Year 12 Physics 2012

Motion and Forces Test 2

Name:

Mark: / 57

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Notes to Students:

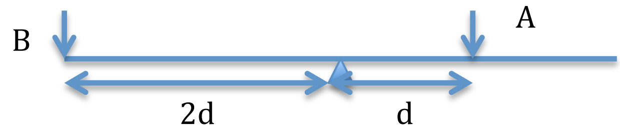
- You must include **all** working to be awarded full marks for a question.
- Marks will be deducted for incorrect or absent units.
- Answers should be given to 3 significant figures.

1. Two brothers are sitting on a seesaw. Alan, the older brother has twice the mass of Bob, the younger brother.

a) Sketch an arrangement that will allow the seesaw to balance, indicating approximate distances.

[2 marks]

Diagram showing A closer to pivot than B *(1 mark)*
Appropriate labels eg d, 2d *(1 mark)*



b) The seesaw is 6.00 m in length, and Alan's mass is 64.0 kg. If Bob is sitting at the very end of the seesaw, calculate the furthest distance from the pivot that Alan can sit to allow the seesaw to balance.

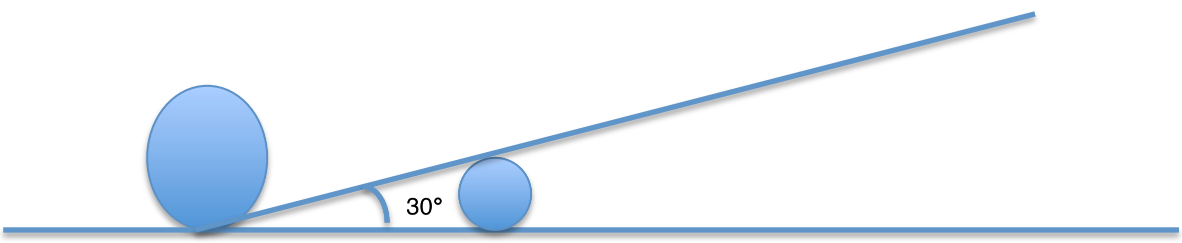
[3 marks]

$\Sigma\tau = 0$ $\tau = Fr$ *(1 mark for both)*

$\frac{64 \times 9.8}{2} \times 3 = 64 \times 9.8 \times r$ *(1 mark)*

$r = 1.50$ m *(1 mark answer with units)*

After playing on the seesaw, Alan shows off his strength by lifting a large rock of mass 120 kg. He uses a steel rod of length 9.00 m and mass 20.0 kg as a lever and a fallen tree as a pivot, placed a third of the way along the length of the rod, as shown in the diagram below. He applies a force directly down to lift the rock.



c) Calculate the force that he must apply to the lever to lift the rock.

[5 marks]

$\Sigma\tau = 0$ $\tau = Fr$ *(1 mark for both)*

$\Sigma\tau_{cw} = (1.5\cos30 \times 20g) + (6\cos30 \times F)$ *(1 mark for both)*
$\Sigma\tau_{acw} = 3\cos30 \times 120g$

$\Sigma\tau_{cw} = \Sigma\tau_{acw}$ *(1 mark for showing relationship)*
(1.5~~cos30~~ x 20g) + (6~~cos30~~ x F) = (3~~cos30~~ x 120g) *(1 mark working)*
6F = (3 x 120 x 9.8) – (1.5 x 20 x 9.8)
F = 539 N directly down *(1 mark answer with units)*

2. When astronauts are in a space station that is orbiting the Earth they are said to be weightless.

a) Explain why an astronaut is "said to be weightless"

[3 marks]

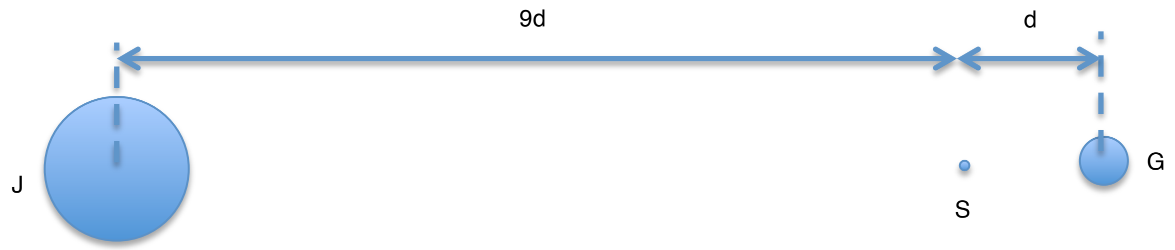
The astronaut and the space station are in free fall. *(1 mark)*
The astronaut and the space station are travelling at the same rate. *(1 mark)*
The astronaut experiences no reaction force from the space station. *(1 mark)*

b) Is "weightless" the correct term to use? Explain your answer.

[2 mark]

No. The astronaut is still affected by gravitational fields so has weight. *(1 mark)*
Apparent weightlessness is a better term. *(1 mark)*

3. The diagram below shows a space vehicle S at a point between the Jupiter and Ganymede at which the pull of the Jupiter on it is equal in size to the pull of the Ganymede on it. Use Newton's law of gravitation to express the mass of the Jupiter M_J as a ratio of the mass of Ganymede M_G.



[4 marks]

$F = \frac{GMm}{r^2}$ *(1 mark)*

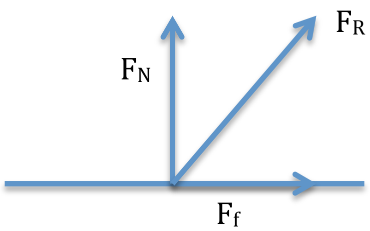
$F_J = \frac{GM_J m_S}{(9d)^2}$ $F_G = \frac{GM_G m_S}{d^2}$ *(1 mark)*

$F_J = F_G$ $\frac{\cancel{G}M_J \cancel{m_S}}{81\cancel{d^2}} = \frac{\cancel{G}M_G \cancel{m_S}}{\cancel{d^2}}$ $\frac{M_J}{81} = M_G$ *(1 mark)*

1:81 ratio *(1 mark)*

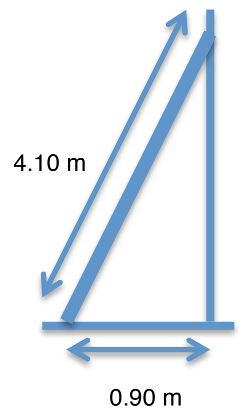
4. A cyclist taking part in a race is seen to lean into corners when he makes a turn. With use of a free body diagram, explain why it is important that he does this.

[4 marks]



Resultant reaction force is caused by friction and normal force.
If resultant reaction force does not go through centre of mass, it creates a turning effect.
This turning effect causes the bike to topple.
If the resultant reaction force goes through the centre of mass, there is no turning effect.

5. A ladder of mass 15.0 kg leans with its upper end against a frictionless wall as shown in the diagram below.



a) Calculate R, the normal contact push of the wall on the top of the ladder.

[4 marks]

Calculate angle at base $cos\theta = \frac{0.9}{4.1}$ $\theta = 77.3°$ *(1 mark)*

$\Sigma F = 0$ $\Sigma\tau = 0$ $\tau = Fr$ *(1 mark)*
Take base as pivot
$\Sigma\tau_{cw} = 15g \times 0.45$ *(1 mark for both)*
$\Sigma\tau_{acw} = R \times 4.1 \sin\theta$
$\Sigma\tau_{cw} = \Sigma\tau_{acw}$
$15g \times 0.45 = R \times 4.1 \sin\theta$
$R = 16.5$ N *(1 mark)*

b) What is the magnitude of the frictional force keeping the base of the ladder in place?

[1 mark]

$F_f = R = 16.5$ N

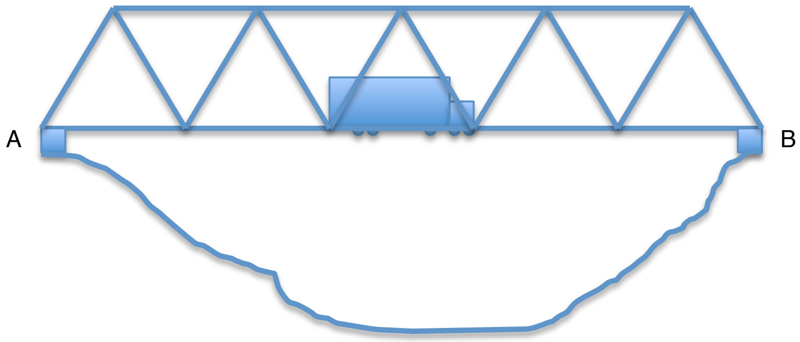
c) The maximum frictional force the floor can provide is 135 N. What height from the ground can a person of mass 65.0 kg reach before the base of the ladder will slip?

[5 marks]

$\Sigma F = 0$ $\Sigma\tau = 0$ $\tau = Fr$ *(1 mark)*
Take base as pivot
a = perpendicular distance to person from pivot
$\Sigma\tau_{cw} = (15g \times 0.45) + (65g\ a)$ *(1 mark for both)*
$\Sigma\tau_{acw} = 4R = 4 \times 135 = 540$ Nm
$\Sigma\tau_{cw} = \Sigma\tau_{acw}$
$(15g \times 0.45) + (65g\ a) = 540$
$a = 0.744$ m *(1 mark)*

$\tan\theta = h / 0.744$ *(1 mark)*
$h = 3.30$ m from ground *(1 mark)*

6. The diagram shows a road train of mass 4.50×10^4 kg crossing a bridge of mass 6.00×10^4 kg. The distance of A to B is 32.0 m.



a) When the road train is at the centre of the bridge, what is the upward reaction force of each of the bridge supports A and B on the bridge structure?

[3 marks]

$\Sigma F = 0$ *(1 mark)*

$(4.50 \times 10^4 \times 9.8) + (6.00 \times 10^4 \times 9.8) - R_A - R_B = 0$

$R_A + R_B = 1.03 \times 10^6$ *(1 mark)*

Each support = $1.03 \times 10^6 / 2 = 5.15 \times 10^5$ N *(1 mark)*

b) Where on the bridge will the road train be when the additional upward push of the bridge support at A is 1.2×10^5 N?

[4 marks]

$\Sigma F = 0 \quad \Sigma \tau = 0 \quad \tau = Fr$ *(1 mark)*

$R_A + R_B = 1.03 \times 10^6$ *(1 mark)*

$(1.2 \times 10^5 + R_B) + R_B = 1.03 \times 10^6$

$R_B = 4.55 \times 10^5$ N

Take A as pivot

$\Sigma \tau_{cw} = (4.5 \times 10^4\ g \times a) + (6 \times 10^4\ g \times 16)$ *(1 mark)*

$\Sigma \tau_{acw} = R_B \times 32 = 4.55 \times 10^5 \times 32 = 1.46 \times 10^7$

$\Sigma \tau_{cw} = \Sigma \tau_{acw}$

$(4.5 \times 10^4 g \times a) + (6 \times 10^4 g \times 16) = 1.46 \times 10^7$

$\underline{a = 11.8 \text{ m}}$ *(1 mark)*

OR

Use of simultaneous equations (or other appropriate method)

$(R_B + 1.2 \times 10^5) \times 32 = (6 \times 10^4 \times 16) + (4.5 \times 10^4 \times a)$

and $(4.5 \times 10^4 \times (32-a)) + (6 \times 10^4 \times 16) = R_B \times 32$

7. The Hubble space telescope was launched in 1990 into a circular orbit near to the Earth. It travels around the Earth once every 97 minutes.

a) Calculate the radius of orbit of the Hubble telescope.

[5 marks]

$$v = \frac{2\pi r}{T} \qquad F = G\frac{Mm}{r^2} \qquad F = \frac{mv^2}{r}$$

(1 mark)

$$G\frac{Mm}{r^2} = \frac{mv^2}{r} \qquad v = \sqrt{\frac{GM}{r}}$$

(1 mark)

$$\frac{2\pi r}{T} = \sqrt{\frac{GM}{r}} \qquad T^2 = \frac{4\pi^2 r^3}{GM}$$

(1 mark)

$$(97 \times 60)^2 = \frac{4\pi^2 (r)^3}{6.67\times10^{-11} \times 5.97\times10^{24}}$$ *(1 mark)*

$r = 6.99 \times 10^{6}$ m *(1 mark)*

b) Calculate the linear velocity of the Hubble telescope.

[3 marks]

$v = \frac{2\pi r}{T}$ *(1 mark)*

$v = (2 \times \pi \times 6.99 \times 10^{6}) / 97 \times 60$ *(1 mark)*

$v = 7.55 \times 10^{3}$ ms^{-1} *(1 mark)*

c) The mass of the Hubble telescope is 1.10×10^4 kg. Calculate the magnitude of the centripetal force that acts on it.

[3 marks]

$F = \frac{mv^2}{r}$ *(1 mark)*

$F = 1.1 \times 10^4 \times (7.55 \times 10^{3})^2 / 6.99 \times 10^6$ *(1 mark)*

$F = 8.97 \times 10^{4}$ N *(1 mark)*

8. In 1798 Cavendish investigated Newton's law of gravitation by measuring the gravitational force between two unequal lead spheres. In a similar experiment, the radius of the larger sphere was 100 mm and that of the smaller sphere was 25.0 mm.
The mass of the larger sphere was 47.0 kg and the mass of the smaller sphere was 0.74 kg.

a) Calculate the gravitational force between the spheres when their surfaces were 0.50 m apart.

[3 marks]

$$F = G\frac{Mm}{r^2}$$

(1 mark)

F = (6.67 x 10^{-11} x 47 x 0.74) / $(0.025 + 0.1 + 0.5)^2$ *(1 mark)*
F = 5.94 x 10^{-9} N *(1 mark)*

b) The smaller ball was replaced with one of an unknown mass, but with the same radius as the smaller ball. What mass would the ball have had, to be able create the same force as in part (a) when its surface was held 3.00 m away from the surface of the larger mass.

[3 marks]

$$F = G\frac{Mm}{r^2}$$ *(1 mark)*

$$m = \frac{Fr^2}{GM}$$

$$m = \frac{5.94\times10^{-9} \times (3 + 0.025 + 0.1)^2}{6.67\times10^{-11}\times47}$$

(1 mark)

m = 18.5 kg *(1 mark)*

END OF TEST