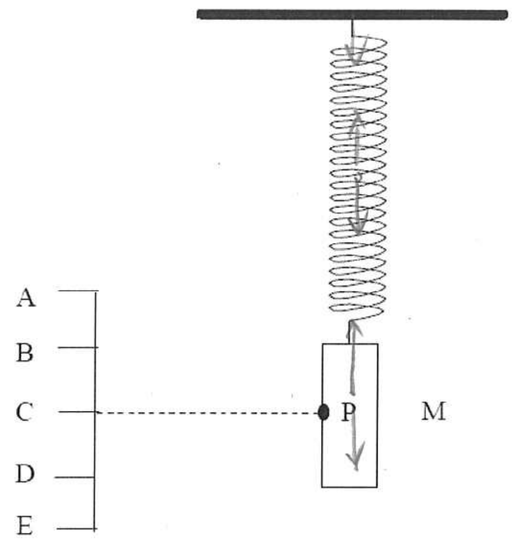
First Year SHM , Circular Motion and Gravitation Name: Maggie .

44/44

1. The diagram below shows a magnet M suspended vertically from a spring. When the magnet is in equilibrium its mid-point P coincides with the line C on the adjacent scale. The magnet is pulled down such that P is now opposite E. It is then released.

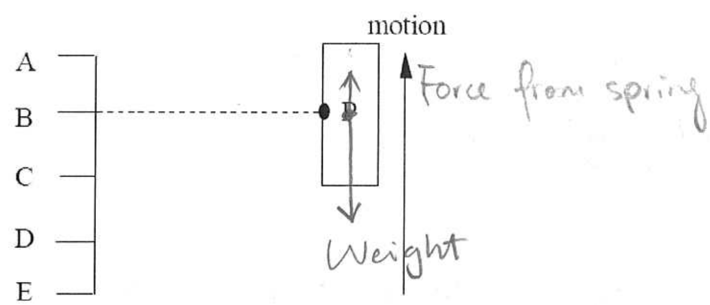


(a) What conditions must be satisfied by the acceleration of the magnet in order for its motion after release to be **simple harmonic**? *[2]*

Acceleration should be proportional to the displacement and opposite in direction. i.e. $a = -\omega^2 x$.

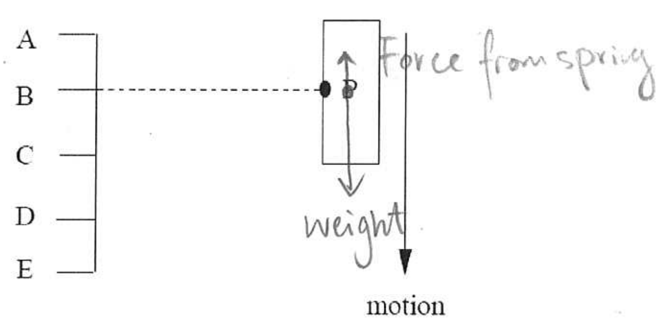
2

(b) (i) On the diagram below the magnet is moving up at the moment the point P is opposite B. Draw and name the forces acting on the magnet, showing both magnitude and direction. *[3]*



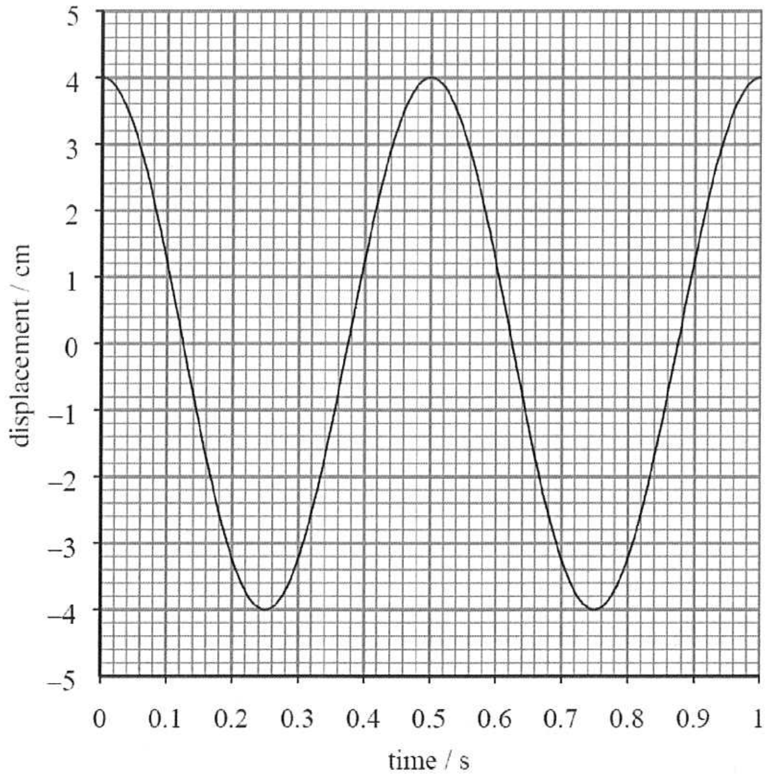
3

(ii) On the diagram below draw and name the forces acting on the magnet when the magnet is in the same position but moving downwards. Show the magnitude and direction of the forces. *[2]*



2

(c) The graph below shows how the displacement of the magnet varies with time for two oscillations.



Using information from this graph and the fact that the mass of the magnet is 0.30 kg calculate the

(i) value of the spring constant. [3]

$T = 2\pi\sqrt{\frac{m}{k}}$ so $k = 47\ N/m$.

$0.5 = 2\pi\sqrt{\frac{0.30}{k}}$

2

(ii) maximum kinetic energy of the magnet. [4]

From the graph, $X(t) = 0.04\cos(4\pi t)$

So $V_{max} = \omega x_0 = \cancel{(0.04)(4\pi)} = (0.04)(4\pi) = 0.5\ m/s$.

$E_{K max} = \frac{1}{2} m v_{max}^2 = \frac{1}{2}(0.30)(0.5)^2$

$= 0.0375\ J$

$\approx 0.04\ J$.

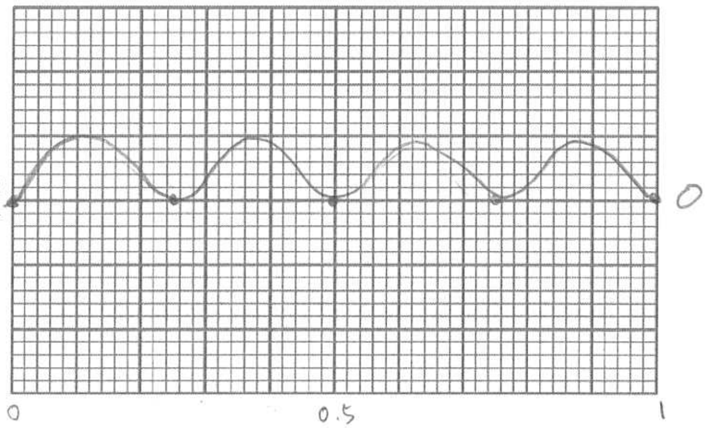
4

(d) On the two grids below sketch

(You do not need to give any values of energies on either graph.)

(i) a graph to show how the kinetic energy of the magnet varies with time for **one** complete oscillation. *[2]*

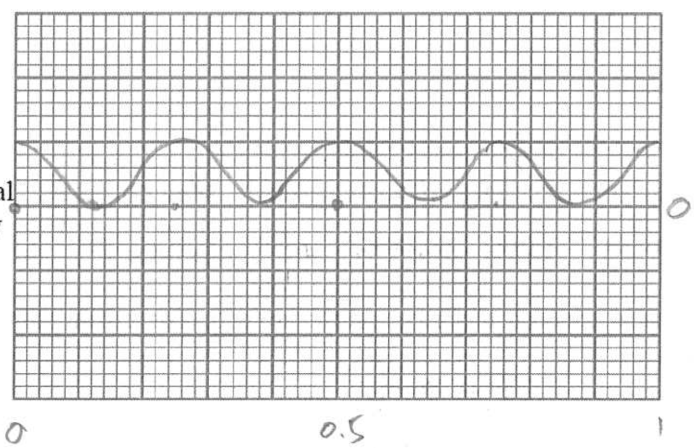
kinetic energy



✓ 2

(ii) a graph to show how the elastic potential energy of **the spring** varies with time for **one** complete oscillation. *[3]*

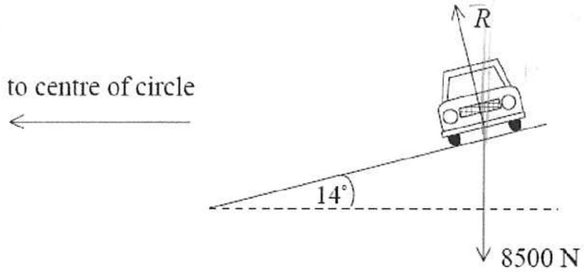
potential energy



✓ 3

2. This question is about the motion of a car.

A car of weight 8500 N is travelling at constant speed along a road that is an arc of a circle. In order that the car may travel more easily round the arc, the road is banked at 14° to the horizontal, as shown below.



At one particular speed v of the car, there is no frictional force at 90° to the direction of travel of the car between the tyres and the road surface. The reaction force of the road on the car is R.

(a) Deduce that the horizontal component of the force R is approximately 2100 N. *[2]*

$R_x = 8500 \times \cancel{\sin(14°)}\ \tan(14°)$

$= 2100\ N$

(b) State the magnitude and direction of the resultant force acting on the car. *[2]*

The resultant force is the horizontal force of 2100 N, towards the center of circle.

2

(c) Determine the speed v of the car at which it travels round the arc of radius 150 m without tending to slide. *[3]*

$F = m\frac{v^2}{r}$

$2100 = 850 \frac{v^2}{150}$

$v = 19\ m/s$

3

(d) Deduce in which direction the car will tend to slide if it travels round the curve at a speed greater than v. *[2]*

since $F = m\frac{v^2}{r} = 2100$, ~~As $v\uparrow$, $r\downarrow$~~ As $v\uparrow$. $r\uparrow$

So the car would slide towards the center of circle. away from.

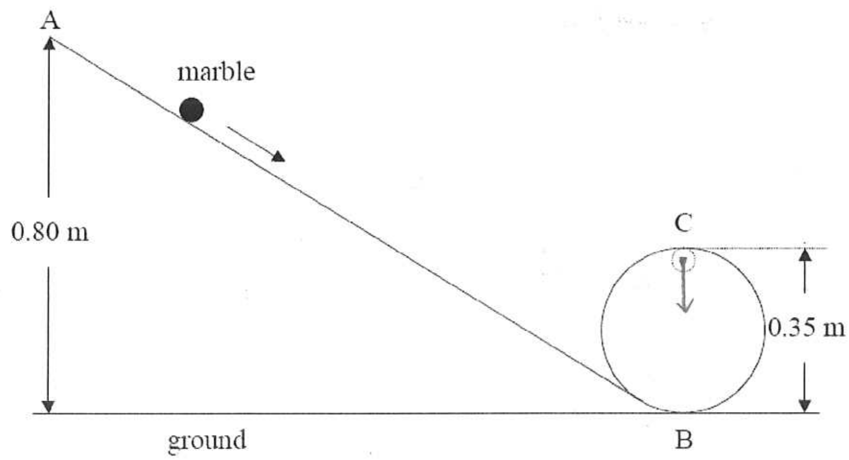
X.

(a) A car goes round a curve in a road at constant speed. Explain why, although its speed is constant, it is accelerating. [2]

When it goes around a curve, the direction changes. So the velocity is changing, which means there must be an acceleration towards the center of the curve.

2

3. In the diagram below, a marble (small glass sphere) rolls down a track, the bottom part of which has been bent into a loop. The end A of the track, from which the marble is released, is at a height of 0.80 m above the ground. Point B is the lowest point and point C the highest point of the loop. The diameter of the loop is 0.35 m.



The mass of the marble is 0.050 kg. Friction forces and any gain in kinetic energy due to the rotating of the marble can ~~be ignored~~. The acceleration due to gravity, $g = 10\,\text{m}\,\text{s}^{-2}$.

Consider the marble when it is at point C.

(b) (i) On the diagram opposite, draw an arrow to show the direction of the resultant force acting on the marble. [1]

(ii) State the names of the **two** forces acting on the marble. [2]

Weight;
Normal force from the track.

2

(iii) Deduce that the speed of the marble is $3.0\,\mathrm{m\,s^{-1}}$. [3]

$\Delta E_p = \Delta E_k$

$\cancel{m}g\Delta h = \frac{1}{2}\cancel{m}v^2$

$10(0.80 - 0.35) = \frac{1}{2}v^2$

$v = 3.0\,\mathrm{m/s}$.

3

(iv) Determine the resultant force acting on the marble and hence determine the reaction force of the track on the marble. [4]

$F = \frac{mv^2}{r}$

$\frac{(0.050)(3.0)^2}{\frac{0.35}{2}} = 2.6N = \cancel{0.26N}$

$F_N = F - W$
$= 2.6 - 0.5$
$= 2.1\,N$

4

4. The speed of a spacecraft in a low earth orbit is approximately 7.8 $\mathrm{kms^{-1}}$. The earth has a radius of approximately 6.4 km.

(a) What is the orbital period of the spacecraft ? (2 marks)

$$T = \frac{2\pi r}{v} = \frac{2\pi(6.4\times10^6)}{7.8\times10^3} = 5200\ s.$$

2

(b) What is the magnitude and direction of the acceleration experienced by the spacecraft? (3 marks)

$$a = \frac{v^2}{r} = \frac{(7.8\times10^3)^2}{6.4\times10^6} = 9.5\,\mathrm{ms^{-1}}.$$

3

A satellite is in a geostationary orbit about the earth. The orbital period of a geostationary orbit is 24 hours.

(c) How many times further is the satellite from the centre of the earth as compared to the spacecraft

(2 marks) $$\frac{r_2}{r_1} = \left(\frac{T_2^2}{T_1^2}\right)^{\frac{1}{3}} = \left(\frac{(24\times3600)^2}{5200^2}\right)^{\frac{1}{3}} = 6.5\ \text{times}.$$

2

(d) Why is the speed of the satellite less than the speed of the spacecraft ? (2 marks)

The speed is less because the radius is larger,

and since $a = \frac{v^2}{r} = \frac{GM}{r^2}$, $v^2 = \frac{GM}{r}$, so

as $v\uparrow$, $r\downarrow$. The further, the weaker force, the ~~veto~~ speed has to $\downarrow$ in order to hold it.

1