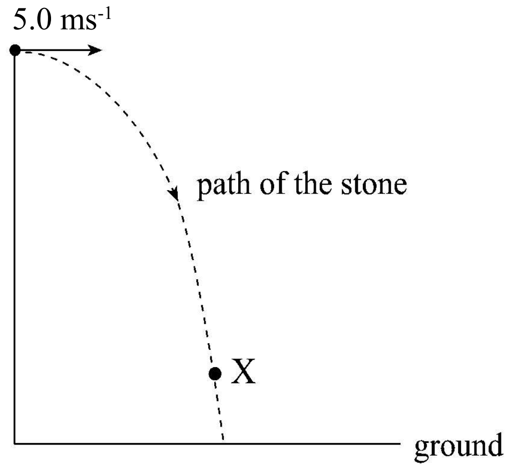
Year 12 Physics NAME______________________

Test: Motion

Total marks: 76

Projectile Motion, Forces and Momentum, Circular Motion and Gravitation

1. A stone is thrown from a position near the surface of the Earth with an initial horizontal velocity of 5.0 ms^{-1}, as shown in the diagram below. The vertical component of the velocity of the stone at point X is 6.0 ms^{-1}. *Ignore the effect of air resistance.*



(a) Draw a vector on the diagram above showing the direction of the acceleration of the stone at point X. (1)

(b) Draw and label a vector diagram to show the addition of the horizontal and vertical components of velocity of the stone at the instant it reaches point X.
(The diagram does not have to be drawn to scale.)

(2)

(c) Calculate the magnitude and direction of the velocity of the stone at point X.

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____ (3)

The presence of air resistance can have a significant effect on a projectile's motion.

(d) Explain the effect air resistance would have on the stone's time of flight.

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____ (2)

(e) In the space below, draw an arrow to show the direction of the stone's terminal velocity.

(1)

(f) Consider this throw is repeated with a stone which has the same size and shape but a greater mass. The launch height and velocity are also kept the same as before.

State the effect of this increased mass on the drag force experienced by the stone:

(i) at the moment it is launched

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____ (1)

(ii) at terminal velocity

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____ (1)

2. A projectile is launched from ground at an angle of 34° with a speed of 21 ms^{-1}.

(a) Calculate the initial vertical and horizontal components of the projectile's velocity.

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____ (2)

(b) Calculate the time of flight of the projectile.

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(c) Hence calculate the range of the projectile.

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(d) Calculate the maximum height reached by the projectile.

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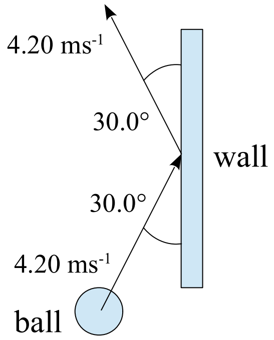
3. A 31.0 g ball travelling at 4.20 ms^{-1} bounces off a wall without a change in speed, as shown below. The diagram is not to scale.



(a) Use a vector diagram in the space above to find the magnitude and direction of change in momentum of the ball.

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___ (5)

(b) Calculate the average force on the ball, if the collision lasts 2.00×10^{-2} s.

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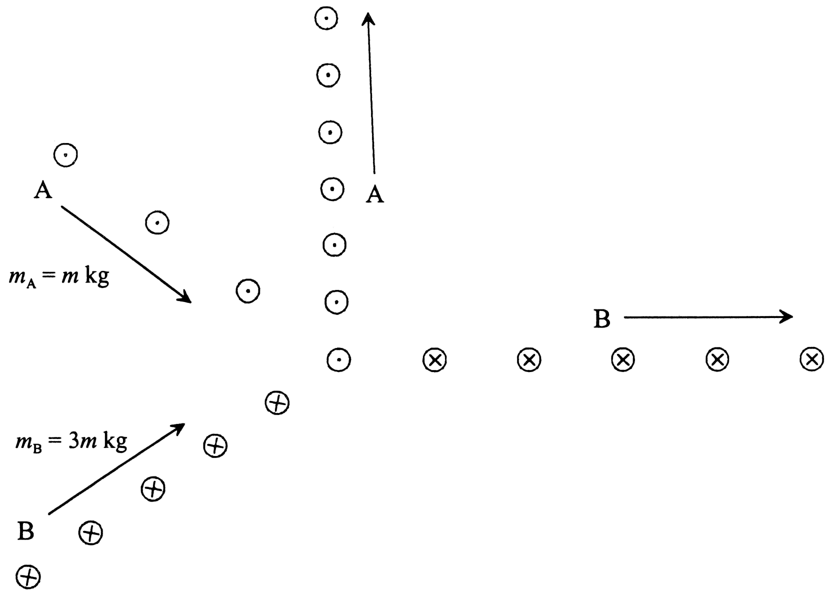
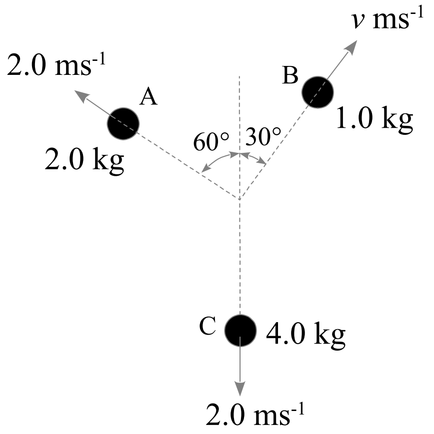
4. Students perform a multiple image investigation to study the collision of two masses, by sliding the masses along an air table. The results of the experiment are shown below.



Show that momentum is conserved in the multiple image photograph of the collision of masses A and B above. (4)

5. A stationary object of mass 7.0 kg explodes to form three fragments, A of mass m_A = 2.0 kg, B of mass m_B = 1.0 kg, and C of mass m_C = 4.0 kg.

The fragments move in the directions shown in the diagram below. A is travelling at speed v_A = 2.0 ms^{-1}, B at speed v ms^{-1}, and C at speed v_C = 2.0 ms^{-1}.
Assume no external forces are acting. The diagram is not to scale.



(a) State the total final momentum of the three fragments after the explosion.

____ (1)

(b) In the space above, draw a clearly labelled diagram showing the vector addition of the final momenta ($\vec{p}_A, \vec{p}_B$, and $\vec{p}_C$) of the fragments. (2)

(c) Calculate the magnitude of the velocity v of fragment B.

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6. Spacecraft can be propelled by various means, including ion thrusters.

Explain, in terms of the law of conservation of momentum, the change in motion of a spacecraft as a result of the emission of ions from an ion thruster.

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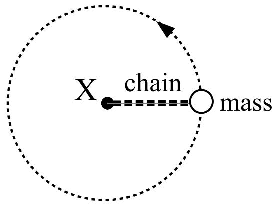
7. A mass of 16g is in uniform circular motion on a chain around point X as shown below. The radius of the circle of motion is 12 cm, and the period of motion is 1.2 s.



(a) Calculate the speed of the mass.

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____ (2)

(b) Calculate the magnitude of the centripetal force.

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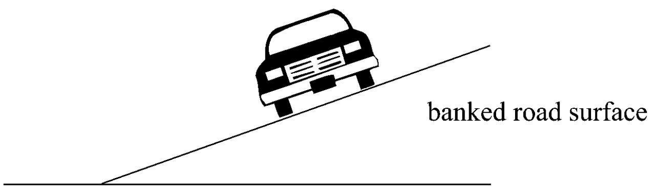
8. A car travelling with uniform circular motion around a banked curve on a road is shown in the diagram below. The car is able to travel around the curve without relying on friction.



(a) On the diagram above, draw and label a vector to show the normal force acting on the car. (1)

(b) Using the vector you have drawn in part (a), explain how the banking angle enables the car to travel around the curve in the road without relying on friction.

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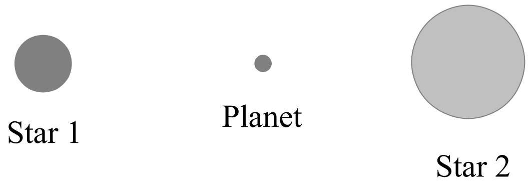
9. A 'binary star system' arises when a star orbits another star.

(a) Consider a planet positioned exactly halfway between the centre of masses of two stars, as shown below:



[This diagram is not drawn to scale.]

Star 2 has double the mass of Star 1, and the force on Planet due to Star 1 is 3.9×10^{22} N. Using proportionality, determine the force on Planet due to Star 2.

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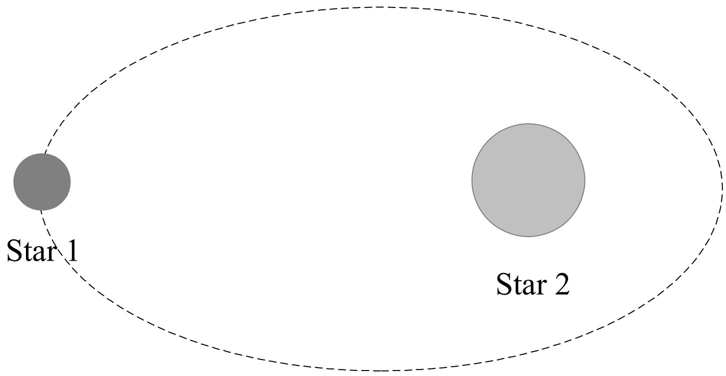
(b) The orbit of Star 1 around Star 2 is shown below.

Ignore gravitational effects of Planet.



[This diagram is not drawn to scale.]

Describe how the orbit of Star 1 around Star 2 is consistent with Kepler's First Law.

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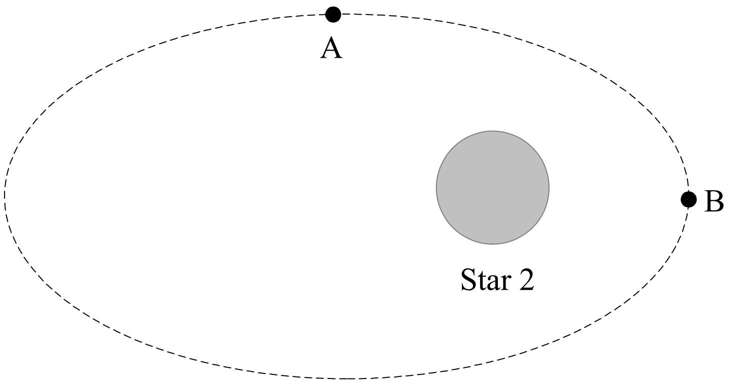
(c) Consider points A and B in the orbit of Star 1 around Star 2 is shown below.



[This diagram is not drawn to scale.]

Explain whether Star 1's speed will be greater at point A or at point B.

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10. Two satellites, A and B, orbit Earth. Satellite A orbits at a radius of 2.112×10^{7} m. Satellite B orbits at a radius of 4.224×10^{7} m and at a speed of 3072 ms^{-1}.

(a) Show that the speed v of a satellite moving in an orbit of radius r around a planet of mass M is given by $v = \sqrt{\frac{GM}{r}}$.

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(b) Hence show that the mass of the Earth is approximately 5.98×10^{24} kg.

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(c) Calculate the orbital speed of satellite A.

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(d) Calculate the magnitude of acceleration due to gravity at the altitude of satellite B.

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11.

(a) Using the relationships - and $v = \frac{2\pi r}{T}$, show that the radius of a satellite orbiting the Earth can be given by the equation $r = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$, where M is the mass of the Earth, T is the period of the satellite, and r is the radius of the orbit.

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(b) State two differences between geostationary orbits and polar orbits.

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(c) Explain why the centre of the circular orbit of any Earth satellite must coincide with the centre of the Earth.

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12.

> Transiting Exoplanet Survey Satellite (TESS) was launched by the private company SpaceX. Scientists use the cameras on the satellite to search for and understand exoplanets — planets outside our solar system.
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> The wide-field cameras and detectors aboard TESS are capable of searching more of the sky than any previous technology is. TESS will monitor over 200 000 nearby bright stars and identify planets that are much smaller than those that can be detected by ground-based technologies.
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> Partly due to the presence of liquid water, the Earth is the only planet known to be able to support life. Another satellite launched in 2021 will examine the atmosphere of exoplanets identified by TESS for evidence of liquid water.
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> TESS has found types of planets that were not predicted to exist: massive planets orbiting very close to their stars, and planets approximately three times the size of the Earth. Other unexpected discoveries include planets in binary star systems and planets orbiting dead stars.
>
> The TESS project involves partnerships between the United States National Aeronautics and Space Administration (NASA), the Massachusetts Institute of Technology, the Space Telescope Science Institute, and the aerospace manufacturing company Orbital ATK. Many universities, research institutes, and individual astronomers will be able to use data from TESS for their own research.

Using the information above, describe three examples of how the Transiting Exoplanet Survey Satellite (TESS) project demonstrates science as a human endeavour.

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