

SPACE

1st Quarter; Module 1

PERIOD 2

Variations in "g" &
Gravitational Potential energy

H S C P H Y S I C S																		
SPACE				MOTORS and GENERATORS					From IDEAS to IMPLEMENTATION									
1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	5	6



The Earth has a gravitational field that exerts a force on objects both on it and around it

Students learn to:

- define weight as the force on an object due to a gravitational field
- explain that a change in gravitational potential energy is related to work done
- define gravitational potential energy as the work done to move an object from a very large distance away to a point in a gravitational field

$$E_p = -G \frac{m_1 m_2}{r}$$

Students:

- perform an investigation and gather information to determine a value for acceleration due to gravity using pendulum motion or computer-assisted technology and identify reasons for possible variations from the value 9.8 m s^{-2}
- gather secondary information to predict the value of acceleration due to gravity on other planets
- analyse information using the expression $F = mg$ to determine the weight force for a body on Earth and for the same body on other planets

2007 HSC PAPER

- 4 The acceleration due to gravity on Earth's surface is g . Suppose the radius of Earth was reduced to a quarter of its present value while its mass remained the same.

What would be the new value of the acceleration due to gravity on the surface?

(A) $\frac{1}{16}g$

(B) $\frac{1}{4}g$

(C) $4g$

(D) $16g$

$$g = \frac{GM}{d^2}$$
$$g' = \frac{GM}{\left(\frac{d}{4}\right)^2}$$
$$\frac{GM}{\frac{d^2}{16}} = \frac{GM}{1} \times \frac{16}{d^2}$$
$$g' = \frac{GM}{\frac{d^2}{16}} = 16 \times \frac{GM}{d^2} = 16g$$

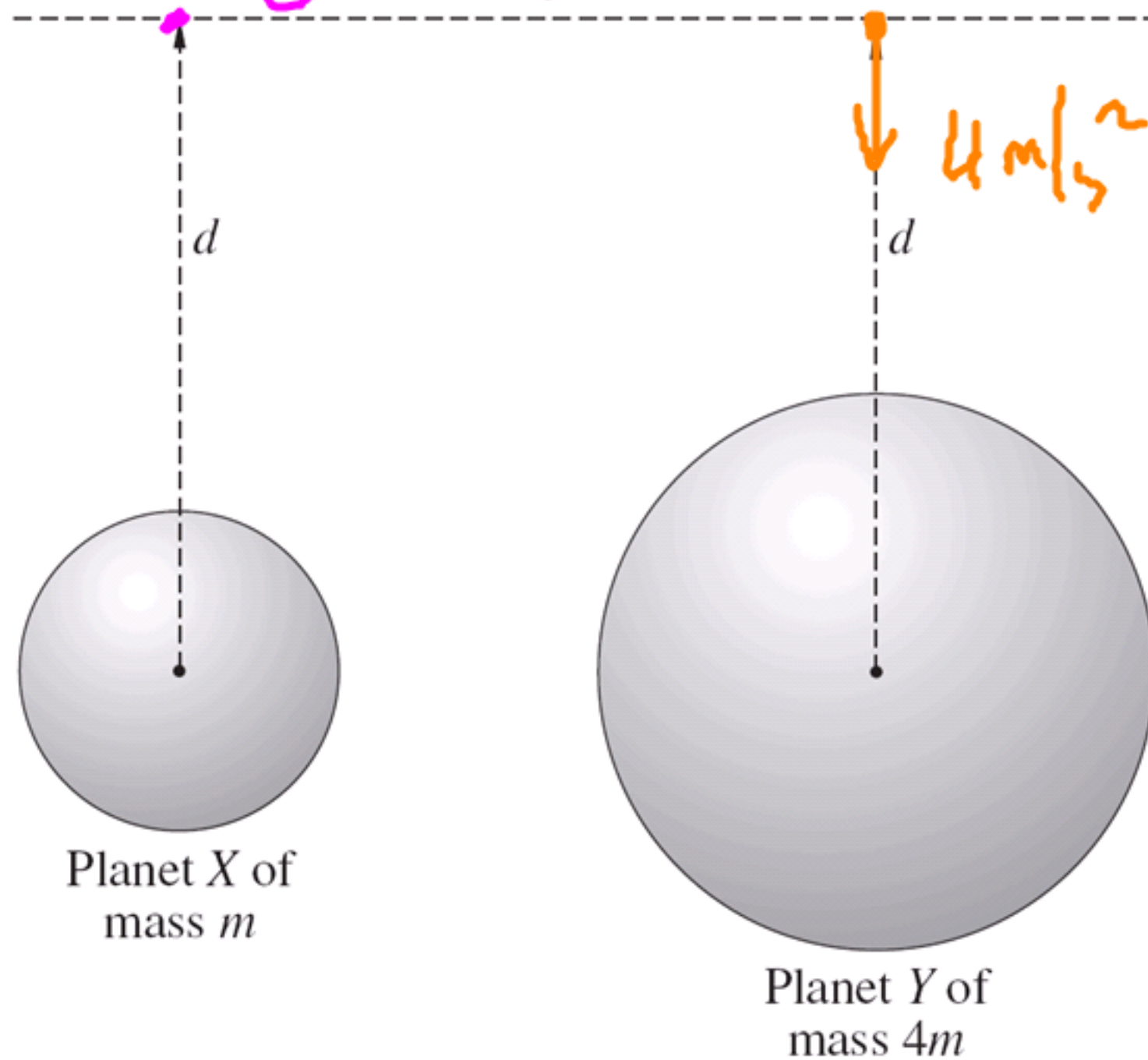
2006 HSC PAPER

- 1 Given that G is the universal gravitational constant, and g is the magnitude of the acceleration due to gravity, which statement is true?

- (A) The values of G and g depend on location.
- (B) The values of G and g are independent of location.
- ☒ (C) G is the same everywhere in the universe, but g is not.
- (D) g is the same everywhere in the universe, but G is not.

2004 HSC PAPER

- 2 The diagram shows two planets X and Y of mass m and $4m$ respectively.



$$\frac{G4m}{d^2} = 4 \text{ m/s}^2$$

$$4 \frac{Gm}{d^2} = 4$$

$$\frac{GM}{d^2} = 1$$

At the distance d from the centre of planet Y the acceleration due to gravity is 4.0 m s^{-2} .

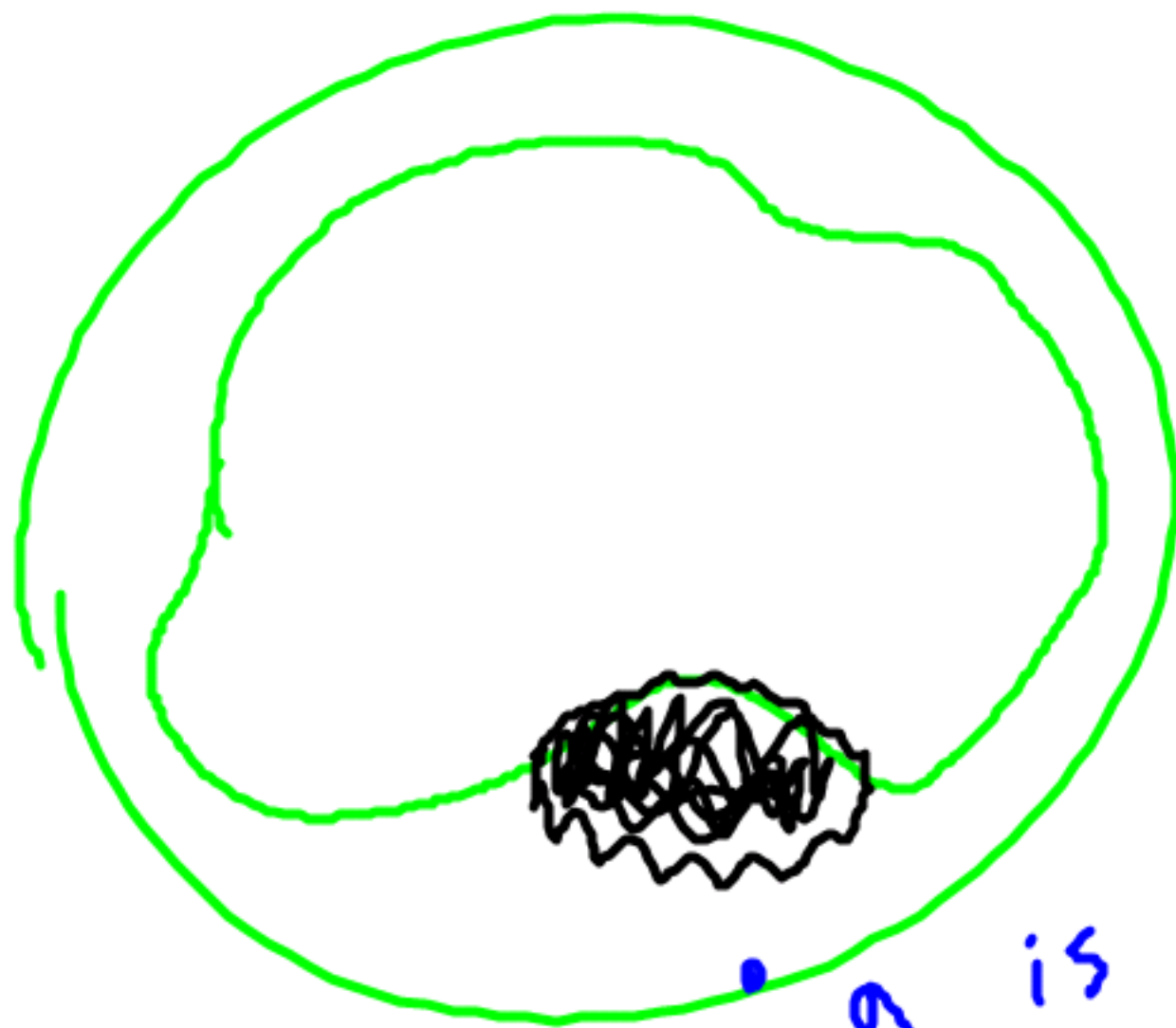
What is the acceleration due to gravity at distance d from the centre of planet X?

- (A) 1.0 m s^{-2}
- (B) 2.0 m s^{-2}
- (C) 2.8 m s^{-2}
- (D) 4.0 m s^{-2}

VARIATIONS IN THE VALUE OF THE GRAVITATIONAL ACCELERATION

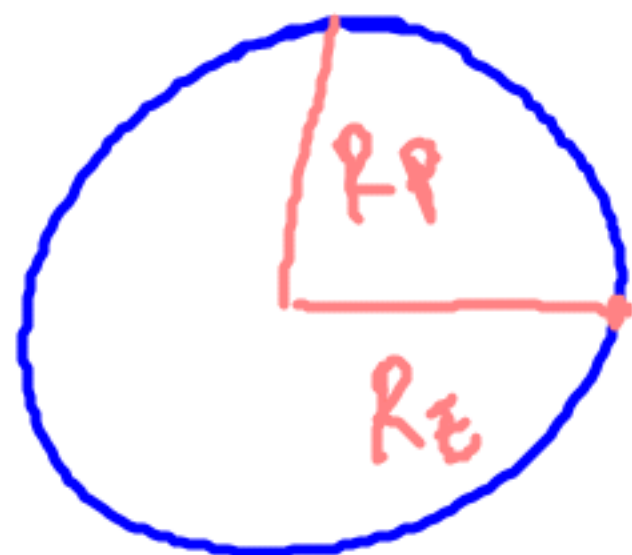
A) VARIATIONS DUE TO THE GEOGRAPHICAL LOCATION

- 1) The Earth's crust is not even, its thickness & composition varies, this changes the " g "



g is higher than the average value

2)

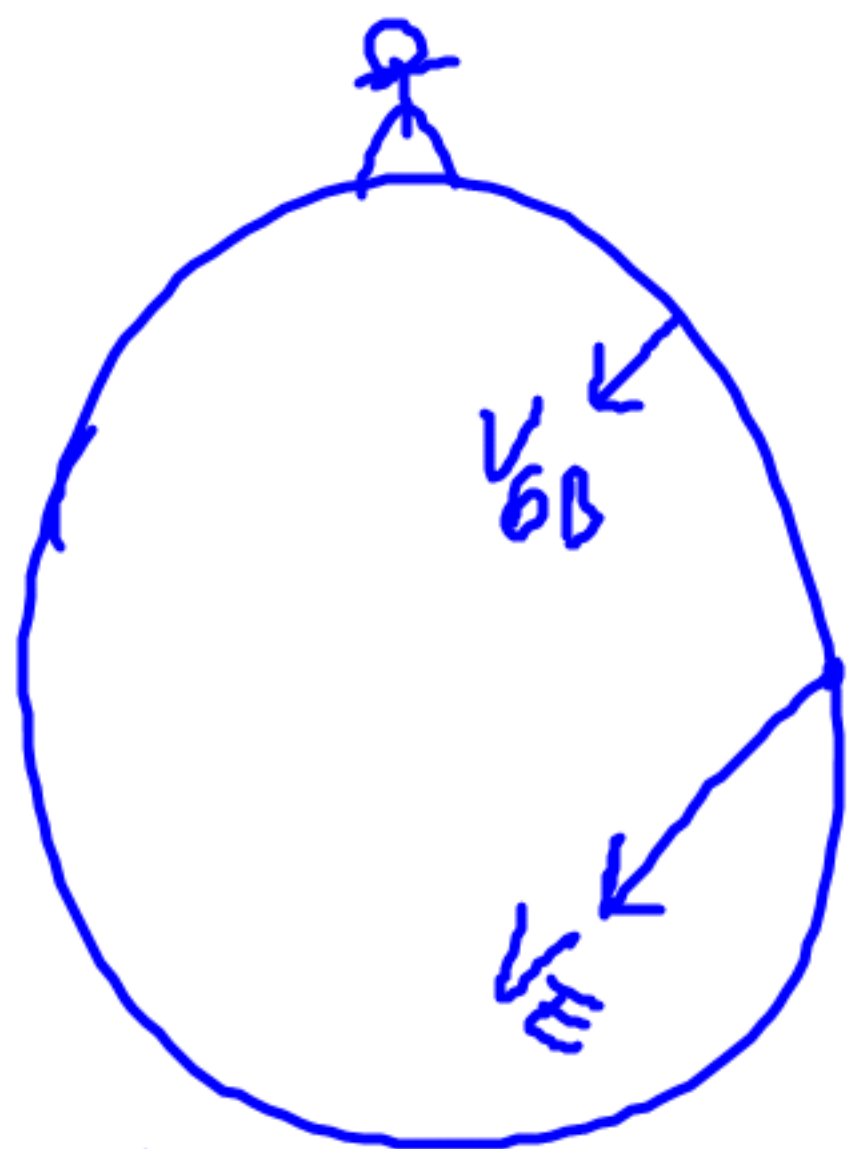


"geoid"

$$R_E > R_P \Rightarrow g_E < g_P$$

$$g = \frac{GM}{d^2}$$

3)

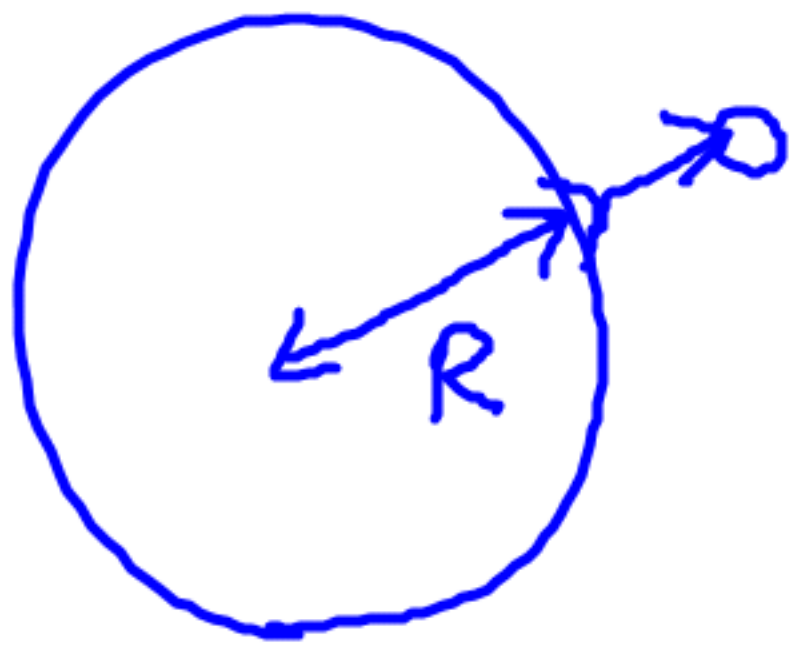


rotation of earth on its axis causes "centrifugal" effects on the surface. This effect is greatest at the ~~po~~ equator, "0" zero at poles.

$$V_E > V_{GB} \Rightarrow g_E < g_{GB}$$

VARIATIONS IN THE VALUE OF THE GRAVITATIONAL ACCELERATION

B) VARIATIONS DUE TO ALTITUDE ABOVE SURFACE



$$R = 6380 \text{ km}$$

$$d = R + h$$

altitude

$$= 6380 + 10$$

$$= 6390 \text{ km}$$

$$g = \frac{GM}{(R+h)^2}$$

VARIATIONS IN THE VALUE OF G

A) VARIATION WITH GEOGRAPHICAL LOCATION

The actual value of the acceleration due to gravity, g , that will apply in a given situation will depend upon geographical location. Minor variations in the value of g around the Earth's surface occur because:

- the Earth's crust or lithosphere shows variations in thickness and structure due to factors such as tectonic plate boundaries and dense mineral deposits. These variations can alter local values of g .
- the Earth is not a perfect sphere, but is flattened at the poles. This means that the value of g will be greater at the poles, since they are closer to the centre of the Earth.
- the spin of the Earth creates a centrifuge effect that reduces the effective value of g . The effect is greatest at the Equator and there is no effect at the poles.

As a result of these factors, the rate of acceleration due to gravity at the surface of the Earth varies from a minimum value at the Equator of 9.782 m/s^2 to a maximum value of 9.832 m/s^2 at the poles. The usual value used in equations requiring g is 9.8 m/s^2 .

easily be calculated. It is clear from the table that the effect of the Earth's gravitational field is felt quite some distance out into space. Note that as altitude increases the value of g decreases, dropping to zero only when the altitude has an infinite value.

$$g = G \frac{m_E}{(r_E + \text{altitude})^2}$$

$$g = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(3.84 \times 10^8)^2} = 2.7 \times 10^{-3} \text{ m/s}^2$$

$$= 0.0027 \text{ m/s}^2$$

$$d = 384000 \text{ km} = 3.84 \times 10^5 \text{ km}$$

$$= 3.84 \times 10^8 \text{ m}$$

$$W_{\text{moon}} = m_m \times g$$

$$= 7.35 \times 10^{22} \times 0.0027$$

$$= 1.98 \times 10^{20} \text{ N}$$

384 000
moon
→ centre
- value

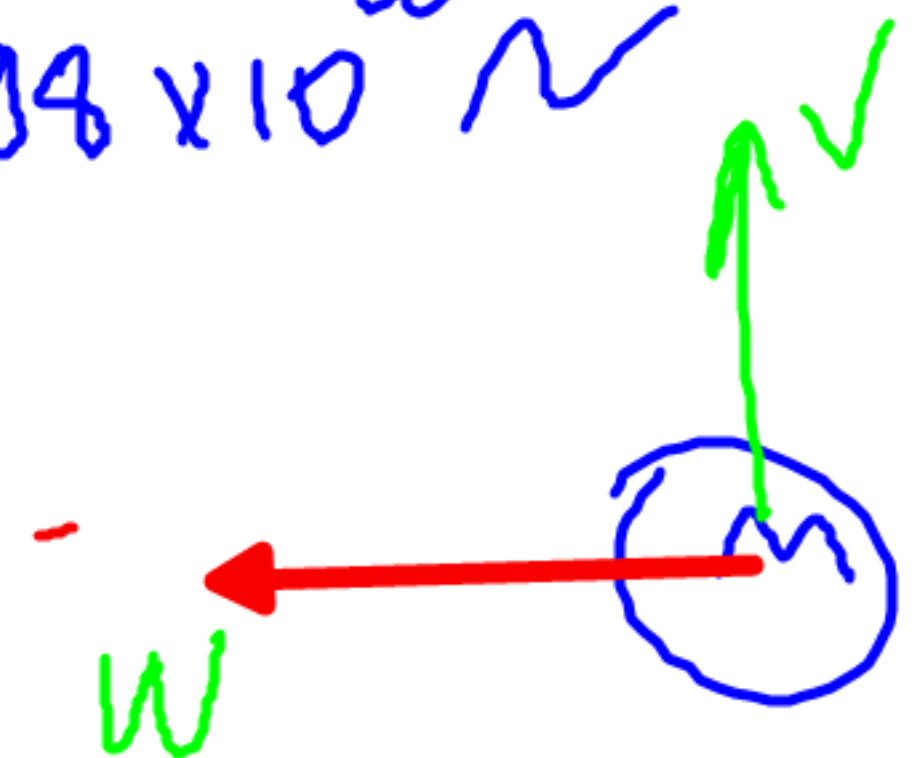


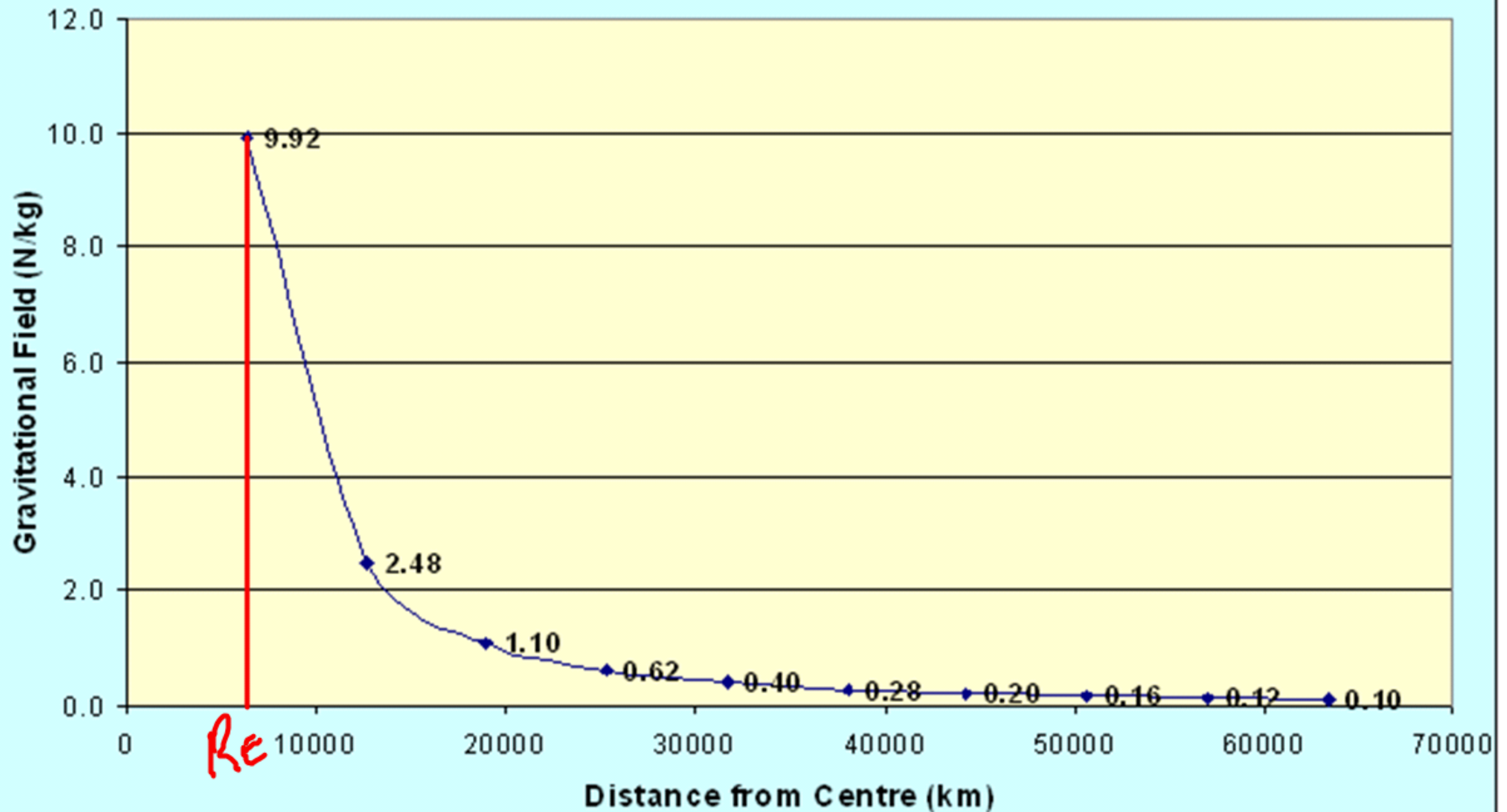
Table 1.1 The variation of g with altitude above Earth's surface

ALTITUDE (km)	g (m s^{-2})	COMMENT
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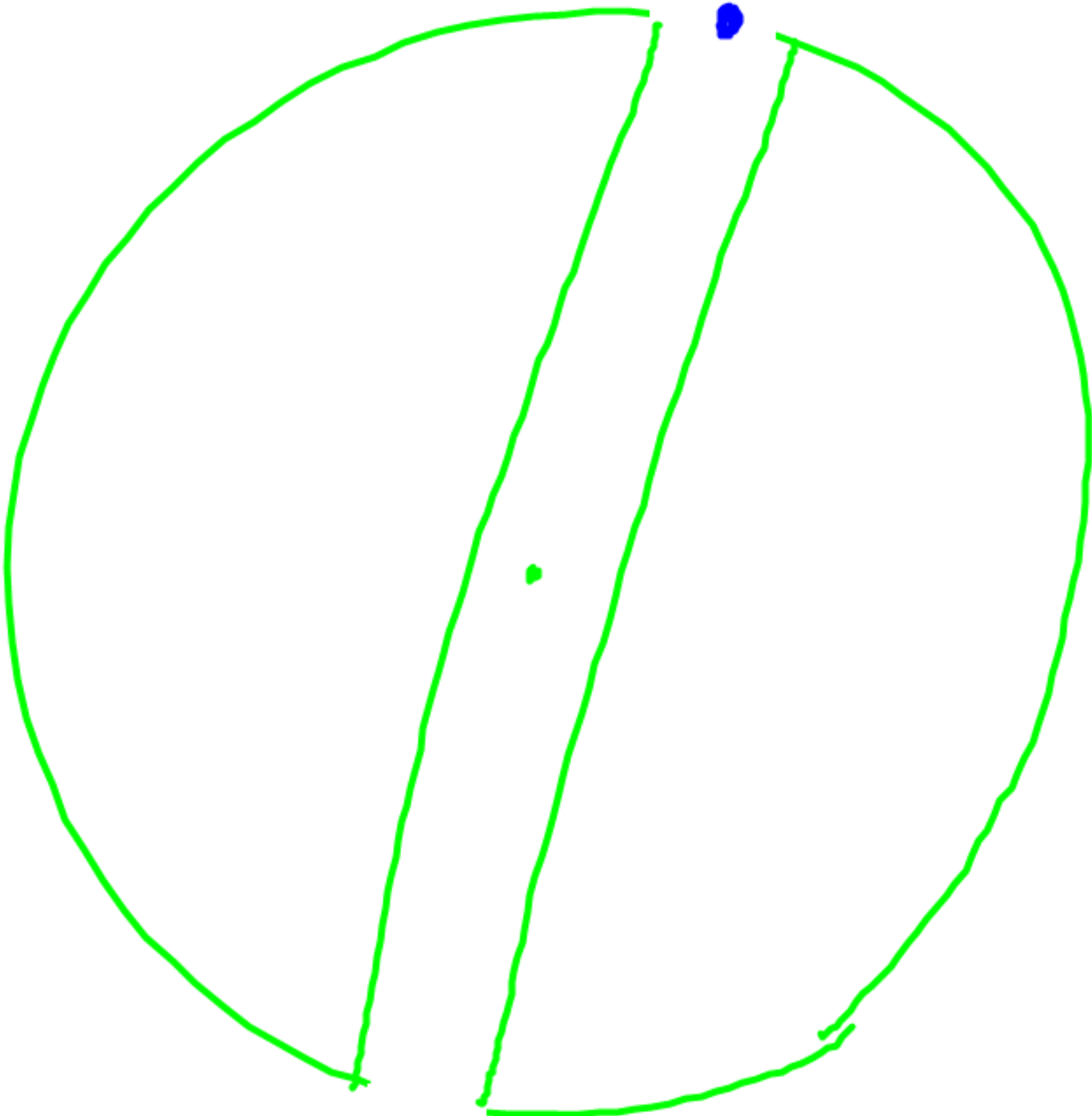
VARIATIONS OF "g" WITH ALTITUDE.

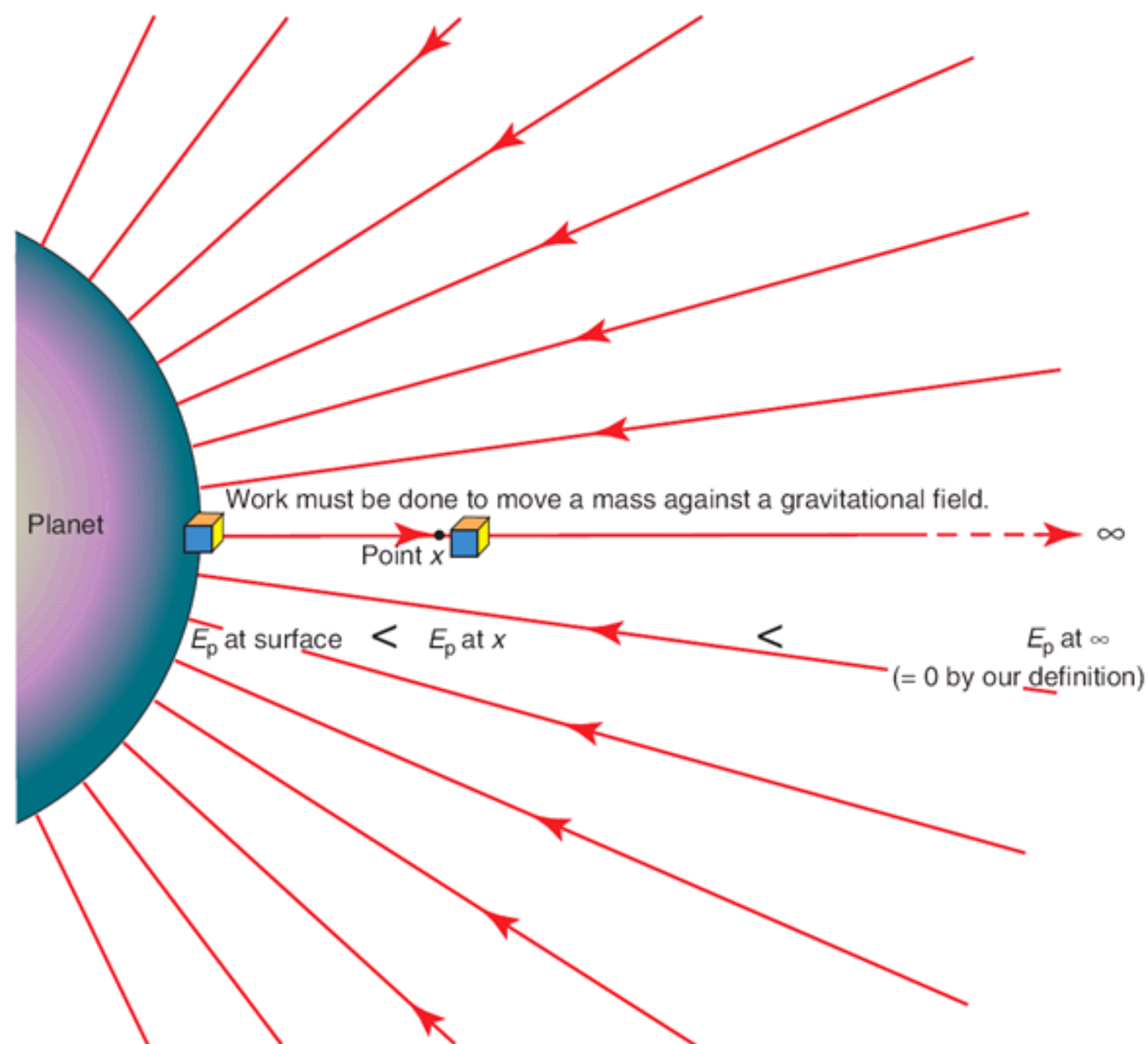
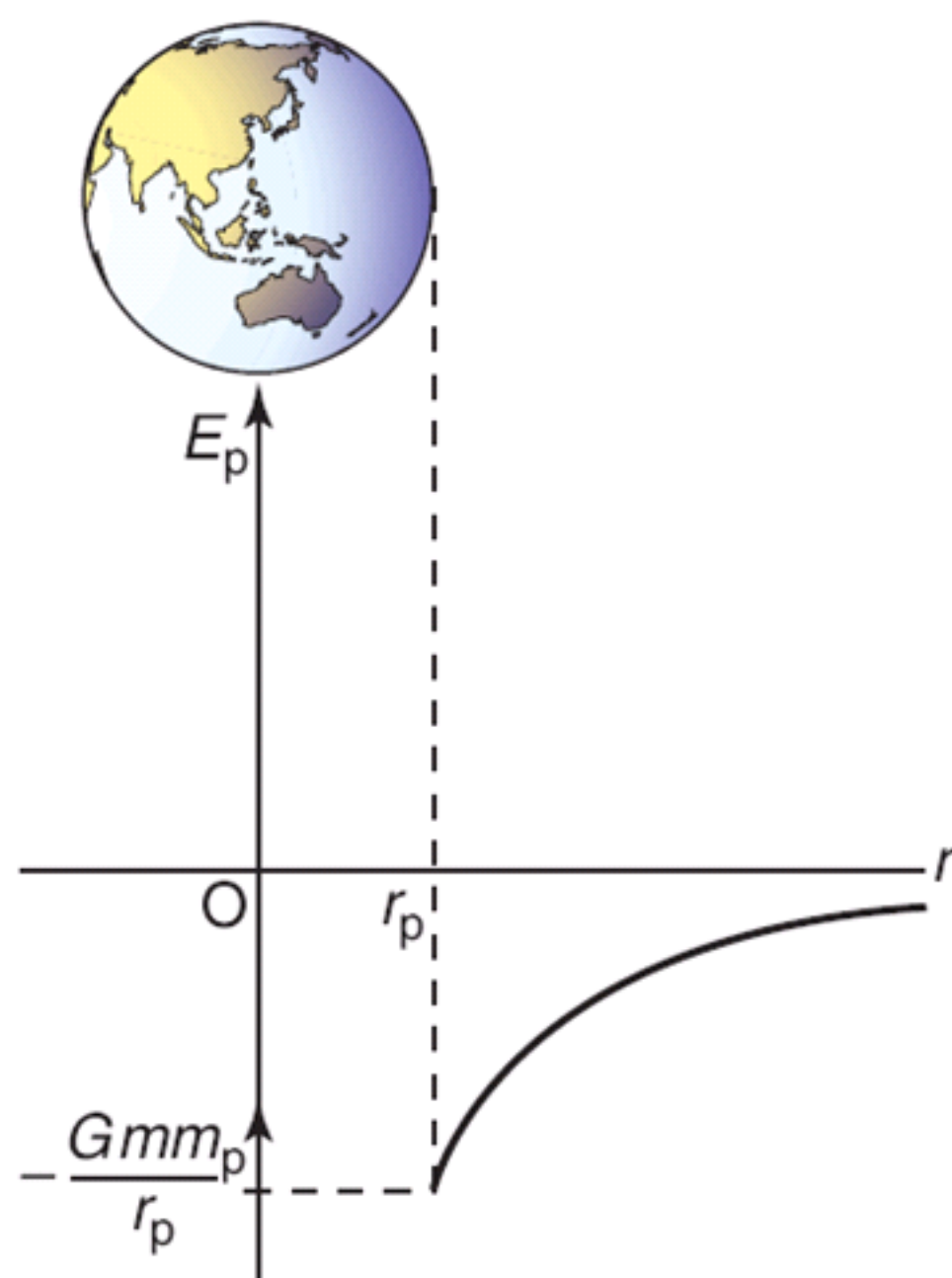
Earth's radius is ~~4340~~ ^{6340 km} show. show it on the graph.

Gravitational Field, g versus Distance from Center, d
(for Earth)



GRAVITATIONAL POTENTIAL ENERGY





1.3

Gravitational potential energy in the Sun–Earth–Moon system

Given the following data, determine the gravitational potential energy of:

- (a) the Moon within the Earth's gravitational field
- (b) the Earth within the Sun's gravitational field.

$$\text{Mass of the Earth} = 5.97 \times 10^{24} \text{ kg}$$

$$\text{Mass of the Moon} = 7.35 \times 10^{22} \text{ kg}$$

$$\text{Mass of the Sun} = 1.99 \times 10^{30} \text{ kg}$$

$$\text{Earth–Moon distance} = 3.84 \times 10^8 \text{ m on average}$$

$$\text{Earth–Sun distance} = 1.50 \times 10^{11} \text{ m on average (one astronomical unit, AU)}$$

Find the GPE of ISS (150 tonnes), positioned 200 km from the surface of the Earth.

HOMEWORK

- ✦ Homework is an integral part of your "Learning Curve", take it seriously!
- ✦ Target minimum 1 hour of Physics everyday
- ✦ Divide your physics home study in three segments:
 - ✓ Revision (past)
 - ✓ Homework (present)
 - ✓ Tomorrow (future)
- ✦ Homework is due next period, unless otherwise stated
- ✦ If you cannot do all, at least do a few from each piece

Apart from reading the relevant pages from the textbook your homework is:

1. Rest of the questions in this booklet
2. Study Chapter 1
3. ~~Chapter 1 questions - ALL~~
4. Study "CSU Space 1 Notes"
5. Study experiment - page 11

[1-5]



1.1 USING A PENDULUM TO DETERMINE g

Aim

To determine the rate of acceleration due to gravity using the motion of a pendulum.

NEXT PERIOD >

CHANGE IN GRAVITATIONAL POTENTIAL ENERGY