**IB PHYSICS: Gravitational Forces Review**

**1.** This question is about gravitation and ocean tides.

(a) State Newton's law of universal gravitation.

**(2)**

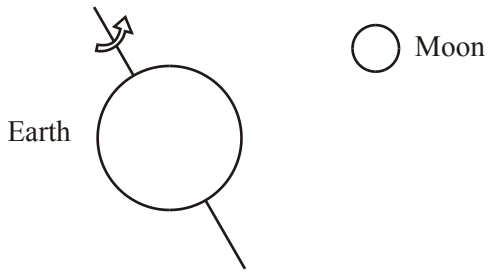
(b) Use the following information to deduce that the gravitational field strength at the surface of the Earth is approximately 10 N $kg^{-1}$.

Mass of the Earth = $6.0 \times 10^{24}$ kg

Radius of the Earth = 6400 km

**(2)**

The Moon's gravitational field affects the gravitational field at the surface of the Earth. A high tide occurs at the point where the resultant gravitational field due to the Moon and to the Earth is a minimum.




(c) (i) On the diagram above label, using the letter P, the point on the Earth's surface that experiences the greatest gravitational attraction due to the Moon. Explain your answer.

**(2)**

(ii) On the diagram above label, using the letter H, the location of a high tide. Explain your answer.

**(2)**

(iii) Suggest **two** reasons why high tides occur at different times of the day in different locations.

**(2)**

**(Total 10 marks)**

**2.** This question is about gravitational fields.

(a) Define *gravitational field strength*.

**(2)**

The gravitational field strength at the surface of Jupiter is 25 N $kg^{-1}$ and the radius of Jupiter is $7.1 \times 10^7$ m.

(b) (i) Derive an expression for the gravitational field strength at the surface of a planet in terms of its mass *M*, its radius *R* and the gravitational constant *G*.

**(2)**

(ii) Use your expression in (b)(i) above to estimate the mass of Jupiter.

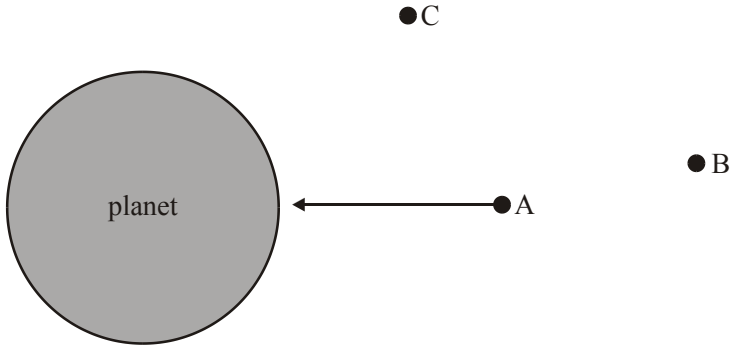
**(2)**
**(Total 6 marks)**

**3.** This question is about gravitation and orbital motion.

(a) Define *gravitational field strength* at a point in a gravitational field.

**(2)**

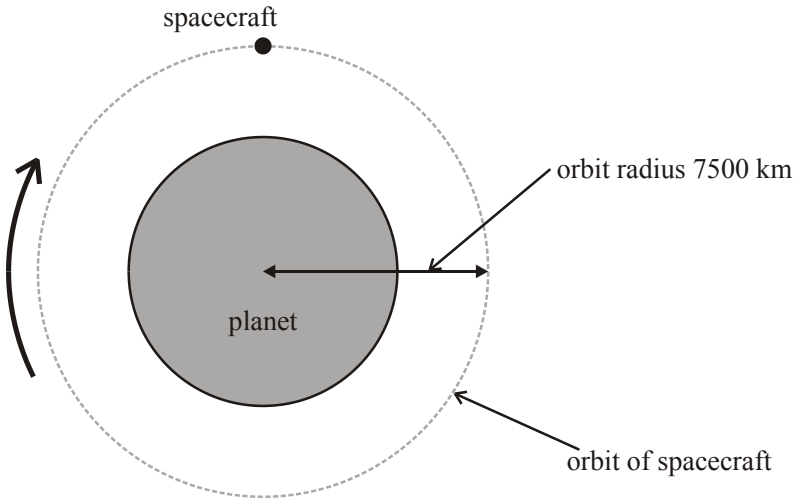
The diagram below shows three points above a planet. The arrow represents the gravitational field strength at point A.




(b) Draw arrows to represent the gravitational field strength at point B and point C.

**(2)**

A spacecraft is in a circular orbit around the planet as shown in the diagram below. The radius of the orbit is 7500 km.




(c) For the spacecraft in the position shown, draw and label arrows representing

(i) the velocity (label this arrow V).

**(1)**

(ii) the acceleration (label this arrow A).

**(1)**

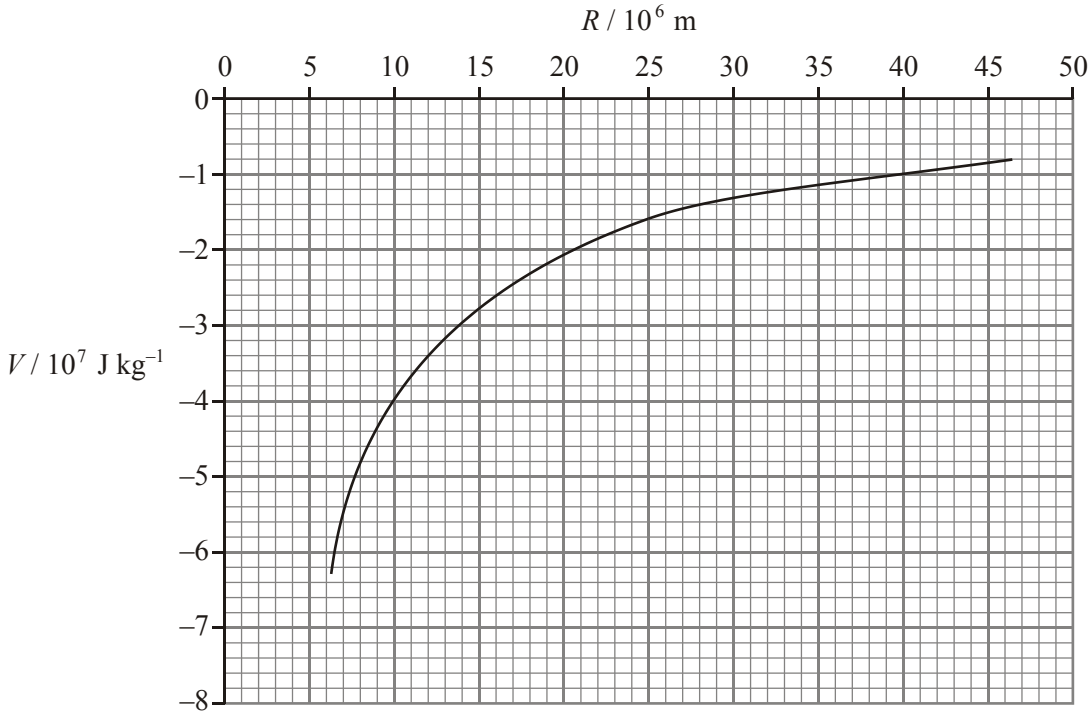
The speed of the spacecraft is 6.5 km $s^{-1}$.

(d) Deduce the value of the magnitude of the gravitational field strength at a point in the spacecraft's orbit.

**(3)**
**(Total 9 marks)**

**4.** This question is about gravitational potential energy.

The graph below shows the variation of gravitational potential $V$ due to the Earth with distance $R$ from the centre of the Earth. The radius of the Earth is $6.4 \times 10^6$ m. The graph does not show the variation of potential $V$ within the Earth.




(a) Use the graph to find the gravitational potential

(i) at the surface of the Earth.

**(1)**

(ii) at a height of $3.6 \times 10^7$ m above the surface of the Earth.

**(2)**

(b) Use the values you have found in part (a) to determine the minimum energy required to put a satellite of mass $1.0 \times 10^4$ kg into an orbit at a height of $3.6 \times 10^7$ m above the surface of the Earth.

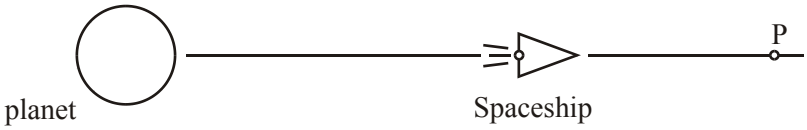
**(3)**

(c) Give **two** reasons why more energy is required to put this satellite into orbit than that calculated in (b) above.

**(2)**

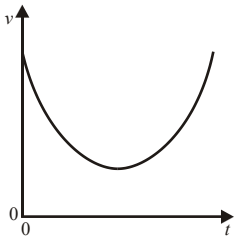
**(Total 8 marks)**

**5.** A powered spaceship is moving directly away from a planet as shown below.

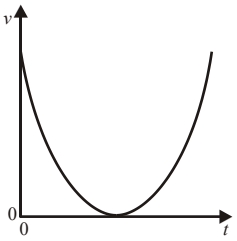



At point P the motors of the spaceship are switched off but the spaceship remains under the influence of the planet. Which **one** of the following graphs best represents the variation with time $t$ of the **velocity** $v$ of the spaceship after it passes point P?

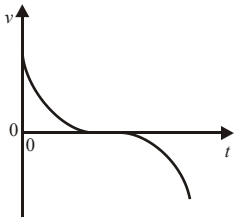
A.



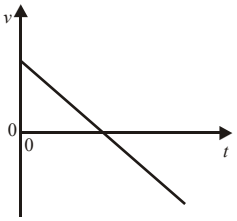

B.




C.




D.




**(1)**

**6.** Gravitational field strength at a point may be defined as

A. the force on a small mass placed at the point.

B. the force per unit mass on a small mass placed at the point.

C. the work done to move unit mass from infinity to the point.

D. the work done per unit mass to move a small mass from infinity to the point.

**(1)**

**7.** The rings of Saturn are made of rocky particles that orbit the planet. The period $T$ of each particle $n$ depends on its distance $r$ from the centre of Saturn. The period $T$ is proportional to $r^n$. Which **one** of the following is $n$ equal to?

A. 1.0

B. 1.5

C. 2.0

D. 3.0

**(1)**

**8.** This question is about gravitation.

A space probe is launched from the equator in the direction of the north pole of the Earth. During the launch, the energy $E$ given to the space probe of mass $m$ is

$$E = \frac{3GMm}{4R_e}$$

where $G$ is the Gravitational constant and $M$ and $R_e$ are, respectively, the mass and radius of the Earth. Work done in overcoming frictional forces is not to be considered.

(a) (i) Explain what is meant by *escape speed*.

**(2)**

(ii) Deduce that the space probe will not be able to travel into deep space.

**(3)**

The space probe is launched into a circular polar orbit of radius $R$.

(b) Derive expressions, in terms of $G$, $M$, $R_e$, $m$ and $R$, for

(i) the change in gravitational potential energy of the space probe as a result of travelling from the Earth's surface to its orbit.

**(1)**

(ii) the kinetic energy of the space probe when in its orbit.

**(2)**

(c) Using your answers in (b) and the total energy supplied to the space probe as given in (a), determine the height of the orbit above the Earth's surface.

**(4)**

A space probe in a low orbit round the Earth will experience friction due to the Earth's atmosphere.

(d) (i) Describe how friction with the air reduces the energy of the space probe.

**(2)**

(ii) Suggest why the rate of loss of energy of the space probe depends on the density of the air and also the speed of the space probe.

**(2)**

(iii) State what will happen to the height of the space probe above the Earth's surface and to its speed as air resistance gradually reduces the total energy of the space probe.

**(2)**

**(Total 18 marks)**

**9.** The gravitational potential at point X due to the Earth is $-7$ kJ kg$^{-1}$. At point Y, the gravitational potential is $-3$ kJ kg$^{-1}$.
The change in gravitational potential energy of a mass of 4 kg when it is moved from point X to point Y is

A. 4 kJ.

B. 10 kJ.

C. 16 kJ.

D. 40 kJ.

**(1)**