Physics 3AB

Motion and Forces
Test Two
2013

Mark: / 54

= %

Name:

Notes to Students:

- You must include **all** working to be awarded full marks for a question.
- Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
- **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(12 marks)**

A Space Shuttle mission was in a circular orbit 3.00 x 10^2 km above the surface of the Earth.

(a) Determine the value of the gravitational field strength at this position.

(3 marks)

$g = \dfrac{GM_E}{R^2}$ √ $R = (6.37 \times 10^6) + (3.00 \times 10^2 \times 10^3) = 6.67 \times 10^6$

$= \dfrac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(6.67 \times 10^6)^2}$ √

$= 8.97 \text{ N kg}^{-1}$ √

(b) Dr Andy Thomas, a famous Australian astronaut, was on this Shuttle with a mass of 78.0 kg. What was his weight whilst orbiting the Earth at that altitude?

(3 marks)

W = mg √

W = 78 x 8.97 √

W = 699.6 N = 700 N √ (Direction to centre of mass of Earth)

(699N is acceptable if calculator memory is used)

(c) Explain why Dr Thomas experienced 'weightlessness' whilst in orbit about the Earth.

(2 marks)

•Your apparent weight is due to the normal force that the ground exerts upon us.

•Dr Thomas experiences apparent weightlessness because he (along with the Shuttle) is in free fall towards the Earth at 8.97 m s^{-2} and experiences no normal force from the floor of the shuttle.

(d) Using your knowledge of contexts of motion, state how **you** could experience 'weightlessness' at or near the Earth's surface.

(1 mark)

•In a loop the loop when you are moving in a vertical circle with just sufficient velocity such that $mv^2/r = mg$ (√) you experience no normal force.

•You are in free fall e.g in a lift falling to earth at 9.8 m s^{-2} (√) where you experience no normal force or

•In a plane diving towards the Earth with an acceleration equal to the acceleration of gravity (√) where your body experiences no normal force.

• Being a human cannon ball - following a parabolic path (√) as a projectile, no normal force . or any other suitable answer

(e) Does the shuttle need to produce a force from its rockets to keep it moving at constant speed? Assuming negligible air resistance, explain.

(3 marks)

• No. The shuttle is being accelerated about the Earth because of the force of gravitational attraction, which acts as a source of centripetal force.

• The shuttle is a projectile with a circumferential speed, which is analogous to the horizontal component of projectiles at the Earth's surface, unchanged due to Newton's first Law of inertia.

• The force acts perpendicular to the motion so does not affect it.

Question 2 **(3 marks)**

A fork lift truck as shown in the adjacent photo is a vehicle used to lift and place heavy loads in a warehouse.

Typically loads can have a mass of up to 1.5 tonnes.

Explain, using the diagram, why the rear section of the truck behind the driver (shown by the arrow) is made from a massive block of steel as a fundamental safety design feature.

• Any mass being lifted at the front will create an anticlockwise torque about a pivot point such as the front wheel of the fork lift.

• This anticlockwise torque will increase as the height of the load increases.

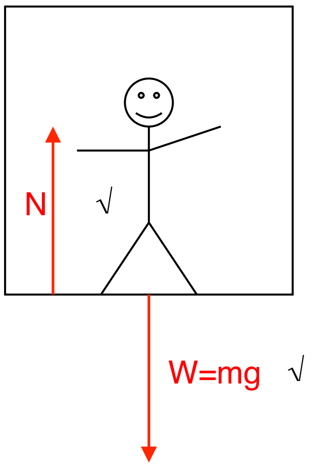
• The large weight at the back of the fork lift at a small height above the pivot acts as a counterbalance to provide a clockwise torque that will stop the forklift from becoming unstable and toppling.

Question 3 **(5 marks)**

Geoff who is 70.0 kg steps into a lift on the ground floor of a twenty-story building.

(a) Draw a force diagram in the space below that shows the forces acting on Geoff as he stands in the lift.

(2 marks)



ΣF = W + N

ΣF = 0

N = -W (same in magnitude but opposite in direction

(b) The lift then accelerates upwards at 2.50 ms^{-2}. Calculate Geoff's apparent weight for this situation.

(3 marks)

ΣF = W + N √

N (apparent weight) = ΣF - W

N = ma - (-g).m

N = (70 x 2.5) - (-9.8 x 70) √

N = 175 + 686

N = 861 N (up) √ -1/2 if no direction

Question 4 **(9 marks)**

With the recent landing of the unmanned roving vehicle Curiosity on Mars there has been a lot of interest in the planet. The mass of Mars is 6.46 x 10^{23} kg and the mean distance between it and the Sun is 2.28 x 10^{11} m.

(a) Calculate the gravitational force of the Sun acting on Mars.

(3 marks)

$$F_g = \frac{GM_M M_S}{R^2} \ \surd$$

$$= \frac{6.67 \times 10^{-11} \times 6.46 \times 10^{23} \times 1.99 \times 10^{30}}{(2.28 \times 10^{11})^2} \ \surd$$

$$= 85.7 \times 10^{42} / 5.12 \times 10^{22}$$

$$= 1.65 \times 10^{21} \text{ N towards the Sun} \ \surd$$

(b) Assuming Mars has a circular orbit calculate its circumferential speed.

(3 marks)

$m_M v^2/r = F_g$ so $v = \sqrt{F_g x r / m_M}$ √

$v = \sqrt{(1.70 \times 10^{21} \times 2.28 \times 10^{11}) / 6.64 \times 10^{23}}$ √

$v = 2.41 \times 10^4 \text{ ms}^{-1}$ √

(c) Calculate the time it takes Mars to complete one orbit about the Sun.

(3 marks)

$v = s/t$ where $s = 2\pi r$ √

$2\pi \times 2.28 \times 10^{11})/ 2.41 \times 10^4 \text{ ms}^{-1} = T$ √

$T = 5.94 \times 10^7$ s √

Question 5 **(8 marks)**

A moon of Jupiter makes a complete revolution about Jupiter in 1.53 x 10^5 s. Its orbit can be considered as a circle of radius 4.21 x 10^8 m.

(a) Use this data to calculate the mass of Jupiter.

(5 marks)

$F = \frac{GM_JM_M}{R^2} = \frac{M_Mv^2}{R}$ √ where $v = \frac{2\Pi R}{T}$

so $\frac{GM_J}{R^2} = (2\Pi R/T)^2$ √

therefore $\frac{GM_J}{R^2} = \frac{(4\Pi^2R^2/T)^2}{R}$ $M_J = \frac{4\Pi^2R^3}{GT^2}$ √

$M_J = \frac{4\Pi^2 \times (4.21 \times 10^8)^3}{6.67 \times 10^{-11} \times (1.53 \times 10^5)^2}$ √

$M_J = 2.95 \times 10^{27} / 1.56 = 1.89 \times 10^{27}$ kg √

(b) Determine the orbital speed of this moon in km s^{-1}.

(3 marks)

$v = \frac{2\pi R}{T}$ √

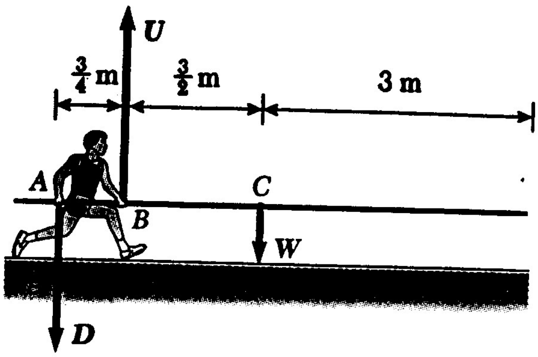
$= \frac{2\pi \times 4.21 \times 10^8}{1.53 \times 10^5}$ √

$= (2645221014)/ (1.53 \times 10^5)$

$= 1.73 \times 10^4$ m s^{-1} $= 17.3$ km s^{-1} √

Question 6 **(5 marks)**

A pole vaulter holds his 6.00 m pole horizontally and in equilibrium by exerting an upward force **U** with his leading hand, which is 1.50 m behind the centre of mass of the pole, and a downward force **D** with his trailing hand which is located 0.75 m behind his leading hand. Assume that the centre of mass of the pole acts at its midpoint and the mass of the pole is 3.00 kg. Calculate the values of **U** and **D.**



For static equilibrium $\Sigma F = 0$, $\Sigma M = 0$ √

W pole = 3.00 x 9.8 = 29.4 N

Take moments about point A, where $\tau = Fr\sin\theta$ √

Σ cwm = W x (1.5 + 0.75) = 29.4 x 2.25 = 66.15 Nm cw

Σ acwm = (D x 0) + (U x 0.75) = 66.15 Nm √

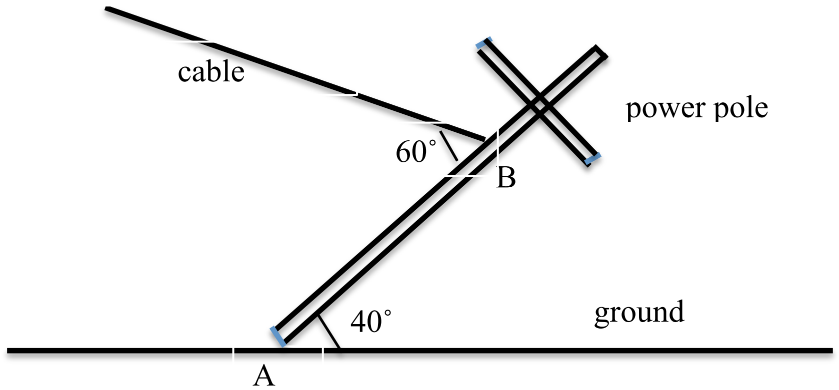
U = 66.15/0.75 = 88.2 N up √

ΣF = 29.4 N down + 88.2 N up + D = 0,

D = 58.8 N down √

Question 7 **(12 marks)**

Electricity engineers are using a crane to place a non-uniform power pole of length 14.0 metres and mass 648 kilograms into position next to a country road as shown in the diagram below.



The centre of mass of the pole is one third of its length from the base and the cable from the crane is attached at point B, 9.50 m from the base of the pole. If the crane has stopped lifting and the pole is at rest in the position shown in the diagram find,

(a) The tension in the cable

(4 marks)

Take moments about point A

Σacwm = Σcwm √

$T \times 9.5 \cos 30^\circ = W_{pole} \times 4.67 \cos 40^\circ$√

$T = 648 \times 9.8 \times 4.67 \cos 40^\circ/(9.5 \cos 30^\circ)$ √

$T = 22702/8.23$

$T = 2759.3 = 2.76 \times 10^3$ N √

(b) The frictional force on the pole at point A.

(3 marks)

$F_F = F_H$ where $F_H = T \cos 20^\circ$ √

$F_F = 2.76 \times 10^3$ N $\times \cos 20^\circ$ √

$F_F = 2.59 \times 10^3$ N to right √ -1/2 no direction

(c) The force that the ground exerts on the pole at point A.

(5 marks)

$\Sigma F_{up} = \Sigma F_{down}$ √

$\Sigma F_{up} = T \cos 70^{\circ} + F_N \quad = 648 \text{ X } 9.8$

$F_N = 6.35 \times 10^3 - 2759.3 \cos 70^{\circ} \quad = 5.41 \times 10^3$ N √

$F_{ground} = \sqrt{\ }((2.59 \times 10^3)^2 + (5.41 \times 10^3)^2)$

$F_{ground} = 6.00 \times 10^3$ N √

$\text{Tan}\theta = (5.41 \times 10^3)/(2.59 \times 10^3)$ √

$\theta = 64.4^{\circ}$ above the ground √

END OF TEST