ARANMORE CATHOLIC COLLEGE

YEAR 12 PHYSICS 3A3B - 2010

MOTION TOPIC TEST 2

NAME: SOLUTIONS **MARK:**

/50

Instructions:

1. Answer all questions in the spaces provided on the test paper.
2. Show full working out to get full marks as shown in brackets after each question.
3. Calculators as per Curriculum Council guidelines are permitted.
4. Answers **must** be in blue or black ink.

Questions:

1. Would a planet with twice the Earths' mass and twice the Earths' radius have the same acceleration due to gravity at its surface as the Earth? Explain your answer. [3 marks]

(1) NO.

$$g = \frac{GM}{r^2}$$

(1 MASS EFFECT)
(1 RADIUS EFFECT)

$$g_P = \frac{G\,2M_E}{(2r_E)^2} = \frac{2\,GM_E}{4\,r_E^2} = \frac{1}{2}\left(\frac{GM_E}{r_E}\right)$$

$$= \frac{1}{2}g_E.$$

IT WOULD HAVE HALF THAT OF THE EARTH.

2. Explain the difference between apparent weightlessness and true weightlessness. [3 marks]

(1) APP. WTLESSNESS IS WHEN $F_N = 0$

(1) – GIVE EXAMPLE – FALLING OBJECTS DUE TO g NEAR EARTH

SO g MAY BE ANY VALUE e.g. $9.8\ N\,kg^{-1}$.

(1) TRUE WTLESSNESS IS WHEN $g = 0$

e.g. IN DEEP SPACE $g \approx 0$.

3. Tito was given the task of designing a drinking cup for a small child. He came up with a design of a short cup with a wide base. With the aid of diagrams explain the physics behind Tito's design.

[4 marks]

(1) DIAGRAM: $\sqcup$ VS $\|$

(1) – LOW CENTRE OF MASS (OR GRAVITY)

(1) – LARGE FORCE REQ'D TO TIP OVER (CM BEYOND BASE OF SUPPORT)

OR LARGER ANGLE TO PIVOT

(1) – HENCE MORE STABLE.

4. A spherical asteroid, T307 (named after its discoverer, Taylah) has a mass of 8.50 x 10^{17} kg and a radius of 299 km.

[4 marks each]

a) Calculate the gravitational field strength at the surface of asteroid T307.

(1) $$g = \frac{GM}{r^2}$$

$$= \frac{6.67\times10^{-11} \times 8.5\times10^{17}}{(299000)^2}$$

(1) $$= 6.34\times10^{-4}\ N\,kg^{-1}\ (\text{or } ms^{-2})$$

(1 – km to m) (1 UNITS)

b) Determine the speed of a satellite in orbit at a height of 25.0 km above the surface of asteroid T307.

$a_c = g$ (BUT g CHANGES FROM PART (a)).

(1) $r = 299 + 25\ km$
$= 324000\ m$

(1) $$\frac{v^2}{r} = \frac{GM}{r^2}$$

$$v = \sqrt{\frac{GM}{r}}$$

$$= \sqrt{\frac{6.67\times10^{-11} \times 8.5\times10^{17}}{324000}} \quad (1)$$

$$= \sqrt{175}$$

$$v = 13.2\ ms^{-1}. \quad (1)$$

5. Perth television stations can use pictures from the Japanese GMS weather satellite which is in geostationary orbit over the equator to the north of Australia. Why is it not possible to place the satellite directly over Perth?

[3 marks]

(1) PLANE OF ORBIT OF SATELLITE MUST PASS THROUGH CENTRE OF MASS OF EARTH ∴ EQUATORIAL ORBIT FOR

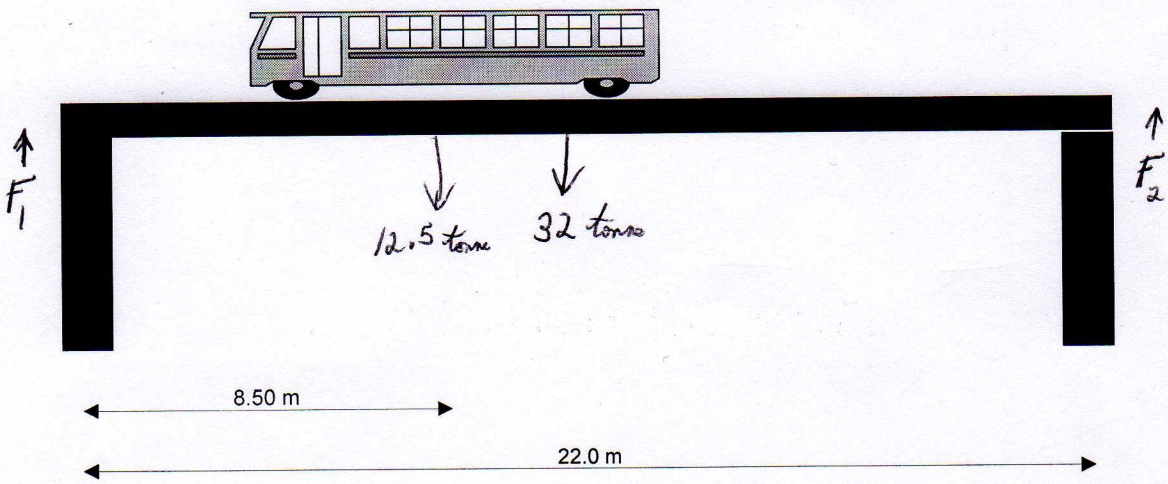
(1) GEOSYNCHRONOUS.

SINCE PERTH IS SOUTH OF EQUATOR (32°S) NOT POSSIBLE

(1) FOR ORBIT IN PLANE WHICH INCLUDES EARTH'S CENTRE TO REMAIN OVER PERTH.

6. Ceara parks her bus part-way along a bridge that is supported by two pillars, as shown in the diagram below. The 22.0 m bridge is uniform and has a mass of 32.0 tonne. The bus has a mass of 12.5 tonne and its centre of mass is 8.50 m from the left end of the bridge. Find the force exerted by each pillar.

[4 marks]



$\sum F = 0$ $\quad F_1 + F_2 = 12.5\times10^3 \times 9.8 + 32\times10^3\times 9.8$

$= 122500 + 313600$ (1)

$= 436100$ N. (1 - tonnes to kg)

PIVOT AT F_1:

$\sum \tau = 0$

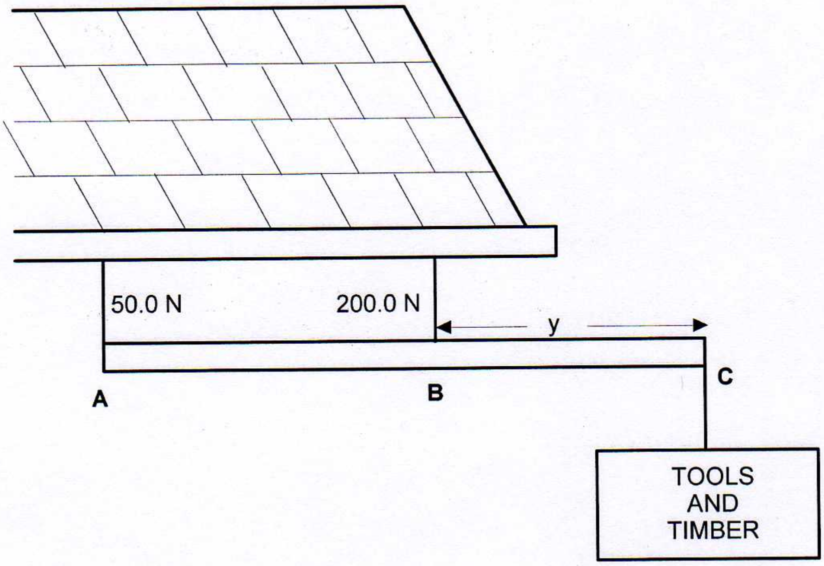
$F_2 \times 22 = 11 \times 313600 + 8.5 \times 122500$

$F_2 = \frac{4490850}{22}$

$F_2 = 2.04 \times 10^5$ N UP. (1)

$\therefore F_1 = 2.32 \times 10^5$ N UP. (1)

7. A sign outside Steve's hardware shop is suspended from a uniform beam ABC, which is 2.10 m long and has a mass of 20.0 kg. The beam is suspended by two identical wires attached at A and B. The tensions in the two wires are 50.0 N and 200.0 N respectively (see the diagram below).



a) What is the weight of the sign 'Tools and Timber'? [4 marks]

(1) $\sum F = 0$

(1) $F_A + F_B = F_W + F_C$

(1) $F_C = 50 + 200 - 20 \times 9.8$

$F_C = 54\ N.$ (1)

$m = \frac{54}{9.8} = 5.51\ kg.$

[MASS NOT REQUIRED, BUT FULL MARKS STILL IF ONLY CORRECT MASS.]

b) What is the distance 'y'? [5 marks]

TAKE PIVOT AT C:

(1) $\sum \tau = 0$

(1) $F_A \times 2.1 + F_B \times y = \frac{1}{2} \times 2.1 \times F_W$ (1)

$50 \times 2.1 + 200y = 1.05 \times 196$

(1) $y = \frac{205.8 - 105}{200}$

$y = 0.504\ m.$ (1)

8. Describe and compare rotational and translational equilibrium. What are the conditions required for static equilibrium? [4 marks]

($\frac{1}{2}$) ROTATIONAL $\Sigma \tau = 0$

(1) + DESCRIPTION

($\frac{1}{2}$) TRANSLATIONAL $\Sigma F = 0$

(1) + DESCRIPTION

(1) STATIC – BOTH OF ABOVE.

9. A uniform, 3.40 m ladder of weight 110 N, is leaning against a building. (Assume that the ground is rough and the wall is smooth, i.e. the reaction force will be perpendicular.) The ladder makes an angle of 65° with the ground and Tom, who weighs 690 N, is standing on a rung halfway up the ladder in order to paint a nearby window frame. Find the reaction force at the ground. [6 marks]

(1) $\Sigma F = 0$

$$F_{UP} = F_{DOWN}$$
$$= 110 + 690 = 800\ N$$

$F_{UP} = F_{R,V} = 800N$ UP. $F_{R,H} = -F_{WALL}$. (1)

$\Sigma \tau = 0$ LET PIVOT BE AT BASE:

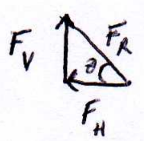
(1)
$$\tau_{AC} = \tau_{C}$$

$$F_{WALL} \times 3.40 \times \sin 65° = 800 \times 1.70 \cos 65°$$ (1)

$$F_{WALL} = \frac{574.76}{3.08}$$

$$F_{WALL} = 186.5\ N$$

$$F_{R,H} = 186.5\ N$$ (1)



$F_R = \sqrt{F_V^2 + F_H^2} = 821\ N$ AT 77° TO THE HORIZONTAL.

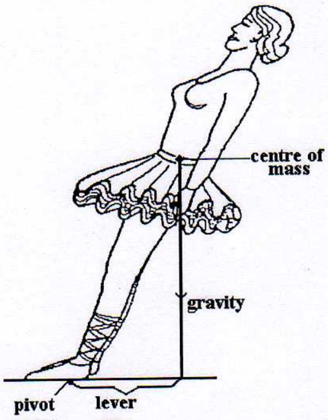
(1)

$\tan\theta = \frac{F_V}{F_H}$ $\theta = 77°$.

PART B **[6 Marks]**

BALLET (Article adapted from: **Scientific America.**)

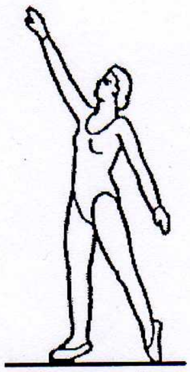
A large part of the early skills a ballet dancer must learn is to maintain balance while moving gracefully through the ballet forms. Balance is achieved when an area of support lies in an appropriate plane below the dancer's body. If the support area is off to one side, gravity pulls or turns the dancer towards the floor.



Gravity, of course, pulls constantly on every part of the body, but the concept of a centre of mass of the body helps to simplify the picture. The centre of mass is a mathematical point whose position is determined by the distribution of mass within the body. The combined pull of gravity on all the parts of the body is said to operate through the centre of mass.

When that centre is not over a support area on the floor, the pull of gravity creates a torque on the body (see above). The torque arising from the tilt tends to rotate the body about the feet. The greater the tilt, the longer the lever arm and a stronger torque is therefore produced. If the dancer stood upright, the length of the lever arm would be zero and gravity would create zero torque; the position would be stable.

The routine for the beginning student seeks to develop a sense of balance gradually. The position called the arabesque is a simple first version and is then advanced to the first arabesque penchee. In the simple version (Fig 1: arabesque a terre) the right leg is put forward, the left leg back with the toes touching the floor; the weight is therefore on the right leg. The arm reaches forward, the left arm slightly backwards.

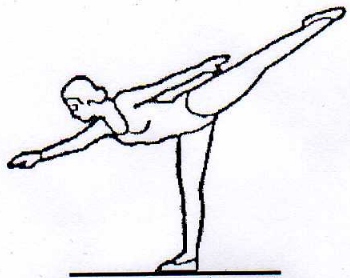


arabesque a terre
Fig 1

first arabesque allongee
Fig 2

Moving the left leg to the rear shifts the centre of mass in that direction. Without a compensating movement the dancer would fall over backward. To shift the centre of mass back over the support area of the right foot the dancer must lean forward and extend the right arm. This motion serves two purposes: it is graceful and it ensures balance is maintained. Fig 2 above shows the dancer moving from the arabesque a terre to the first arabesque allongee.

In the first arabesque allongee the dancer continues the motion until the torso and right arm are almost horizontal and the rear leg is tilted upward. In the first arabesque penchee (Fig 3 below) the dancer's torso and right arm are tilted downward and the rear leg is tilted upward at 45^{o} or more. In both forms of the position the mass moved rearward by the leg must be matched by the mass shifted forward by means of leaning the torso and extending the arm. Only then will the centre of mass remain over the support area so that the dancer is stable.



first arabesque penchee
Fig 3

a) Explain, in terms of the principle of moments (torques), the conditions necessary for equilibrium to be maintained for a dancer. [2 marks]

$\sum \tau = 0$

(1) MEANING ANY TORQUE CREATED BY MOVING PART OF BODY OUTSIDE OF BASE OF SUPPORT MUST BE BALANCED BY AN

(1) EQUAL TORQUE IN OPP. DIRECTION BY EXTENDING ANOTHER PART OF BODY ON OPP. SIDE.

b) Explain why the first arabesque a terre position is easier for a beginning dancer to maintain than the more advanced arabesque penchee position. [2 marks]

(1) - CENTRE OF MASS OVER PIVOT FOOT (OR BTWN FEET IS OK)

(1) - ONLY SMALL TORQUES CREATED BY ARM AND LEG
$\therefore$ EASIER TO BALANCE.

c) Compare the position of centre of mass of the dancer in the first arabesque a terre position and the first arabesque penchee position. [2 marks]

(1) A TERRE POSITION HAS CENTRE OF MASS OVER HEEL (OR BTWN FEET OK) OF RIGHT FOOT AND IS HIGHER UP THAN PENCHEE

(1) WHICH HAS CENTRE OF MASS LOWER AND MORE FORWARD - OVER FRONT OF FOOT.

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END OF TEST