**1 (a)** State what is meant by angular velocity and write down its SI unit.

………………………………………………………………………………………….

………………………………………………………………………………………….

……………………………………………………………………………………….[2]

**(b)** The acceleration of free fall on the surface of the Earth at the pole differs slightly from that at the equator. The Earth is assumed to be a uniform sphere. A man of mass 90 kg stands at the equator of the Earth. The radius of the Earth is 6.37 x 106 m and its period is 24 hours.

Using Newton’s second law of motion, calculate the apparent weight of the man.

weight = …………….. N [2]

**(c)** Fig. 1.1 shows how the total potential *φ* between the Moon and the Earth varies along the line of centres.

0

- 1.3

Earth

Moon

*φ*/ 106 J kg-1

- 62.3

- 3.9

**Fig. 1.1**

1. Explain qualitatively why the graph has a maximum.

………………………………………………………………………………….

………………………………………………………………………………….

………………………………………………………………………………[2]

1. A cannon ball of mass 120 kg on the Moon is to be projected directly towards the Earth. Determine the minimum speed that the cannon ball must be projected in order to reach the Earth. Assume no energy loss due to resistive forces.

minimum speed = ……………….. m s-1 [2]

1. On Fig. 1.1, sketch a graph to show the variation with distance of the gravitational force *F*, experienced by the cannon ball as it travels from the Moon to the Earth. A force towards the Earth is taken to be positive. [2]

**Solution**

(a) Angular velocity is the rate of angular displacement. [1]

Unit: rad s-1 [1]

(b) F = m a

True Weight – Normal Reaction = Centripetal force needed

 mg – N = mrω2 [1]

 N = mg – mrω2

 = 90 (9.81) – 90 (6.37 x 106) (2π/24x60x60)2

 N = 883 – 3.03 = 880 N [1]

(c) (i) Maximum point corresponds to the point where the gravitational field strength (or force) due to the Moon is equal and opposite to that due to the Earth. Hence, g = 0. [No mark for merely stating that g = 0.]

 [1]

Since gravitational field strength is proportional to the potential gradient, the gravitational potential has a maximum.

 [1]

(ii) Initial KE – Final KE = Change in Gravitational Potential Energy

½ m Vmin2 - 0 = m Δφ [1]

½ Vmin2 = (-1.3 – (-3.9)) x 106

 Vmin = 2280 m s-1 [1]

(iii)

0

- 1.3

Earth

Moon

*φ*/ 106 J kg-1

- 62.3

- 3.9

Fig. 1

Net force between

Moon & Earth

*Max point dφ/dr = 0*

*Net force = 0*

1 m for correct shape

1 m for x-intercept corresponding to max potential and |F| at Earth surface being greater than that at Moon surface