EUNOIA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS 2023
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME

| CIVICS GROUP | 2 | 2 | - | | |
|---|---|---|---|---|---|

| REGISTRATION NUMBER | | |
|---|---|---|

**PHYSICS**
Longer Structured Questions

**9749/03**

**19th September 2023**

**2 hours**

**READ THESE INSTRUCTIONS FIRST**

Write your name, civics group and registration number on all the work you hand in.
The use of an approved scientific calculator is expected where appropriate.

**Section A**
Answer **all** questions.

**Section B**
Answer **one** question only.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use paper clips, highlighters, glue or correction fluid.
The number of marks is given in brackets [ ] at the end of each question or part question.

| For Examiner's Use | |
|---|---|
| **Section A** | |
| **Q1** | / 14 |
| **Q2** | / 10 |
| **Q3** | / 9 |
| **Q4** | / 17 |
| **Q5** | / 10 |
| **Section B** | |
| **Q6** | / 20 |
| **Q7** | / 20 |
| **s.f.** | |
| **P3 Total** | / 80 |

This document consists of **26** printed pages and **2** blank pages.

**Data**

| | |
|---|---|
| speed of light in free space, | $c = 3.00 \times 10^{8}$ m s$^{-1}$ |
| permeability of free space, | $\mu_0 = 4\pi \times 10^{-7}$ H m$^{-1}$ |
| permittivity of free space, | $\varepsilon_0 = 8.85 \times 10^{-12}$ F m$^{-1}$ |
| | $(1/(36\pi)) \times 10^{-9}$ F m$^{-1}$ |
| elementary charge, | $e = 1.60 \times 10^{-19}$ C |
| the Planck constant, | $h = 6.63 \times 10^{-34}$ J s |
| unified atomic mass constant, | $u = 1.66 \times 10^{-27}$ kg |
| rest mass of electron, | $m_e = 9.11 \times 10^{-31}$ kg |
| rest mass of proton, | $m_p = 1.67 \times 10^{-27}$ kg |
| molar gas constant, | $R = 8.31$ J K$^{-1}$ mol$^{-1}$ |
| the Avogadro constant, | $N_A = 6.02 \times 10^{23}$ mol$^{-1}$ |
| the Boltzmann constant, | $k = 1.38 \times 10^{-23}$ J K$^{-1}$ |
| gravitational constant, | $G = 6.67 \times 10^{-11}$ N m$^{2}$ kg$^{-2}$ |
| acceleration of free fall, | $g = 9.81$ m s$^{-2}$ |

**Formulae**

| | |
|---|---|
| uniformly accelerated motion, | $s = ut + \frac{1}{2}at^2$ <br> $v^2 = u^2 + 2as$ |
| work done on/by a gas, | $W = p\Delta V$ |
| hydrostatic pressure, | $p = \rho gh$ |
| gravitational potential, | $\phi = -\frac{Gm}{r}$ |
| temperature, | $T / \text{K} = T / {}^\circ\text{C} + 273.15$ |
| pressure of an ideal gas, | $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ |
| mean translational kinetic energy of an ideal gas molecule | $E = \frac{3}{2}kT$ |
| displacement of particle in s.h.m. | $x = x_0 \sin \omega t$ |
| velocity of particle in s.h.m. | $v = v_0 \cos \omega t$ <br> $= \pm \omega \sqrt{\left(x_0^2 - x^2\right)}$ |
| electric current, | $I = Anvq$ |
| resistors in series, | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel, | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| electric potential, | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage, | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 N I}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 n I$ |
| radioactive decay, | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

## Section A

Answer all the questions in this section in the spaces provided.

**1 (a)** Three sheets of polaroids P, Q and R are placed close to one another. Polaroids P and R have their polarising axes fixed and perpendicular to each other.

The incoming beam of intensity $I_o$ is polarised parallel to the polarising axis of P before reaching P.

Polaroid Q is rotated about the axis of the light beam, as shown in Fig. 1.1. The plane of Polaroid Q remains parallel to that of P and R.

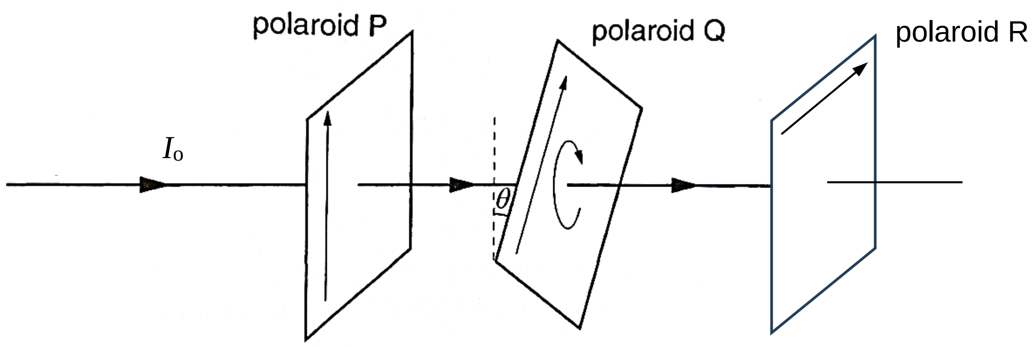


**Fig. 1.1**

Complete Fig. 1.2 to show the variation of the angle of rotation with intensity of the light transmitted after passing Polaroid R.

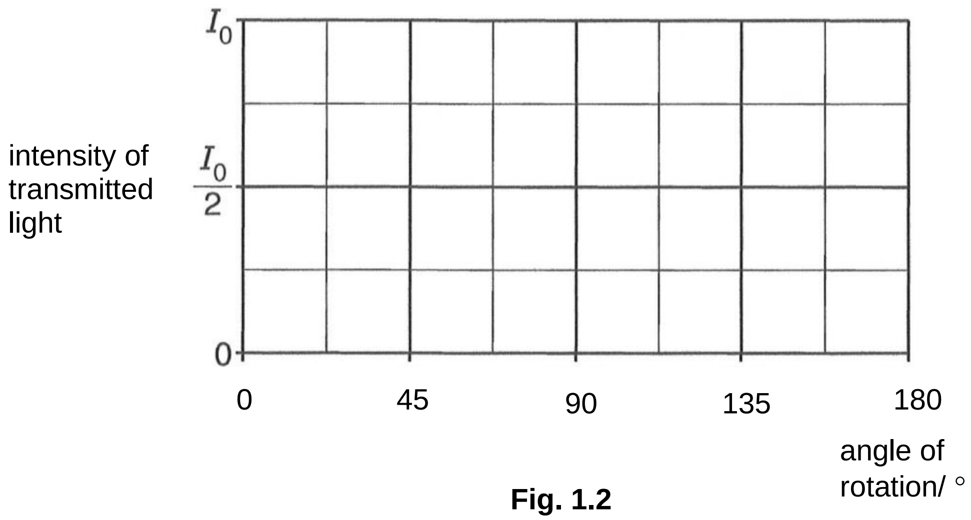


**Fig. 1.2**

[2]

**(b)** A parallel beam of wavelength 600 nm is incident normally on a diffraction grating.

Fig. 1.3 shows part of the diffraction grating used.

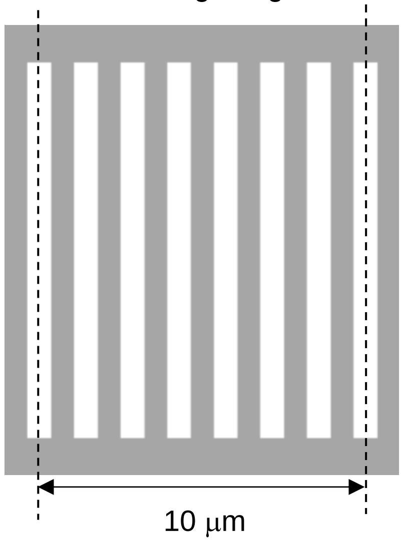


**Fig. 1.3**

**(i)** Determine the distance between adjacent slits on the grating.

distance = ……………………………. m [2]

**(ii)** Fig 1.4 shows how the parallel beam of light that was incident on the diffraction grating.

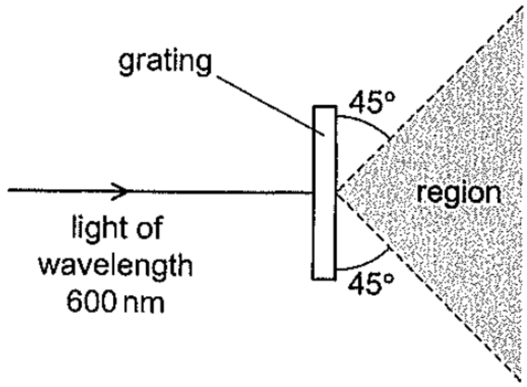


**Fig. 1.4**

Calculate the total number of images that emerge from the grating within the shaded 90° region shown in Fig. 1.4.

total number of images = ………………………… [2]

**(iii)** In a mass production of diffraction gratings with slit separation *d*, a monochromatic laser light with a fixed wavelength $\lambda$ was used to check for the quality of the diffraction gratings produced. In a certain test, a few defective pieces were found.

In a good product, the first order maximum occurs at an angle of $\alpha$ from the zeroth order maximum. In a defective product, the first order maximum is not a single sharp point but a band of light extending from angle $\alpha$ to $\beta$, where $\beta$ is larger than $\alpha$. The band of light is brightest at an angle of $\alpha$ and reduces towards the angle of $\beta$.

Describe what could be the fault in the manufacturing of the grating to result in this observation.

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………………………………………………………………………………………………..….. [2]

**(c)** On an initially calm day out at sea, water waves of constant speed approach a sea wall and a stationary wave is formed.

**(i)** State how the stationary wave is formed.

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………………………………………………………………………………………………….…….. [2]

**(ii)** When the waves hit the wall, an increase in amplitude of the wave was observed at the sea wall.

State and explain if the water waves experienced a phase change when hitting the wall to result in the increase in amplitude.

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…………………………………………………………………………………………………………

…………………………………………………………………………………………………………

……………………………………………………………………………………………………….. [2]

**(iii)** In Fig. 1.5, fine sand is spread along the length of a tube fitted with a piston. A small loudspeaker which emits sound of 720 Hz is placed at the opened end and the length of the air column was varied by adjusting the position of the piston.

When the air column is 0.78 m, the sand in the tube forms the pattern as shown.

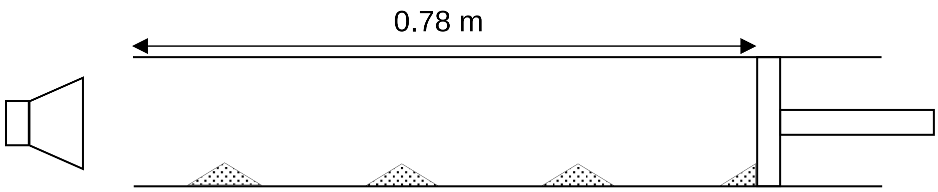


**Fig. 1.5**

Calculate the speed of sound travelling through the air column.

speed of sound = …………………………… m s$^{-1}$ [2]

[Total: 14]

**2** **(a)** **(i)** State the first law of thermodynamics.

………………………………………………………………………………………………………...

………………………………………………………………………………………………………...

……………………………………………………………………………………………..…[2]

**(ii)** Use first law of thermodynamics to explain how roasting of potatoes causes its temperature to rise.

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…………………………………………………………………………………………………[3]

**(b)** An ideal gas undergoes a cycle of changes A → B → C → A as shown in Fig. 2.1.

Process A to B takes place at constant temperature of 310 K. Process B to C takes place at constant volume and during this process, 55 J of heat leaves the system. The temperature at C is 280 K. Process C to A takes place with no heat exchange.

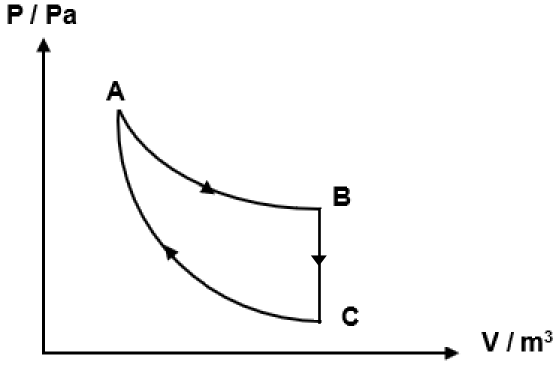


**Fig. 2.1**

**(i)** Calculate the change in internal energy of the gas during the process B to C.

change in internal energy = ……………………… J [2]

**(ii)** Determine the work done by the gas during the process C to A.
Explain your working clearly.

work done by the gas = ……………………… J [3]

[Total: 10]

3 An alternating supply of frequency 50 Hz and having an output of 6.0 V r.m.s. is to be rectified so as to provide direct current for a resistor R. The circuit of Fig. 3.1 is used.

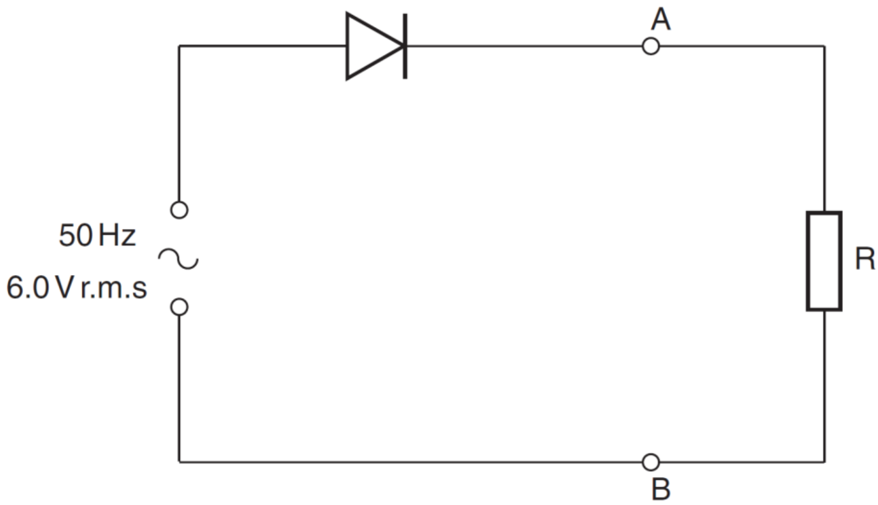


**Fig. 3.1**

The diode is ideal.

The output potential difference $V$ of the alternating power supply is represented by

$$V = V_o \sin(kt)$$

where $V_o$ is the maximum potential difference in volts and $t$ is the time in seconds.

**(a)** By reference to heating effect, state what is meant by the *root-mean-square (r.m.s.)* of an alternating current.

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……………………………………………………………………………………………………[1]

**(b)** Determine the value of $V_o$

$V_o$ = ………………………… V [1]

**(c)** Determine the value and unit of $k$.

value of $k$ = ……………………… unit ……………………... [2]

**(d)** Determine the maximum potential difference across the diode during one cycle.

potential difference = ………………………… V [1]

**(e)** State the potential difference across A and B when the diode has maximum potential difference across it. Give a reason for your answer.

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

**(f)** R has a resistance of 5.0 Ω .

In Fig. 3.2, sketch the variation with time of the power dissipated in R for **one** period of the alternating supply.

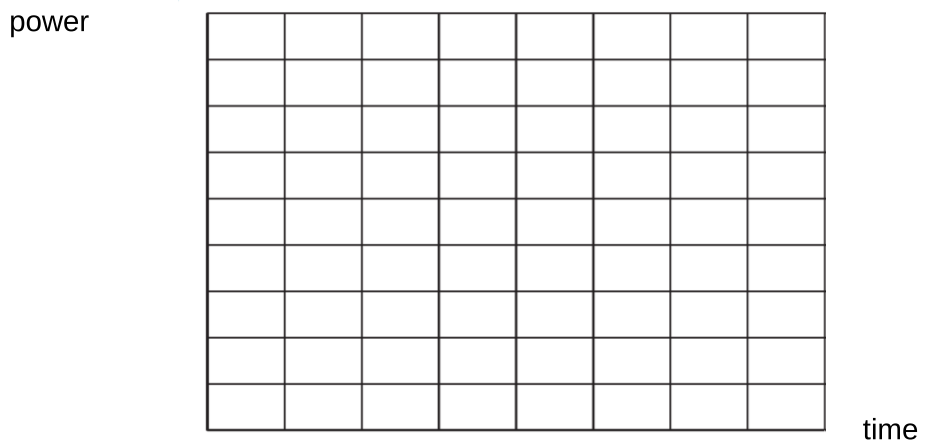


**Fig. 3.2**

[3]

[Total: 9]

4 **(a)** A beam of white light passes through a cloud of gas. The spectrum of the light emerging from the gas is viewed using a diffraction grating.

**(i)** Explain why the spectrum observed contains a number of dark lines.

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**(ii)** Some of the electron energy levels of the atoms in the cloud of the gas are represented in Fig. 4.1.

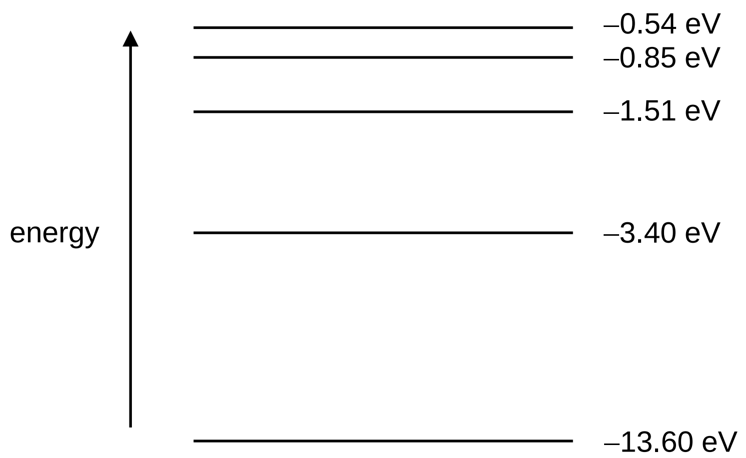


**Fig. 4.1** (not to scale)

The photons of light have energies ranging from 1.60 eV to 2.60 eV.

On Fig. 4.1, draw arrows to show the electron transitions between energy levels that could give rise to dark lines in the absorption spectrum.

[1]

**(b)** A metal surface with a threshold frequency $f_o$ is placed in an evacuated tube and illuminated with monochromatic light. The photoelectrons emitted are collected at an adjacent electrode of the same metal. The photoelectric current $I$ depends on the frequency $f$ of the incident light, and potential difference $V$ between collector and emitter, and the incident power $P$.

In Fig. 4.2 to 4.4, sketch graphs to show the variation of $I$ with

**(i)** $f$, while $V$ and $P$ remain constant.


**Fig. 4.2**

[2]

**(ii)** $V$, while $f$ and $P$ remain constant.

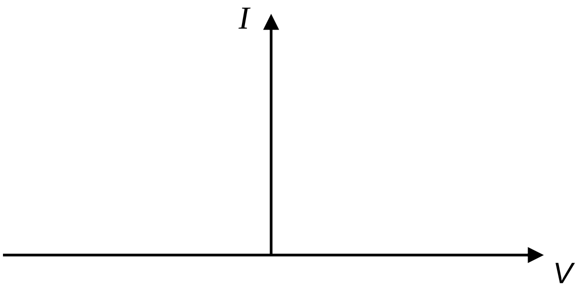


**Fig. 4.3** [1]

**(iii)** $P$, while $f$ and $V$ remain constant.


**Fig. 4.4** [1]

**(c)** A very weak beam of light ray may be detected using a device known as a photo-multiplier, as shown in Fig. 4.5.

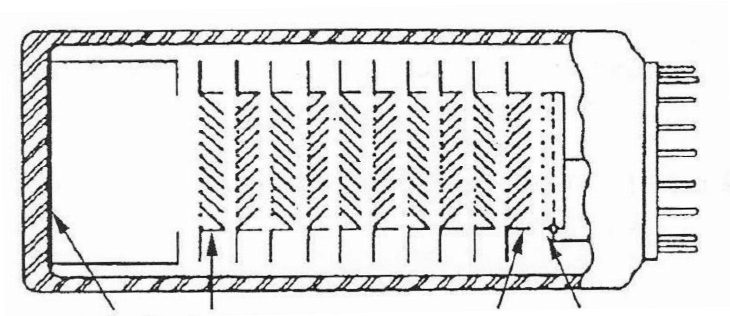


**Fig. 4.5**

The incident light causes photoelectrons to be emitted from the cathode. These photoelectrons are accelerated and strike a target electrode, called the first dynode. For each electron incident, six leave the dynode. These six are accelerated to the second dynode, which emits 36 electrons, which are all accelerated to the third dynode, and so on. The photomultiplier contains a series of ten dynodes in all.

**(i)** Calculate the number of electrons emitted by the tenth dynode for each electron striking the first dynode.

no. of electrons = ……………………………….. [1]

**(ii)** The electrons emitted from the tenth dynode are collected and constitute a current of 9.2 μA.

Determine the rate at which the photoelectrons are being emitted from the cathode.

rate = ……………………………….. $s^{-1}$ [2]

**(iii)** The incident light has a wavelength of 361 nm. At this wavelength, one in three of the incident photons causes an emission of photoelectron from the cathode.

Determine the power of the incident light.

power = ……………………………….. W [2]

**(iv)** The electrons emitted by a dynode have negligible initial energy, and are accelerated through a potential difference of 50 V before striking the next dynode.

Determine the de Broglie wavelength of these electrons right before they strike the next dynode.

wavelength = ……………………………….. m [3]

[Total: 17]

**5** **(a)** When a neutron is captured by a Uranium-235 nucleus, the outcome may be represented by the nuclear equation shown below.

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{95}_{42}\mathrm{Mo} + {}^{139}_{57}\mathrm{La} + 2\,{}^{1}_{0}\mathrm{n} + 7\,{}^{0}_{-1}\mathrm{e}$$

The energy released in the nuclear reaction above is 182 MeV. Fig. 5.1 shows how the binding energy per nucleon varies with mass number *A*.

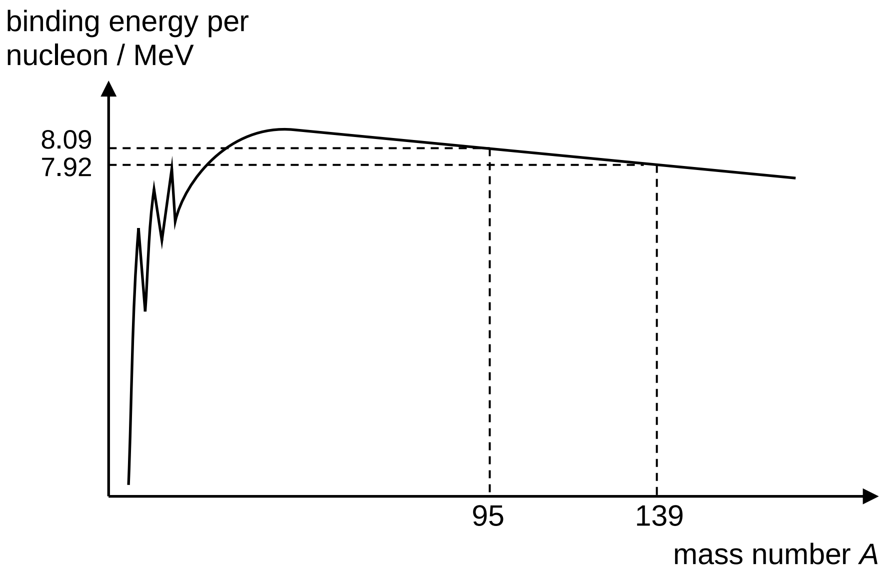


**Fig. 5.1**

**(i)** Determine the binding energy, in MeV, of a nucleus of Uranium-235.

binding energy = ………………………. MeV [3]

**(ii)** Calculate the mass defect, in kg, of a nucleus of Uranium-235.

mass defect = ………………… kg [2]

**(b)** The nuclide Potassium-42 $\left({}^{42}_{19}\text{K}\right)$ undergoes radioactive decay to become Calcium-42 $\left({}^{42}_{20}\text{Ca}\right)$. A radioactive sample contains $N_0$ atoms of Potassium-42 and no atoms of Calcium-42 at time $t = 0$. Fig. 5.2 shows the variation with time $t$ of the ratio $\dfrac{N}{N_0}$ where $N$ is the number of atoms of Potassium-42.

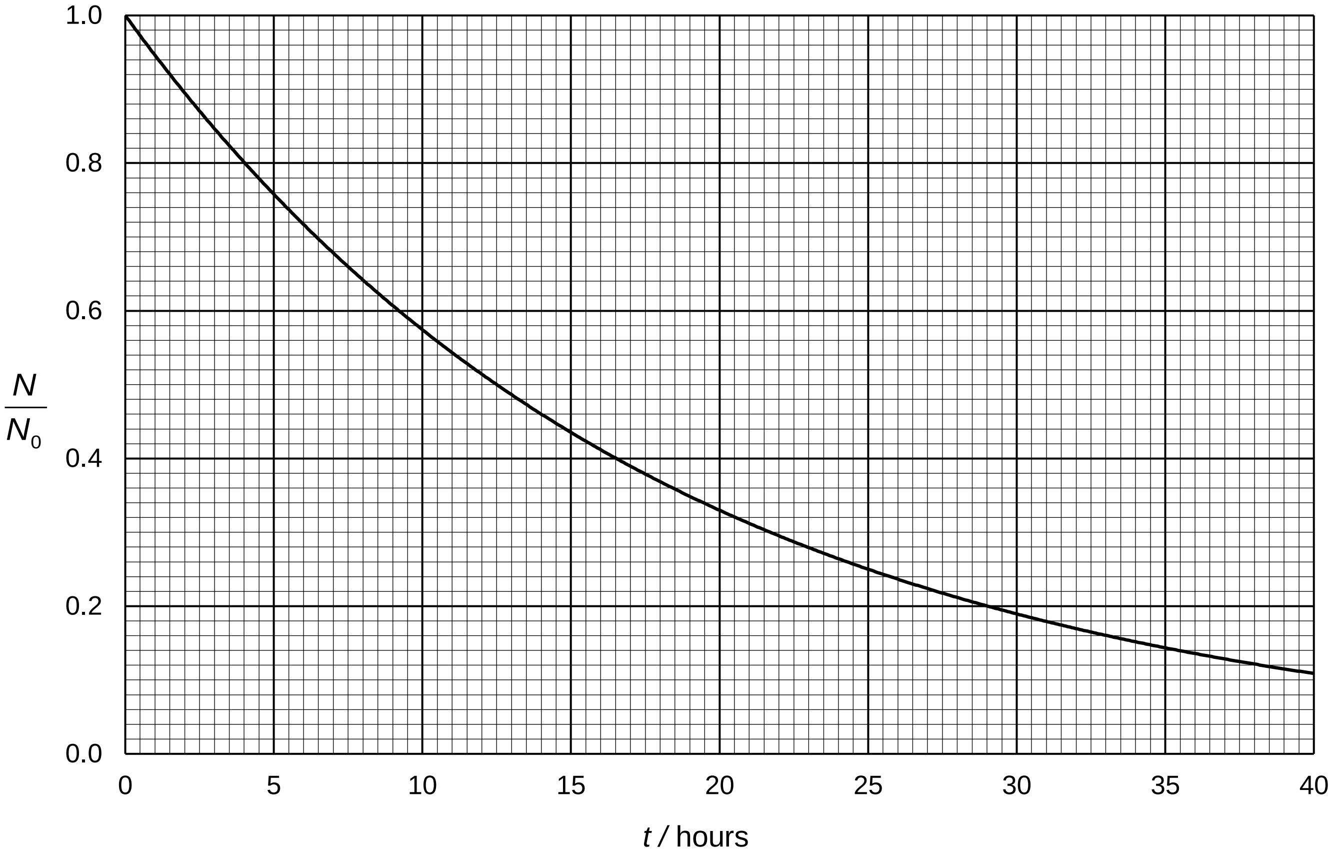


**Fig. 5.2**

**(i)** Write down the equation for the decay of Potassium-42 to Calcium-42. [1]

**(ii)** Use Fig. 5.2 to estimate the half-life of Potassium-42.

half-life = ……………….. hours [1]

**(iii)** Calcium-42 is stable. Using the axes of Fig. 5.2, sketch a graph to show the variation with time *t* of the ratio of Calcium-42 atoms to $N_0$ in the sample. [1]

**(iv)** By reference to Fig. 5.2 or otherwise, determine the age of the radioactive sample when the ratio

$$\frac{\text{number of Calcium - 42 atoms}}{\text{number of Potassium - 42 atoms}}$$

is equal to 4.0.

age = …………………………… hours [2]

[Total: 10]

## Section B

Answer **one** question from this Section in the space provided.

**6** **(a)** State what is meant by *simple harmonic motion*.

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...................................................................................................................... [2]

**(b)** A small ball rests at point P on a curved track of radius r, as shown in Fig. 6.1.

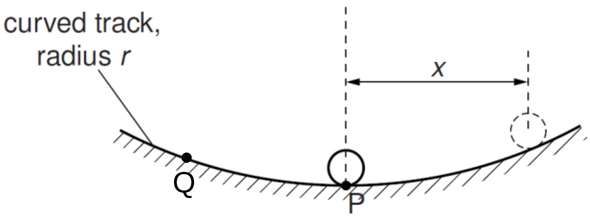


**Fig. 6.1**

The ball is moved a small distance of 2.0 cm to one side and is then released. The horizontal displacement $x$ of the ball is related to its acceleration $a$ towards P by the expression

$$a = -\frac{gx}{r}$$

where $g$ is the acceleration of free fall.

**(i)** Explain how the equation above shows that the ball undergoes simple harmonic motion.

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...................................................................................................................... [2]

**(ii)** The radius $r$ of curvature of the track is 28 cm.

Show that the period $T$ of the oscillation is 1.1 s. [2]

**(iii)** Determine the time interval $\tau$ between the ball passing point P to point Q, where Q is 1.5 cm to the left of P.

$\tau$ = ……………………………….. s [2]

**(iv)** On the axes of Fig. 6.2, sketch a graph to show the variation with displacement $x$ of the velocity $v$.

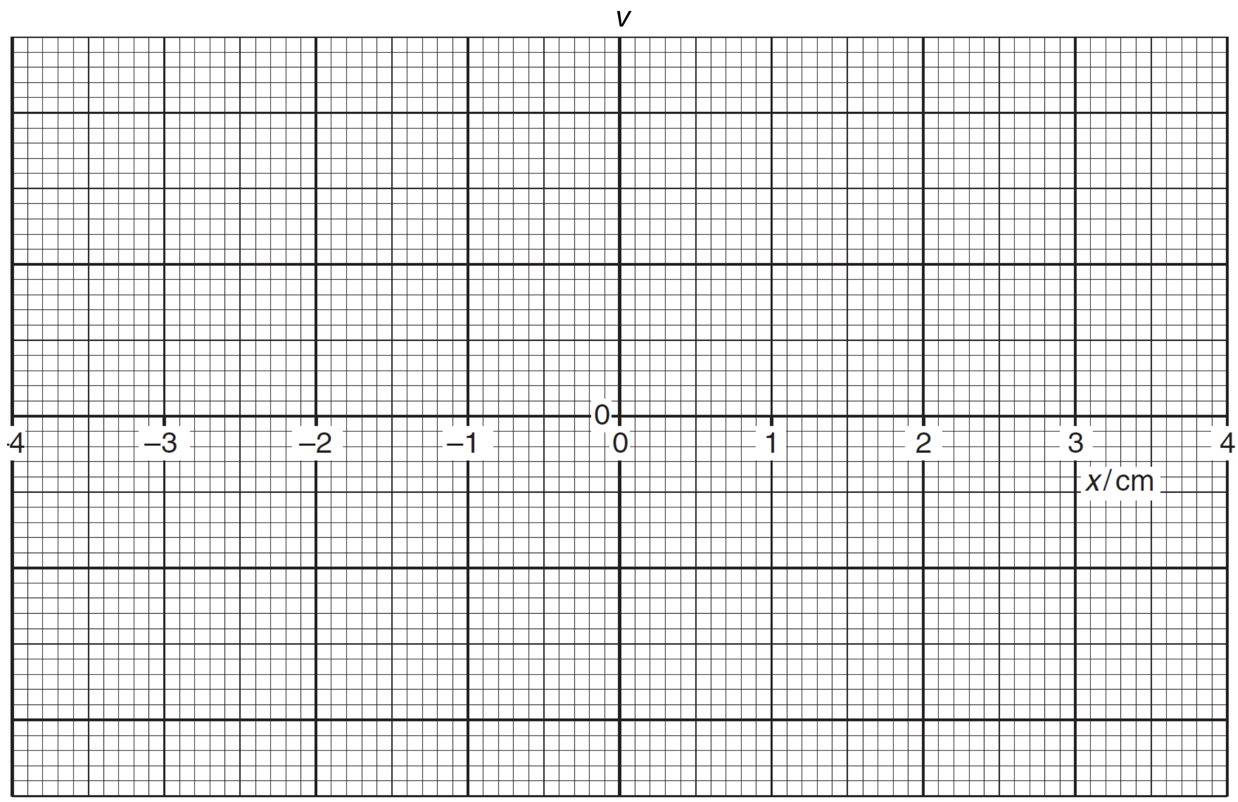


**Fig. 6.2**

[3]

**(v)** The mass of the ball is 0.10 kg. Calculate the total energy of the oscillation.

total energy = ………………………….. mJ [3]

**(vi)** Hence, on the axes of Fig. 6.3, to show the variation with displacement $x$ of

**1.** the total energy (label this TE)
**2.** the kinetic energy (label this KE)
**3.** the potential energy (label this PE)

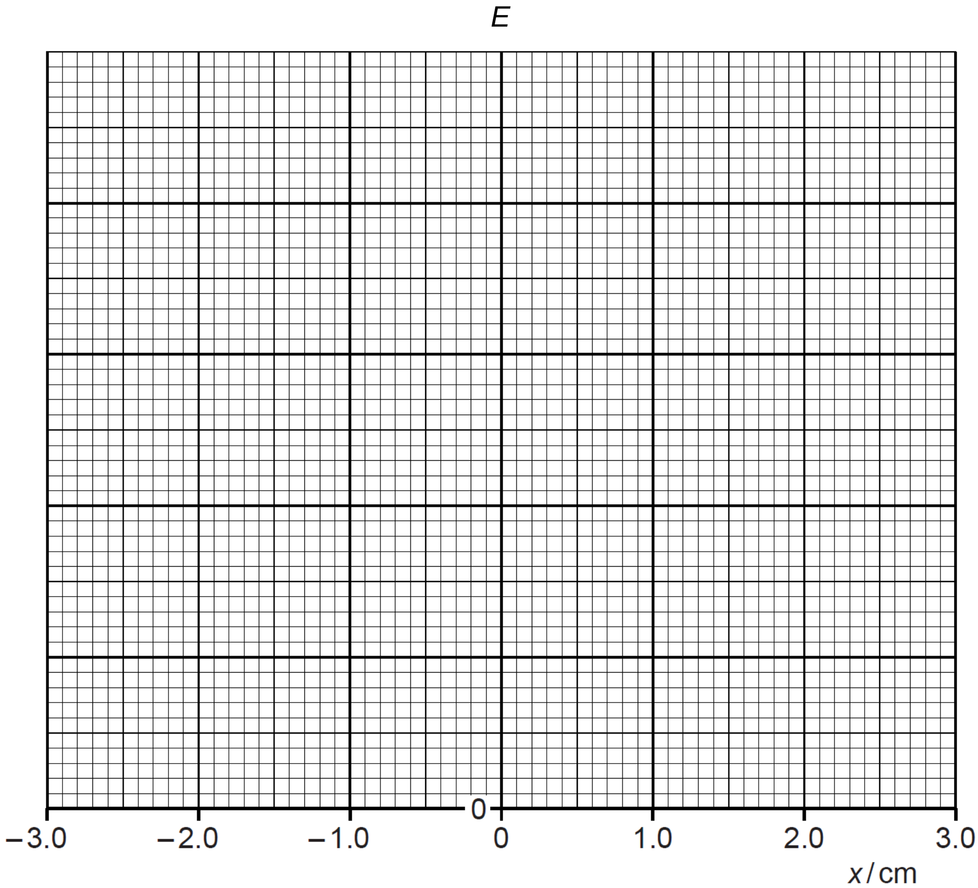


**Fig. 6.3**

[2]

**(vii)** An additional track with a radius of 29 cm is placed beside the track with a radius of 28 cm. One ball is placed on each track and released as shown in Fig. 6.4 so that the balls start to move in phase.

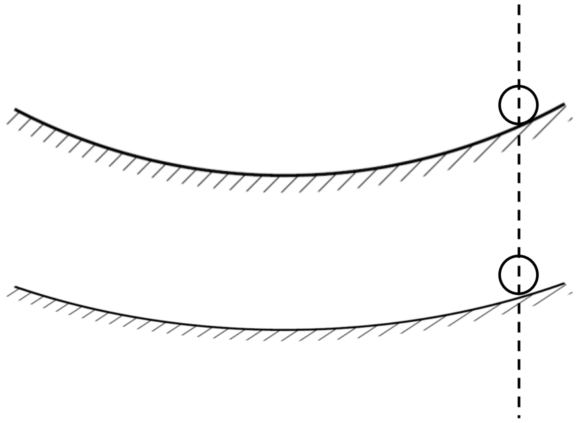

**Fig. 6.4**

The balls will start to move out of phase as they oscillate.

Determine the time it takes from the time of release till the next point in time when the balls are in phase again.

time = …………………………………. s [4]

[Total: 20]

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**7** **(a)** Define the *gravitational potential* at a point.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………. [2]

**(b)** The Earth may be considered to be an isolated sphere of radius $R$ with its mass concentrated at its centre.

The variation of the gravitational potential $\phi$ with distance $x$ from the centre of the Earth is shown in Fig. 7.1.

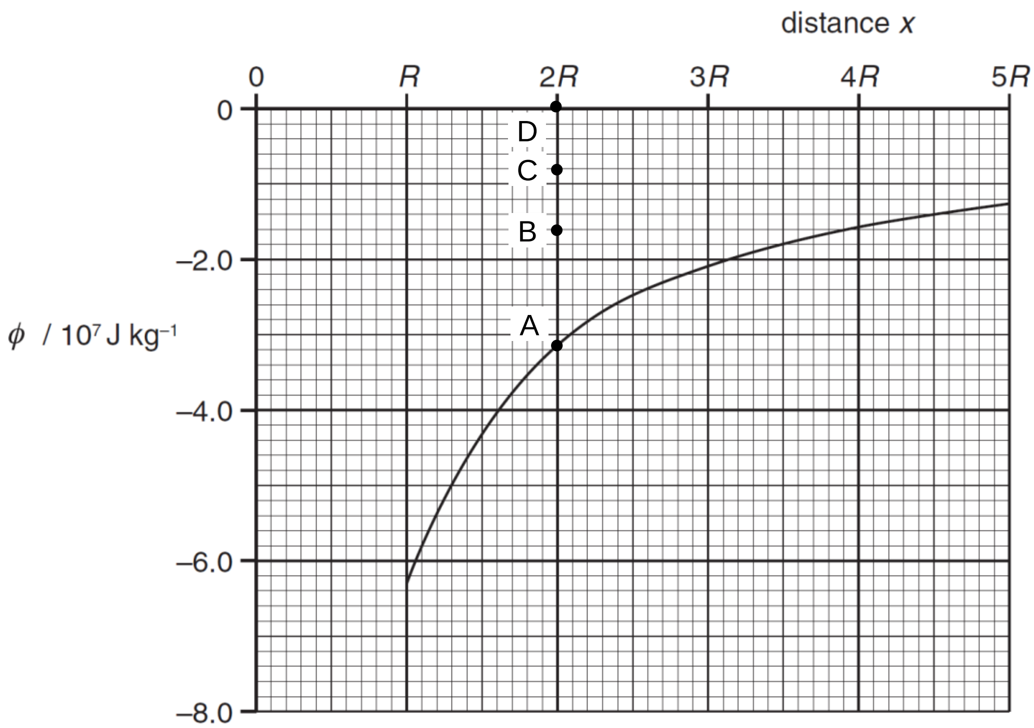


**Fig. 7.1**

The radius $R$ of the Earth is $6.4 \times 10^{6}$ m.

**(i)** Using Fig. 7.1, determine the gravitational field strength at the point $2R$ above the surface of the Earth. Explain your working.

gravitational field strength = ……………………………….. N $kg^{-1}$ [3]

**(ii)** At a certain distance $x = 2R$, the total energy of a space capsule (i.e. the sum of its gravitational potential energy and its kinetic energy) may be represented by one of the 4 points A, B, C and D.

Which point (or points) could represent the total energy of the space capsule

**1.** if it were momentarily at rest at the top of its trajectory,

**2.** if it were falling towards the Earth,

**3.** if it were moving away from the Earth, with sufficient energy to reach an infinite distance,

**4.** if it is moving in a circular orbit around Earth.

In each case, briefly explain how you arrived at your answer.

**1.** ..........................................................................................................

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**2.** ..........................................................................................................

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**3.** ..........................................................................................................

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**4.** ..........................................................................................................

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**(c)** In practice, the Earth is not isolated and the gravitational field around Earth is affected by other celestial bodies such as the Moon.

Fig. 7.2, which is not to scale, shows how the gravitational potential between the surface of the Earth and the surface of the Moon varies along the line joining the centres. At the point P, the gravitational potential is a maximum.

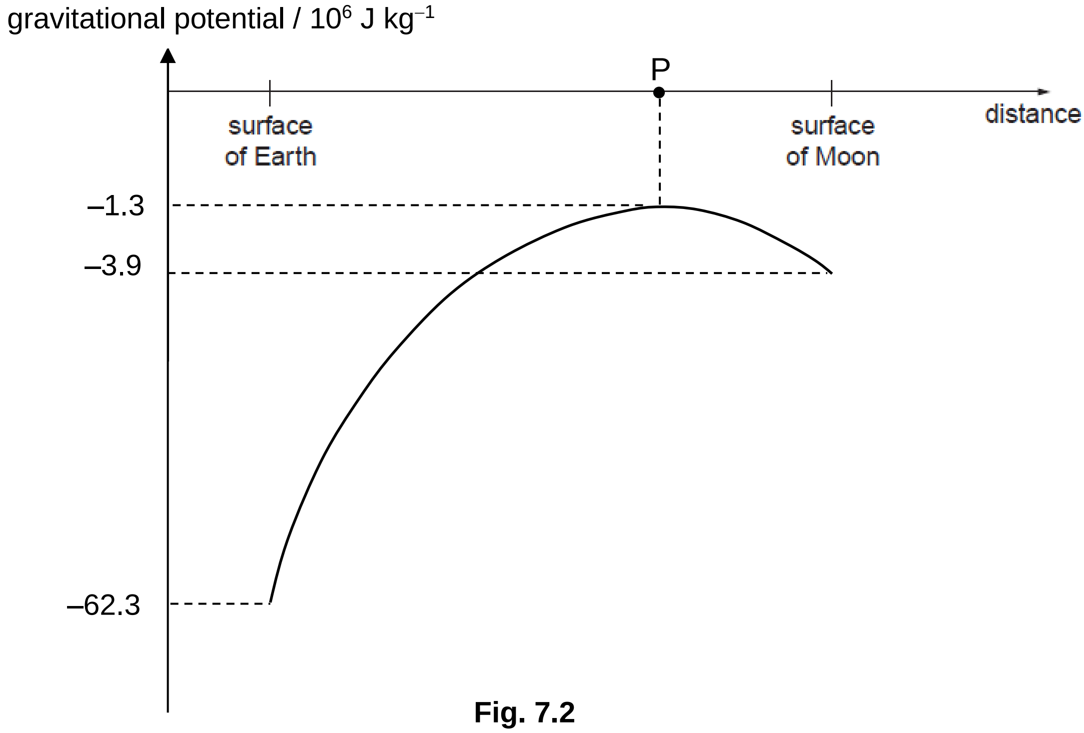


**Fig. 7.2**

**(i)** On the axes of Fig. 7.3, sketch a graph to show the variation of the gravitational field strength with distance between the surface of the Earth and the surface of the Moon.

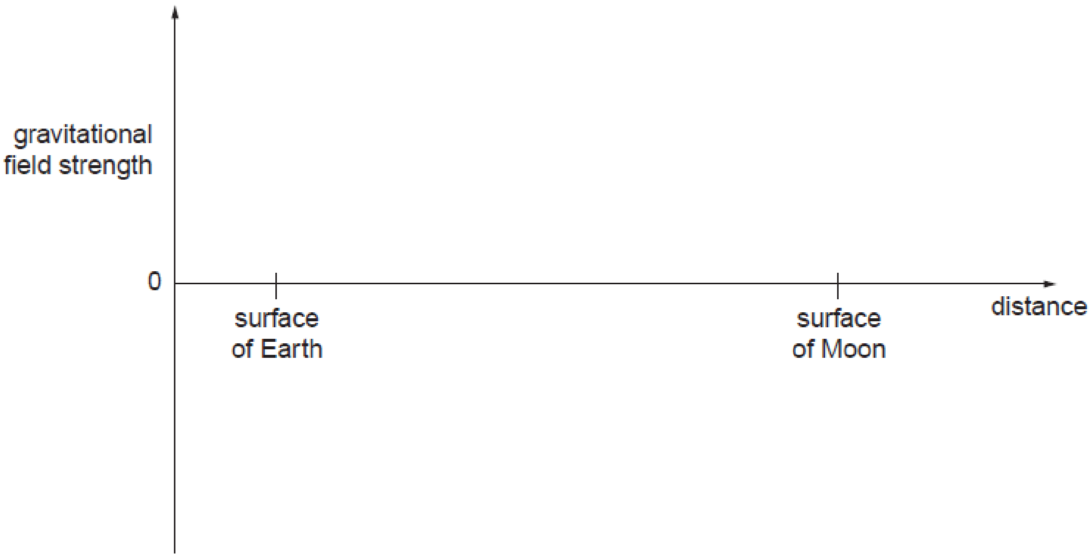


**Fig. 7.3** [3]

**(ii)** Using Fig. 7.2, find the minimum energy needed to send a 4.0 kg object from the surface of Earth to the surface of the Moon.

minimum energy = ……………………………….. J [3]

[Total: 20]

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