 10^{-7}}$$

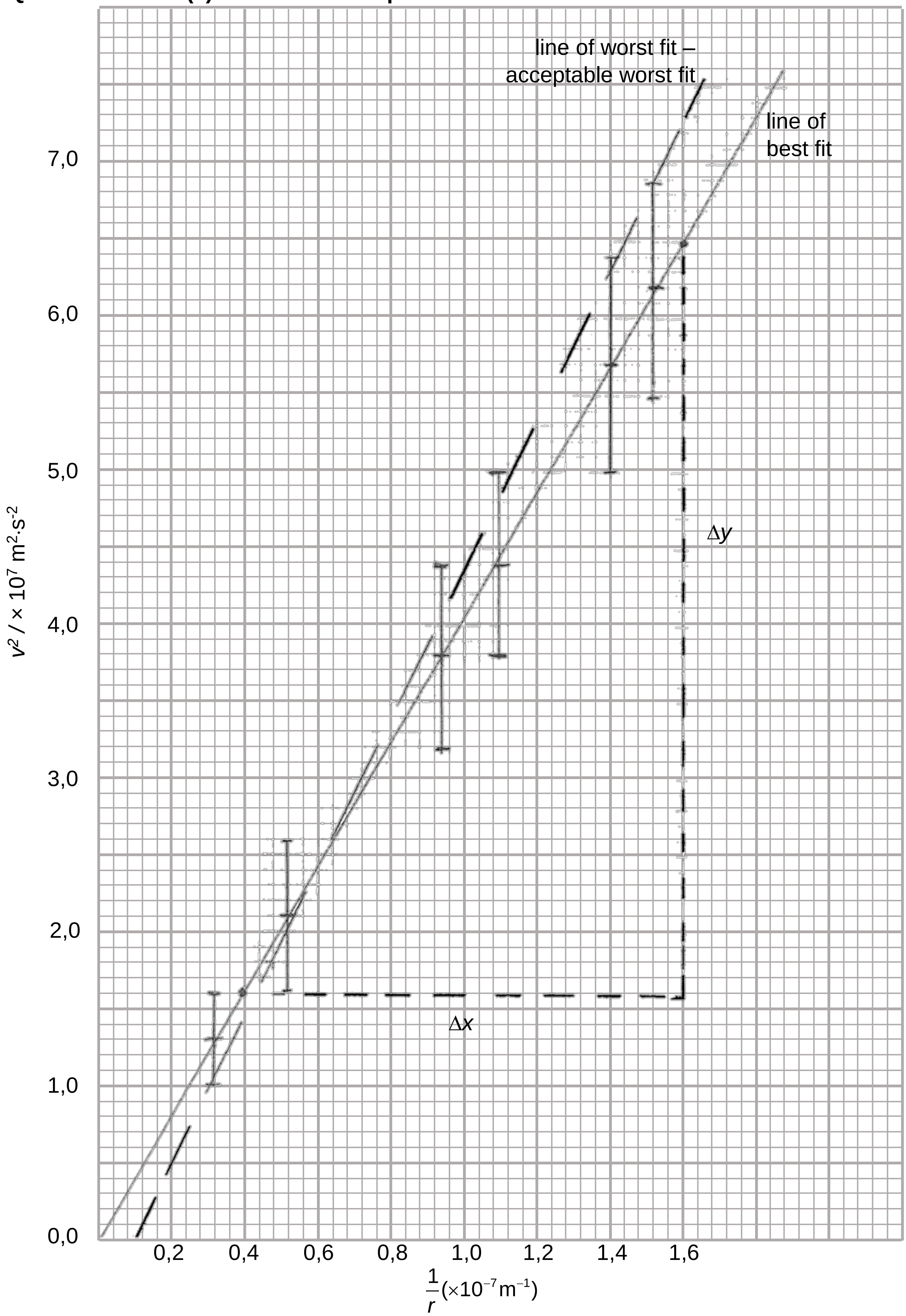
$= 4{,}74 \times 10^{14}$

Δ gradient = $0{,}66 \times 10^{14}$ $\therefore$ gradient = $(4{,}1 \pm 0{,}7) \times 10^{14}$ **written correctly**

7.2.5 $v^2 = GM\dfrac{1}{r}$ and knowing that y = mx + c
the gradient = GM

GM = $4{,}1 \times 10^{14}$ coe from 7.2.6
G $(5{,}98 \times 10^{24}) = 4{,}1 \times 10^{14}$
G = $6{,}8 \times 10^{-11}$ $\mathrm{N \cdot m^2 \cdot kg^{-2}}$ **no unit, no mark**

QUESTION 7.2.3 (a) **Graph of v^2 vs $^1/_r$**



QUESTION 8 CHARGED PARTICLES IN ELECTRIC AND MAGNETIC FIELDS

8.1 8.1.1 Downwards (towards the positive plate)

8.1.2 (a) $qE = qvB$
$400 = 500\ B$
$B = 0{,}8\ \text{T}$

(b) out of the page

8.2 8.2.1 (a) The magnetic field creates the **force** on the moving charged particle (proton) that causes the particle to move in a circular path across the surface of D1 and D2.

(b) Change polarity (oscillating polarity) to (attract and) accelerate the charged particle.

8.2.2 $F_B = F$

$$q\ v\ B = m\ \omega^2\ r = m\left(\frac{v^2}{r^2}\right) r$$

simplify $q\ B\ r = m\ v$

$(1{,}6 \times 10^{-19})\ (1{,}3)\ (r) = (1{,}673 \times 10^{-27})\ (7{,}5 \times 10^{5})$

$r = 6{,}0 \times 10^{-3}\ \text{m}$

8.2.3
- Less radiation scattering OR can achieve highly collimated radiation.
- More energy efficient.
- Can achieve higher velocity of charged particles.

(Any two)

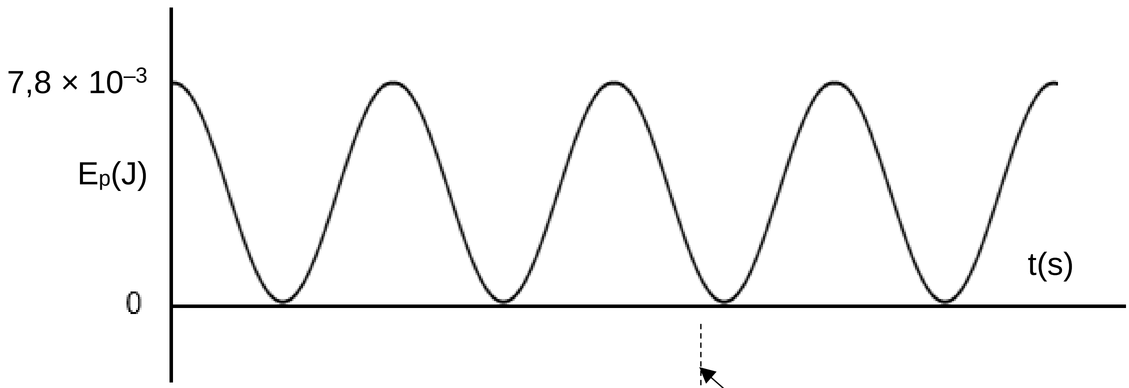
QUESTION 9 OSCILLATIONS

9.1 Motion occurring when a linear restoring force is exerted on an object displaced from an equilibrium position.

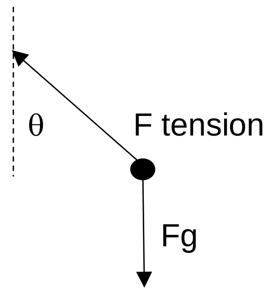
OR acceleration is directly proportional to displacement and in the opposite direction.

9.2 $E_{total} = (E_p + E_k) = m\,g\,h + 0$
$= (88 \times 10^{-3})\,(9{,}81)\,(0{,}9 \times 10^{-2})$
$= 7{,}8 \times 10^{-3}$ J

9.3 shape labels correct number of oscillations all positive.



9.4 9.4.1 Free body diagram. angle



9.4.2 Weight (restoring force) = – mg sinθ

9.4.3 For small angle in radians $\sin\theta = \theta$

$$F_{restore} = -mg\theta = -mg\,{}^{s}/_{L} = ma$$

$$\therefore\ a = \frac{-g}{L}s$$

9.4.4 $\omega^2 = \dfrac{g}{L}$ $\omega = \dfrac{2\pi}{T}$ OR $T = \dfrac{2\pi}{\omega}$

$$\therefore\ T = 2\pi\sqrt{\frac{L}{g}}$$

Total: 200 marks