Year 12 Physics

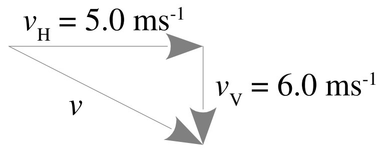
Test: Topics 1-3

Projectile Motion, Circular Motion, Gravitation and Satellites

1.

(a) (arrow going directly downwards)

(b)



(c)
$$\theta = \tan^{-1}\left(\frac{v_V}{v_H}\right) = \tan^{-1}\left(\frac{6.0}{5.0}\right) = 50°\ \text{below horizontal}$$
$$v = \sqrt{v_H{}^2 + v_V{}^2} = \sqrt{5.0^2 + 6.0^2} = 7.8\ \text{ms}^{-1}$$

2.

(a)
$$v_{0_H} = v_0 \cos\theta = 21\cos 34° = 17\ \text{ms}^{-1}$$
$$v_{0_V} = v_0 \sin\theta = 21\sin 34° = 12\ \text{ms}^{-1}$$

(b) $s = v_0 t + \tfrac{1}{2}at^2$

Using the vertical component, $s_V = 0$ (launched from ground)

$$\therefore 0 = v_0 t + \tfrac{1}{2}at^2$$
$$\therefore 0 = t\left(v_0 + \tfrac{1}{2}at\right)$$
$$\therefore t = 0 \text{ or } v_0 + \tfrac{1}{2}at = 0$$

We want time of flight so ignore $t = 0$

$$\therefore t = \frac{-v_0}{\tfrac{1}{2}a} = \frac{-12}{\tfrac{1}{2}\times -9.8} = 2.4\ \text{s}$$

(c) Using the horizontal component, $a_H = 0$

$$\therefore s = v_0 t = 17 \times 2.4 = 42\ \text{m}$$

(d) $v^2 = v_0{}^2 + 2as$

Using the horizontal component, $v = 0$ at max height

$$0 = v_0{}^2 + 2as$$
$$\therefore s = \frac{-v_0{}^2}{2a} = \frac{-12^2}{2\times -9.8} = 7.0\ \text{m}$$

3.

(a) Increasing the launch height of a shot-put will increase its maximum range. Increasing the launch height will increase the time of flight, since the shot-put has further to fall. Since the horizontal component of velocity is constant, this will increase the horizontal displacement ($s_H = v_H t$).

(b) (any one of)

Shotput is smoother than tennis ball; smoother texture decreases force of air resistance

Shotput is larger than tennis ball: greater projected area increases force of air resistance

Shotput is more dense/heavier than tennis ball: density/mass has no effect on the force of air resistance

4.

(a) Tension in the chain

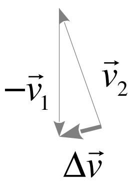
(b) $v = \dfrac{2\pi r}{T} = \dfrac{2\pi \times 0.12}{1.2} = 0.63 \text{ ms}^{-1}$

(c) $F = ma = m\dfrac{v^2}{r} = 0.016 \times \dfrac{0.63^2}{0.12} = 0.053 \text{ N}$

5. The velocity of a particle moving with uniform circular motion about O is shown at two positions in the diagram below:

(a)

(i) $\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$

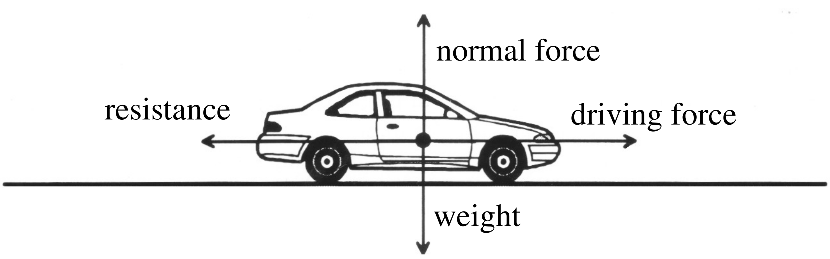


(ii) It is towards the centre of the circle of motion

-or- It is perpendicular to the average of $\vec{v}_1$ and $\vec{v}_2$.

(b) Towards the centre. The formula $\vec{a}_{ave} = \dfrac{\Delta\vec{v}}{\Delta t}$ shows that the average acceleration is in the same direction as change in velocity. Over an infinitely small time difference therefore the instantaneous acceleration would be towards the centre.

6.



7.

(a) (*arrow pointing up to the left, perpendicular to the road)*

(b) The banking angle causes a non-vertical normal force on the car (as shown above) which has a horizontal component directed towards the centre of the curve. The horizontal component acts therefore supplies some centipetal force, reducing the amount that would usually be required by friction.

(c) $$\tan\theta = \frac{v^2}{rg}$$

$$\therefore v = \sqrt{rg\tan\theta} = \sqrt{150\times 9.8\times\tan(11°)} = 17\ \text{ms}^{-1}$$

8.

(a) (arrows equal in length. Vector on star points to right, on planet points to left)

(b) Newton's law of universal gravitation states that the two masses will experience an attractive force of equal magnitude each. Newton's third law of motion states that every force has an equal and opposite force. As shown on the diagram above these forces are equal in magnitude and opposite in direction.

(c) $F_1 = 3.9\times 10^{22}$ N

Let $M_1 = M$

$\therefore M_2 = 2M$

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

G, m, r constant

$\therefore F \propto M$

$$\therefore \frac{F_2}{F_1} = \frac{M_2}{M_1}$$

$$\therefore F_2 = F_1\times\frac{M_2}{M_1} = 3.9\times 10^{22}\times\frac{2M}{M}$$

$$= 3.9\times 10^{22}\times 2 = 7.8\times 10^{22}\ \text{N}$$

9.

(a) Let the satellite's mass be m, and the planet's mass M.

$$F = G\frac{mM}{r^2} \quad \text{and} \quad F = ma = m\frac{v^2}{r}$$

A satellite's centripetal force is provided by gravitation.

$$\therefore G\frac{mM}{r^2} = m\frac{v^2}{r}$$

$$\therefore G\frac{M}{r} = v^2$$

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

(b) Let Earth's mass be M.

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

$$\therefore M = \frac{v^2 r}{G}$$

Inserting the data for Satellite B:

$$M = \frac{3072^2 \times 4.224 \times 10^7}{6.67 \times 10^{-11}} = 5.98 \times 10^{24} \text{ kg}$$

(c) $$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{2.112 \times 10^7}} = 4.35 \times 10^3 \text{ ms}^{-1}$$

(d) $$a = \frac{v^2}{r} = \frac{(3072)^2}{4.224 \times 10^7} = 0.2234 \text{ ms}^{-2}$$

10.

(a) $$\sqrt{\frac{GM}{r}} = \frac{2\pi r}{T}$$

$$\therefore \frac{GM}{r} = \frac{2^2 \pi^2 r^2}{T^2}$$

$$\therefore r^3 = \frac{GMT^2}{4\pi^2}$$

$$\therefore r = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$$

(b) Geostationary orbits must be at a specific altitude/radius, polar orbits may have any radius.

Geostationary orbits must have one particular speed/period, polar orbits can have any

Geostationary orbits are around the equator, polar orbits are from pole to pole.

(c) The Earth spins in a west-to-east direction, meaning the satellite will be launched with some initial speed in the direction of orbit. This is particularly important for a low-altitude orbit since it requires a high orbital speed.

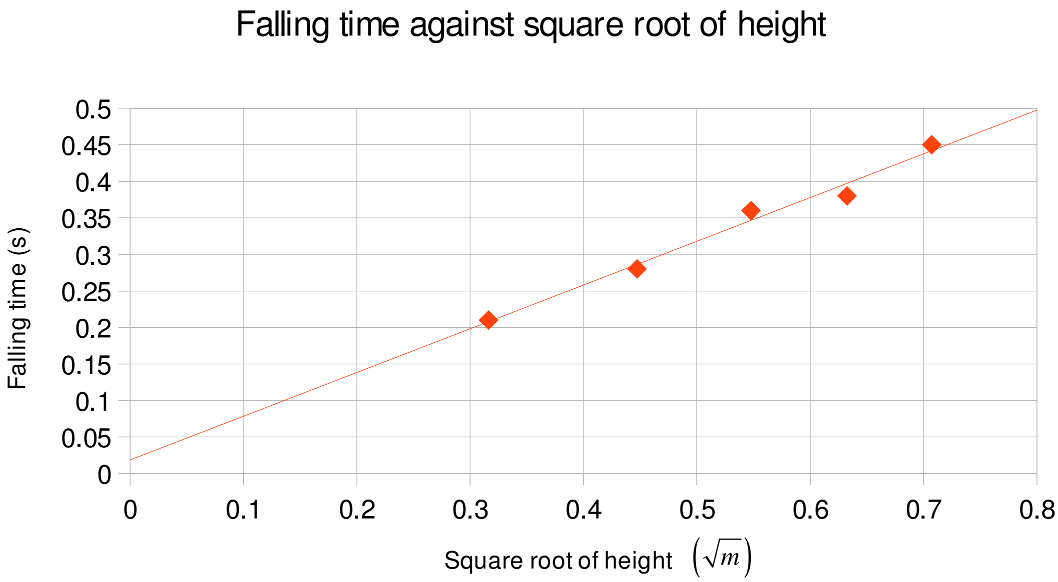
(d) The force acting on a satellite is gravitation, which acts between the centres of mass of objects, meaning the satellite is pulled towards the centre of the Earth. A centripetal force is towards the centre of the circle of motion, and for a satellite the centripetal force is provided by the force of gravitation, therefore their directions must coincide.

11.

(a)

Square root of height ($\sqrt{m}$)
0.71
0.63
0.55
0.45
0.32

(b)



(c) The values for (c), (d) and (e) will depend on the results of (a) and (b)

$$gradient = \frac{rise}{run} = \frac{0.48}{0.8} = 0.6 \text{ s}/\sqrt{m}$$

(d) $t = 0.6\sqrt{h}$

(e) $s_V = v_{0_V} t + \frac{1}{2} a_V t^2$

For an object dropped, $v_{0_V} = 0$

$\therefore s_V = \frac{1}{2} a_V t^2$

$\therefore t = \sqrt{\frac{2h}{a_V}}$

$\therefore t = \sqrt{\frac{2}{a_V}} \sqrt{h}$

$\therefore \sqrt{\frac{2}{a_V}} = 0.6$

$\therefore a_V = \frac{2}{0.6^2} = 6 \text{ ms}^{-2}$

(f) The effects of random error have not been minimised in this experiment; multiple measurements should be taken and averaged.

It's difficult to be sure of the line of best fit. More heights could have been tested.

The projectile is probably being affected by air resistance. A smaller, heavier projectile could minimise this source of error.

The stopwatch is stopped by human reaction time which could be causing a time delay. This could be corrected by using a force plate or light gate to detect the time of impact.

(or any other valid, explained improvement)