15 In 2015 the Messenger spacecraft crashed into the surface of the planet Mercury after four years in orbit observing the surface of Mercury.

Messenger's orbit was highly elliptical, varying between 200 km and 15 000 km above the surface of Mercury. Messenger completed one full orbit every 12 hours.

mass of Messenger spacecraft = 565 kg
mass of planet Mercury = 3.30×10^{23} kg
radius of planet Mercury = 2430 km

(a) It has been suggested that the same orbital period of about 12 hours could have been achieved if Messenger was in a circular orbit 7690 km above the surface of Mercury.

(i) Determine whether this suggestion is correct.

(4)

$\frac{GMm}{r^2} = m\omega^2 r$ and $\omega = \frac{2\pi}{T}$

r=2430km+7690Km = 1.012x10^6m

T=12*60*60=4.32x10^4s

$\frac{GM}{r^3} = \omega^2 = \frac{4\pi^2}{T^2}$ solve for f

$\frac{r^3}{GM} = \frac{T^2}{4\pi^2} \rightarrow r^3 = \frac{GMT^2}{4\pi^2}$

$r^3 = 6.67x10^{-11} * 3.3x10^{23} * \frac{(4.32x10^4)^2}{4 * \pi^2}$

$\therefore r = 1.01x10^7 m$

so height above is $7.7x10^6 m = 7.7Km$

(ii) The elliptical orbit chosen had advantages over this circular orbit.

Explain one advantage.

(2)

get in closer
for better photographs

etc

(b) Calculate the velocity an object would have as it reached the surface of Mercury if it was released from Messenger's maximum orbital height.
Assume the object is released from rest and that Mercury has no atmosphere.

(4)

so max r is (15x10^6+2.43x10^6)km and final r is 2.430x10^6m
find change in Vg

$$Vg = -\frac{GM}{r} \rightarrow \Delta Vg = -GM\left(\frac{1}{rf} - \frac{1}{ri}\right)$$

Where rf is final radius, ri is initial radius

$\Delta V_g = -[6.67\times10^{-11}]\left(\frac{1}{2.43\times10^6} - \frac{1}{1.74\times10^7}\right)$

$\Delta V_g = 7.79\times10^6 = \frac{1}{2}mv^2$ where

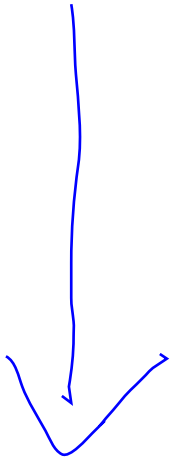
$m = 1\text{kg}$

Velocity = ...

(Total for Question 15 = 10 marks)

$v = 3948\ \text{m/s}$

$3900\ \text{m/s}$



8

9 Electric and gravitational fields have a number of similarities and differences.

An electric field is produced by a point charge and a gravitational field is produced by a point mass.

Which of the following statements applies to both of these fields?

☐ **A** The field causes a force on all particles.

☐ **B** The force caused by the field can be attractive or repulsive.

☐ **C** At a distance x from the centre of the field, field strength is proportional to x^2.

☒ **D** At a distance x from the centre of the field, potential is proportional to $1/x$.

(Total for Question 9 = 1 mark)

(Total for Question 3 = 1 mark)

4 Which of the following is **not** a similarity between gravitational fields and electric fields?

- ☒ **A** For a point charge or point mass, the field follows the inverse square law. ✓
- ☒ **B** For a point charge or point mass, the field is radial. ✓
- ☒ **C** Both fields act at a distance. ✓
- ☒ **D** Both fields act on all particles. ✗

(Total for Question 4 = 1 mark)