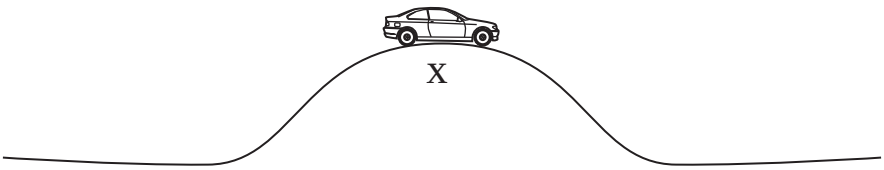
1 The photograph shows a bridge.

The diagram shows a car of mass 950 kg at the highest point X of the bridge.



The bridge forms part of a vertical circle of radius 20.0 m.

(a) Calculate the total upward force R of the road on the car:

(i) when the car is stationary at X,

(1)

R =

(ii) when the car is passing point X at a speed of 12.0 m s^{-1}.

(3)

R =

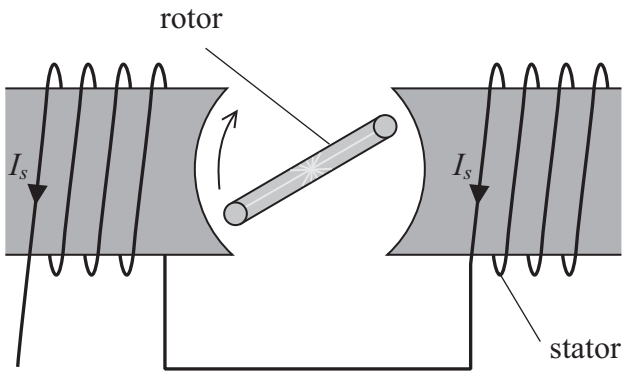
(b) The car is repeatedly driven over the bridge at gradually increasing speeds. Above a certain speed the car loses contact with the road at X.
State why this happens.

(1)

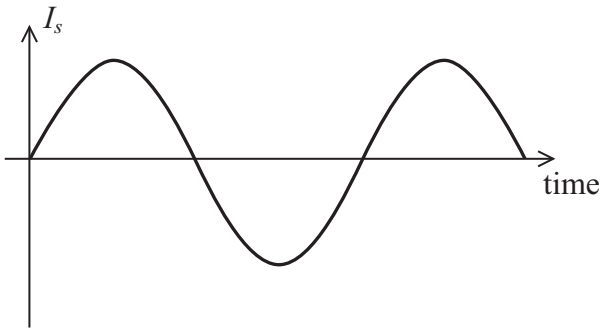
(Total for Question = 5 marks)

2 The diagram represents a simple induction motor. An alternating current I_s is supplied to a stationary coil (stator). This coil is wrapped around an iron core.

A rotating coil (rotor) is shown end on in the diagram.



(a) The graph shows the variation of the alternating current I_s with time.



*(i) Explain how current is induced in the rotor coil.

(4)

(ii) Explain why the rotor turns.

(2)

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(iii) State **two** ways of making the rotor turn faster.

(2)

1 .....

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2 .....

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(b) An induction motor is used to rotate the turntable in a record deck. Long-play records require the turntable to rotate at 33 revolutions per minute.

(i) Calculate the angular velocity of the turntable.

(3)

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Angular velocity .....

(ii) Calculate the acceleration of a speck of dust at the outside edge of a rotating record.

radius of record 12.5 cm

(2)

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Acceleration .....

(Total for Question 13 marks)

*3 The Hubble Space Telescope (HST) was launched in 1990 into an orbit of radius 6940 km. The satellite makes 15 complete orbits of the Earth every 24 hours and its position high above the Earth's atmosphere has allowed high quality images of extremely distant objects to be produced.

(a) (i) Show that the HST has a centripetal acceleration of about 8 m s^{-2}.

(4)

(ii) The HST is kept in orbit by the gravitational pull of the Earth. Use your answer to (a)(i) to calculate a value for the mass of the Earth.

(3)

Mass =

(b) The telescope was named in honour of Edwin Hubble who measured the red shift of light from a number of galaxies and related it to their distance from the Earth.

Explain what is meant by the term *red shift* in this context and state the inference that Hubble made from his measurements.

(2)

(c) The song “Nine Million Bicycles” by Katie Melua includes the lines, “We are 12 billion light years from the edge, that’s a guess, no one can ever say it’s true”.

(i) Explain how the line “12 billion light years from the edge” implies an age of 12 billion years for the universe.

(2)

(ii) Calculate the value of the Hubble constant consistent with an age of 12 billion years for the universe.

1 billion years = 3.15×10^{16} s

(2)

Hubble constant =

(iii) These lyrics were famously contested by Dr Simon Singh in the Guardian newspaper. He argued that the correct age was 13.7 billion years, and disputed that scientists had guessed the age of the universe. As a result Katie performed the song with revised lyrics.

Discuss the suggestion in the song that values for the age of the universe are only guesses.

(3)

(Total for Question = 16 marks)

4 (a) The Moon orbits the Earth in a circular path.

Explain why the Moon maintains this circular path and what determines the radius of the path.

(2)

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(b) A bucket is swung in a vertical, circular path as shown.

The bucket is half filled with water and swung. The water stays in the bucket, even at the top of the circular path, as long as the speed of the bucket exceeds a certain value.

Explain why.

(3)

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(Total for Question 5 marks)

5 In order to make an object move around a circular path at a constant speed a resultant force must act on it.

(a) Explain why a resultant force is required and state the direction of this force.

(2)

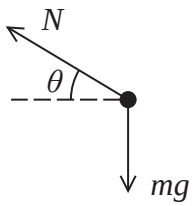
(b) When vehicles move around a bend on a level road, the resultant force is provided by friction between the tyres and the road. For a given vehicle and road surface there is a maximum value for this sideways frictional force.

Explain why roads designed for high-speed travel, such as motorways, do not have any sharp bends.

(2)

(c) Some cycling tracks are banked. When cornering, a cyclist moves up the track until the sideways frictional force is zero.

The free-body force diagram for a cyclist and bicycle is shown. The normal contact force exerted by the track is N and the weight of cyclist and bicycle is mg.



(i) By considering the vertical and horizontal motion, show that

$$\tan \theta = gr/v^2$$

where r is the radius of the cyclist's path and v is the cyclist's speed.

(3)

(ii) Calculate the value of θ for a cyclist travelling at 11.0 m s^{-1} around a bend of radius 18.7 m.

(2)

$\theta =$

(Total for Question = 9 marks)