Q1.

1 (a) work done in bringing/moving unit mass from infinity to the point (use of 1 kg in the definition – max 1/2) .......................................................... M1 A1 [2]

(b) potential at infinity defined as being zero forces are always attractive so work got out in moving to point (max potential is at infinity – allow 1/3) .......................................... B1 B1 B1 [3]

(c) (i) \( \phi = -\frac{GM}{R} \)
change = \( 6.67 \times 10^{-11} \times 6.0 \times 10^{26} \times \{6.4 \times 10^{6}\}^{-1} - \{1.94 \times 10^{7}\}^{-1} \) change = \( 4.19 \times 10^{7} \) J kg\(^{-1}\) (ignore sign) .......................................................... C2 A1

(ii) \( \frac{1}{2}m v^2 = m \Delta \phi \) ...................................................... C1 A1
\( v^2 = 2 \times 4.19 \times 10^7 = 8.38 \times 10^7 \)
\( v = 9150 \) m s\(^{-1}\) .......................................................... A1 [5]

(d) acceleration is not constant .......................................................... B1 [1]

Q2.

3 (a) (i) (force) = \( GM \Delta M / (R_1 + R_2)^2 \) .................................................. B1 [2]

(ii) (force) = \( M_1 R_1 \omega^2 \) or \( M_2 R_2 \omega^2 \) .................................................. B1 [2]

(b) \( \omega = 2\pi \{1.26 \times 10^8\} \) or \( 2\pi / T \)
\( = 4.99 \times 10^8 \) rad s\(^{-1}\) .................................................. A1 [2]
allow 2 s.f.: \( 1.59 \times 10^9 \) scores 1/2

(c) (i) reference to either taking moments (about C) or same (centripetal) force
\( M_1 R_1 = M_2 R_2 \) or \( M_1 R_1 \omega^2 = M_2 R_2 \omega^2 \) hence \( M_1 / M_2 = R_2 / R_1 \) .................................................. B1 [2]

(ii) \( R_2 = 3.4 \times 3.2 \times 10^6 \) m = \( 2.4 \times 10^{11} \) m
\( R_1 = (3.2 \times 10^{11}) - R_2 = 8.0 \times 10^{10} \) m (allow vice versa)
if values are both wrong but have ratio of four to three, then allow 1/2

(d) (i) \( M_2 = \{(R_1 + R_2)^2 \times 8.0 \times 10^{10} \times (4.99 \times 10^8) / (6.67 \times 10^{-11}) \} / \pi \)
\( = 3.06 \times 10^{29} \) kg .................................................. C1 A1

(ii) less massive (only award this mark if reasonable attempt at (i)) (9.17 \times 10^{29} \) kg for more massive star) .................................................. B1 [4]

Total [12]

Q3.
Q4.

1 (a) (i) angular speed = \(2\pi/T\)
   \[= \frac{2\pi(3.2 \times 10^7)}{1.96 \times 10^7} \text{ rad s}^{-1}\]  
   \[= 3.15 \text{ rad s}^{-1}\]  
   C1

(ii) force = \(\frac{m(v^2)}{r}\) or force = \(mv^2/r\) and \(v = r\omega\)
   \[= 6.0 \times 10^{24} \times 1.5 \times 10^{11} \times (1.96 \times 10^{-7})^2\]
   \[= 3.46 \times 10^{22} \text{ N}\]  
   A1 [2]

(b) (i) gravitation/gravity/gravitational field (strength)
   B1 [1]

(ii) \(F = \frac{GMm}{r^2}\) or \(GM = \frac{r^2}{\omega^2}\)
   \[3.46 \times 10^{22} = \frac{6.67 \times 10^{-11} \times M \times 6.0 \times 10^{24}}{(1.5 \times 10^{11})^2}\]
   \[M = 1.95 \times 10^{30} \text{ kg}\]  
   C1 A1 [3]

Q5.

1 (a) centripetal force is provided by gravitational force
   \(\frac{mv^2}{r} = \frac{GMm}{r^2}\)
   hence \(v = \sqrt{\frac{GM}{r}}\)  
   B1 A0 [2]

(b) (i) \(E_K = \frac{1}{2}mv^2 = \frac{GMm}{2r}\)  
   B1 [1]

(ii) \(E_V = -\frac{GMm}{r}\)  
   B1 [1]

(iii) \(E_T = -\frac{GMm}{r} + \frac{GMm}{2r}\)
   \[= -\frac{GMm}{2r}\]  
   C1 A1 [2]

(c) (i) if \(E_T\) decreases then \(-\frac{GMm}{2r}\) becomes more negative
   or \(-\frac{GMm}{2r}\) becomes larger so \(r\) decreases  
   M1 A1 [2]

(ii) \(E_K = \frac{GMm}{2r}\) and \(r\) decreases so \((E_K, \text{ and}) v\) increases  
   M1 A1 [2]

Q6.
Q7.

1 (a) work done moving unit mass from infinity to the point

(b) (i) at R, \( \phi = 6.3 \times 10^7 \text{ J kg}^{-1} \) (allow \( \pm 0.1 \times 10^7 \))
\[
\phi = \frac{GM}{R} = \frac{6.3 \times 10^7}{(6.67 \times 10^{-11} \times M)} \text{ (allow 5.95 to 6.14)}
\]
\( M = 6.0 \times 10^{24} \text{ kg} \) (allow 2/3 for any value chosen for \( \phi \) not at R)

(ii) change in potential = \( 2.1 \times 10^7 \text{ J kg}^{-1} \) (allow \( \pm 0.1 \times 10^7 \))
loss in potential energy = gain in kinetic energy
\[
\frac{1}{2} m v^2 = \phi m \text{ or } \frac{1}{2} m v^2 = GM \frac{1}{3R}
\]
\( \frac{1}{2} v^2 = 2.1 \times 10^7 \)
\( v = 6.5 \times 10^3 \text{ m s}^{-1} \) (allow 6.3 to 6.6)
(answering 7.9 \times 10^3 \text{ m s}^{-1}, based on \( x = 2R \), allow max 3 marks)

(iii) e.g. speed / velocity / acceleration would be greater deviates / bends from straight path
(any sensible ideas, 1 each, max 2)

Q8.

1 (a) (i) force proportional to product of masses
force inversely proportional to square of separation

(ii) separation much greater than radius / diameter of Sun / planet

(b) (i) e.g. force or field strength \( \propto \frac{1}{r^2} \)
potential \( \propto \frac{1}{r} \)

(ii) e.g. gravitational force (always) attractive electric force attractive or repulsive

Q9.
Q10.

1. (a) region (of space) where a particle / body experiences a force B1 [1]

(b) similarity: e.g. force \( \propto \frac{1}{r^2} \)
potential \( \propto \frac{1}{r} \) B1 [1]

difference: e.g. gravitation force (always) attractive
electric force attractive or repulsive B1 [2]

(c) either ratio is \( \frac{Q_1 Q_2}{4 \pi \varepsilon_0 m_1 m_2 G} \)
\[ \frac{(1.6 \times 10^{-19})^2}{4 \pi \times 8.85 \times 10^{-12} \times (1.67 \times 10^{-24})^2} \times 6.67 \times 10^{-11} \]
\[ = 1.2 \times 10^{36} \] C1

or \( F = 2.30 \times 10^{-20} \times R^{-2} \) (C1)
\( F_0 = 1.86 \times 10^{-44} \times R^{-2} \) (C1)
\( F_0 / F_0 = 1.2 \times 10^{36} \) (A1)

Q11.

1. (a) work done in bringing unit mass from infinity (to the point) B1 [1]

(b) gravitational force is (always) attractive B1 [2]

either as \( r \) decreases, object/mass/body does work

or work is done by masses as they come together B1 [2]

(c) either force on mass = \( mg \) (where \( g \) is the acceleration of free fall /gravitational field strength)

\[ g = \frac{GM}{r^2} \]
if \( r @ h, g \) is constant B1

\[ \Delta E_P = \text{force} \times \text{distance moved} \]
\[ = mgh \] M1

or \( \Delta E_P = m\Delta \phi \) (C1)
\[ = GMm(1/r_1 - 1/r_2) = GMm(r_2 - r_1)/r_1 r_2 \] (B1)
if \( r_2 = r_1 \) then \( (r_2 - r_1) = h \) and \( r_1 r_2 = r^2 \) (B1)

\[ g = \frac{GM}{r^2} \]
\[ \Delta E_P = mgh \] (A0) [4]

(d) \( \frac{1}{2}mv^2 = m\Delta \phi \)
\[ v^2 = 2 \times \frac{GM}{r} \] C1
\[ = (2 \times 4.3 \times 10^{13}) / (3.4 \times 10^5) \] C1
\[ v = 5.0 \times 10^3 \text{ m s}^{-1} \] A1 [3]

(Use of diameter instead of radius to give \( v = 3.6 \times 10^3 \text{ m s}^{-1} \) scores 2 marks)
Q12.

1 (a) force proportional to product of masses and inversely proportional to square of separation (do not allow square of distance/radius) M1
   either point masses or separation \( \propto \) size of masses A1 [2]

(b) (i) \( \omega = \frac{2\pi}{(27.3 \times 24 \times 3800)} \) or \( \frac{2\pi}{(2.36 \times 10^6)} \)
   \( = 2.66 \times 10^{-6} \text{rad/s}^{-1} \) M1
   A0 [1]

(ii) \( GM = r^2 \omega^2 \) or \( GM = \frac{v^2r}{2} \)
   \( M = \frac{3.84 \times 10^5 \times 10^3}{2} \times (2.66 \times 10^{-6})^2 / (6.67 \times 10^{-11}) \)
   \( = 6.0 \times 10^{24} \text{kg} \) C1
   M1
   A0 [2]
   (special case: uses \( g = GM/r^2 \) with \( g = 9.81 \), \( r = 6.4 \times 10^6 \) scores max 1 mark)

(c) (i) grav. force \( = \frac{(6.0 \times 10^{24}) \times (7.4 \times 10^{20}) \times (6.7 \times 10^{-10})}{(3.84 \times 10^9)^2} \)
   \( = 2.0 \times 10^{20} \text{N} \) (allow 1 SF) A1 [2]

(ii) either \( \Delta E_r = Fx \) because \( F \) constant as \( x \) \( \propto \) radius of orbit B1
   \( \Delta E_r = 2.0 \times 10^{30} \times 4.0 \times 10^{-3} \)
   \( = 8.0 \times 10^{27} \text{J} \) (allow 1 SF) C1
   M1
   A1 [3]
   or \( \Delta E_r = GMm/r_1 - GMm/r_2 \)
   Correct substitution B1
   \( 8.0 \times 10^{30} \text{J} \) A1

\( \Delta E_r = GMm/r_1 + GMm/r_2 \) is incorrect physics so 0/3.

Q13.
Q14.

4 (a) (i) \( \frac{1}{2}mv^2 = \frac{GMm}{R} \) .................................................. B1
\( v^2 = \frac{2GM}{R} \) .................................................. A0
(ii) \( g = \frac{GM}{R^2} \) .................................................. M1
clear algebra giving \( v^2 = 2gR \) .................................................. A1 [3]

(b) \( \frac{1}{2}mv^2 = 3/2kT \)
\( v^2 = \frac{3kT}{m} \) .................................................. C1
\( 3kT/m = 2gR \) .................................................. C1
\( T = (2 \times 6.6 \times 10^{27} \times 9.81 \times 6.4 \times 10^9) / (1.38 \times 10^{-23} \times 3) \) .................................................. C1
\( T = 2.0 \times 10^4 K \) .................................................. A1 [4]

Q15.

1 (a) (i) radial lines .......................................... B1
pointing inwards .......................................... B1
(ii) no difference OR lines closer near surface of smaller sphere ...... B1 [3]

(b) (i) \( F_G = \frac{GMmR^2}{R^2} \) .................................................. C1
\( = (6.67 \times 10^{-11} \times 5.98 \times 10^{24})/(6380 \times 10^3)^2 \)
\( = 9.80 \text{ N} \) .................................................. A1
(ii) \( F_G = mR\omega^2 \) .................................................. C1
\( \omega = \frac{2\pi}{T} \) .................................................. C1
\( F_G = (4\pi^2 \times 6380 \times 10^3 \times 8.64 \times 10^4)^2 \)
\( = 0.0337 \text{ N} \) .................................................. A1
(iii) \( F_G - F_C = 9.77 \text{ N} \) .................................................. A1 [6]

(c) because acceleration (of free fall) is (resultant) force per unit
mass .......................................... B1
acceleration = 9.77 m s\(^{-2}\) .......................................... B1 [2]

Q16.
Q17.

1 (a) either ratio of work done to mass/charge
or work done moving unit mass/charge from infinity
or both have zero potential at infinity

(b) gravitational forces are (always attractive)
electric forces can be attractive or repulsive
for gravitational, work got out as masses come together
for electric, work done on charges if same sign, work got out if opposite sign as charges come together

Q18.

4 (a) (i) \[ \frac{GMm}{(R + h_2)^1} - \frac{GMm}{(R + h_1)^1} \]

(b) \[ 2M \times 6.67 \times 10^{-11} \times (26.28 \times 10^9)^1 - (29.06 \times 10^9)^1 = 5370^2 - 5090^2 \]
\[ M \times 4.886 \times 10^{18} = 2.929 \times 10^9 \]
\[ M = 6.00 \times 10^{25} \text{ kg} \]

(If equation in (a) is dimensionally unsound, then 0/3 marks in (b). If dimensionally sound but incorrect, treat as e.c.f.)
Q20.

1  (a) \( F = \frac{GMm}{R^2} \) .................................................. M1
    either \( M \) and \( m \) are point masses
    or \( R \gg \) diameter of masses ...(do not allow ‘size’) ...................... A1 [2]

(b) (i) equatorial orbit ................................................................................. B1
    period 24 hours / same angular speed ...................................................... B1
    from west to east / same direction of rotation ........................................ B1 [3]
    (allow one of the last two marks for ‘always overhead’ if 2nd or 3rd marks not scored)

(ii) gravitational force provides centripetal force
    \( \frac{GM}{x^2} = x\omega^2 \) ........................................................................ M1
    \( g = \frac{GM}{R^2} \) ...................................................................................... M1
    to give \( gR^2 = x\omega^2 \) ...................................................................... A0 [3]

(iii) \( \omega = \frac{2\pi}{(24 \times 3600)} = 7.27 \times 10^{-5} \text{ rad s}^{-1} \) ......................... C1
    \( 9.81 \times (6.4 \times 10^{6})^2 = x^2 \times (7.27 \times 10^{-5})^2 \) ...................... C1
    \( x^2 = 7.6 \times 10^{22} \)
    \( x = 4.2 \times 10^7 \text{ m} \) ........................................................................ A1 [3]
    (use of \( g = 10 \text{ m s}^{-2} \), loses 1 mark but once only in the Paper)

[Total: 11]

Q21.
Q22.

1 (a) force per unit mass  
\[(\text{ratio idea essential})\]  
B1  [1]

\[(\text{iii}) \quad g = \frac{GM}{R^2} \]  
\[9.81 = \frac{(6.67 \times 10^{-11} \times M)}{(6.38 \times 10^6)^2} \quad \text{(all 3 s.f.)} \]  
M = 5.99 \times 10^{24} \text{ kg}  
M1  [2]

(b) (i) \(\text{either} \quad GM = \frac{G M S 0}{r^3} \quad \text{or} \quad g R^2 = \frac{G M S 0}{r^3} \)  
\[6.67 \times 10^{-11} \times 5.99 \times 10^{24} = \frac{G M S 0}{r^3} \quad (2.86 \times 10^7)^3 \]  
or \[9.81 \times (6.38 \times 10^6)^2 = \frac{G M S 0}{r^3} \quad (2.86 \times 10^7)^3 \]  
\[\omega = 1.3 \times 10^{-4} \text{ rad s}^{-1} \]  
A1  [3]

\[(\text{use of } r = 2.22 \times 10^7 \text{ m scores max 2 marks})\]

(ii) period of orbit = \[2\pi / \omega \]  
\[= 4.8 \times 10^4 \text{ s} \quad (= 13.4 \text{ hours}) \]  
A1

period for geostationary satellite is 24 hours \(= 8.6 \times 10^4 \text{ s} \)  
A0

(c) satellite can then provide cover at Pole  
B1  [1]

[Total: 10]

Q23.

1 (a) force per unit mass  
\[(\text{ratio idea essential})\]  
B1  [1]

(b) graph: correct curvature  
\[(R, 1.0 \ g_s) & \text{ at least one other correct point}\]  
M1

A1  [2]

(c) (i) fields of Earth and Moon are in opposite directions  
\[(\text{either}) \quad \text{resultant field found by subtraction of the field strength}\]

or \[(\text{any other sensible comment})\]

so there is a point where it is zero  
\[(\allow F_E = -F_M \text{ for 2 marks})\]  
M1

A1

A0  [2]

(ii) \[\frac{G M_E}{x^2} = \frac{G M_M}{(D - x)^2} \]  
\[(6.0 \times 10^{24}) / (7.4 \times 10^{25}) = x^2 / (60R_E - x)^2 \]  
\[x = 54R_E \]  
C1

C1

A1  [3]

(iii) graph: \(g = 0 \) at least \( \frac{1}{2} \) distance to Moon  
g_E and \( g_M \) in opposite directions  
correct curvature (by eye) and \( g_E > g_M \) at surface  
B1

M1

A1  [3]
1 (a) (i) rate of change of angle / angular displacement swept out by radius

\( \omega \times T = 2\pi \)  

M1  

A1 [2]

(ii) \( r \times T = 2\pi \)

B1 [1]

(b) centripetal force is provided by the gravitational force

\[
\text{either} \quad m(rT)^2 = GMmr^2 \quad \text{or} \quad mr\omega^2 = GMm/r^2
\]

\[
r^3 \times 4\pi^2 = GM \times T^2 \\
GM4\pi^2 \text{ is a constant (c)} \\
T^2 = \alpha r^3
\]

B1

M1

A1

A1

A0 [4]

(c) (i) \( T^2 = (45/1.08)^3 \times 0.615^2 \) or \( T^2 = 0.30 \times 45^3 \)

\( T = 165 \text{ years} \)

C1

A1 [2]

(ii) speed = \( (2\pi \times 1.08 \times 10^5) / (0.615 \times 365 \times 24 \times 3600) \)

\( = 35 \text{ km s}^{-1} \)

C1

A1 [2]

Q24.

1 (a) gravitational force provides the centripetal force

\[ GMmr^2 = m \omega^2 \quad \text{(must be in terms of } \omega \text{)} \]

\[ r^2 \omega^2 = GM \text{ and } GM \text{ is a constant} \]

B1

B1

B1 [3]

(b) (i) 1. For Phobos, \( \omega = 2\pi/(7.65 \times 3600) \)

\( = 2.28 \times 10^{-4} \text{ rad s}^{-1} \)

\( (9.39 \times 10^9)^3 \times (2.28 \times 10^{-4})^2 = 6.67 \times 10^{-11} \times M \)

\( M = 6.46 \times 10^{23} \text{ kg} \)

C1

C1

A1 [3]

2. \( (9.39 \times 10^9)^3 \times (2.28 \times 10^{-4})^2 = (1.99 \times 10^5)^3 \times \omega^2 \)

\( \omega = 7.30 \times 10^{-5} \text{ rad s}^{-1} \)

\( T = 2\pi/\omega = 2\pi/(7.30 \times 10^{-5}) \)

\( = 8.6 \times 10^5 \text{ s} \)

\( = 23.6 \text{ hours} \)

C1

C1

A1 [3]

(ii) either almost ‘geostationary’

or satellite would take a long time to cross the sky

B1 [1]

Q25.
Q26.

1 (a) weight = \(\frac{GMm r^2}{(\frac{1}{2} \times 6.79 \times 10^6)^2}\) = 5.20 N C1

(ii) potential energy = \(-\frac{GMm r}{(\frac{1}{2} \times 6.79 \times 10^6)}\)
\(= \frac{-6.67 \times 10^{-11} \times 6.42 \times 10^{23} \times 1.40}{(\frac{1}{2} \times 6.79 \times 10^6)}\)
\(= -1.77 \times 10^7 \) J A0 [2]

(b) \(\frac{1}{2}m v^2 = 1.77 \times 10^7\) C1
\(v^2 = (1.77 \times 10^7 \times 2)/1.40\)
\(v = 5.03 \times 10^7 \) ms\(^{-1}\) A1

or \(\frac{1}{2}m v^2 = GMm/r\) (C1)
\(v^2 = (2 \times 6.67 \times 10^{-11} \times 6.42 \times 10^{23})/(6.79 \times 10^6/2)\)
\(v = 5.02 \times 10^7 \) ms\(^{-1}\) (A1) [3]

Q27.

1 (a) work done in moving unit mass from infinity (to the point)

(b) (i) gravitational potential energy = \(\frac{GMm}{x}\)
energy = \((6.67 \times 10^{-11} \times 7.35 \times 10^{22} \times 4.5)/(1.74 \times 10^9)\)
energy = \(1.27 \times 10^7\) J M1

(ii) change in grav. potential energy = change in kinetic energy
\(\frac{1}{2} \times 4.5 \times v^2 = 1.27 \times 10^7\)
\(v = 2.4 \times 10^7 \) ms\(^{-1}\) A1 [2]

(c) Earth would attract the rock / potential at Earth('s surface) not zero / <0
/ at Earth, potential due to Moon not zero
escape speed would be lower M1 A1 [2]
Q28.

1. (a) force proportional to product of the two masses and inversely proportional to the square of their separation
   either reference to point masses or separation >> 'size' of masses
   \[ M_1 \frac{1}{r^2} \]
   A1 [2]

(b) gravitational force provides the centripetal force
\[ GMm/r^2 = mR_\text{ref} \dot{\phi}^2 \]
where \( m \) is the mass of the planet
\[ GM = R^2 \omega^2 \]
A0 [3]

(c) \( \omega = 2\pi / T \)
either \( \frac{M_{\text{star}}}{M_{\text{sun}}} = \left( \frac{R_{\text{star}}}{R_{\text{sun}}} \right)^3 \times \left( \frac{T_{\text{sun}}}{T_{\text{star}}} \right)^2 \)
\[ M_{\text{star}} = 4 \pi^2 \frac{G}{T^2} R_{\text{star}}^3 \]
\[ = 3.2 \times 10^{31} \text{kg} \]
A1 [3]
or \( M_{\text{star}} = \frac{(2\pi)^2 R_{\text{star}}^3}{G T^2} \)
\[ = \frac{(2\pi)^2 \times (6.0 \times 10^{11})^3}{6.67 \times 10^{-11} \times (2 \times 365 \times 24 \times 3600)^2} \]
\[ = 3.2 \times 10^{31} \text{kg} \]
A1 [3]

Q29.

1. (a) work done bringing unit mass from infinity (to the point)
   \[ W = m \phi \]
   A1 [2]

(b) \( E_\phi = -m \phi \)
   B1 [1]

(c) \( \phi \propto 1/x \)
   C1

either at 6R from centre, potential is \( (6.3 \times 10^7)/6 \)
\[ (= 1.05 \times 10^7 \text{ J kg}^{-1}) \]
and at 5R from centre, potential is \( (6.3 \times 10^7)/5 \)
\[ (= 1.26 \times 10^7 \text{ J kg}^{-1}) \]
change in energy \( (1.26 - 1.05) \times 10^7 \times 1.3 \)
\[ = 2.7 \times 10^6 \text{ J} \]
A1
or change in potential \( (1/5 - 1/6) \times (6.3 \times 10^7) \)
\[ [(C1)] \]
change in energy \( (1/5 - 1/6) \times (6.3 \times 10^7) \times 1.3 \)
\[ = 2.7 \times 10^6 \text{ J} \]

Q30.
Q31.

1 (a) gravitational force provides/is the centripetal force
\[ \frac{GMm}{r^2} = \frac{m v^2}{r} \]
\[ v = \sqrt{\frac{GM}{r}} \]
A0 [2]

allow gravitational field strength provides/is the centripetal acceleration
\[ \frac{GM}{r^2} = \frac{v^2}{r} \]
(M1)

(b) (i) kinetic energy increase/change = loss/change in (gravitational) potential energy
\[ \frac{1}{2}mv_c^2 = \frac{GMm}{x} \]
\[ V_c^2 = 2GM/x \]
\[ V_0 = \sqrt{2GM/x} \]
(max. 2 for use of r not x)
A1 [3]

(ii) \( V_0 \) is (always) greater than \( v \) (for \( x = r \))
so stone could not enter into orbit
M1 [2]

(expressions in (a) and (b)(i) must be dimensionally correct)

Q32.

2 (a) smooth curve with decreasing gradient, not starting at \( x = 0 \)
end of line not at \( g = 0 \) or horizontal
M1 A1 [2]

(b) straight line with positive gradient
line starts at origin
M1 A1 [2]

(c) sinusoidal shape
only positive values and peak/trough height constant
4 'loops'
B1 B1 B1 [3]