

Student name: _____ Student ID: _____



AUT UNIVERSITY
Final Assignment
PHYS400
Foundation Physics A
SEMESTER ONE 2020

Attempt **ALL** questions.

Total marks: 111

All relevant working must be shown. Answers without working do not score highly even if they are correct.

If you need more space for any answer, use the pages at the back of this booklet and clearly number the question. A formula sheet can also be found there.

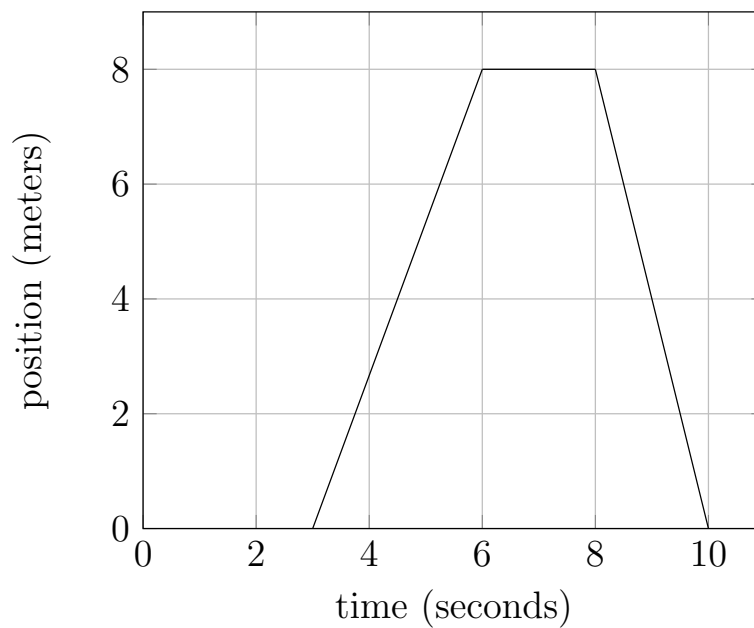
Question:	1	2	3	4	5	6	7	8	9	10	Total
Points:	17	10	10	8	6	10	10	14	12	14	111
Score:											

1. Short questions

- (a) If an object is projected vertically upwards, what is its instantaneous velocity when it reaches the peak of its trajectory? [1]
- (b) A coin is freefalling from a tower. What does its acceleration versus time graph look like? You can describe or sketch the graph. [1]
- (c) The SI unit of force is the newton. Using Newton's second law, express this unit in terms of mass, length and time. [1]
- (d) A car travels 50 km north and then 30 km in a direction 60° east of north.
- (i) Draw a graph to represent the displacement vectors. [2]
- (ii) Using the graph, find the magnitude and direction of the car's resultant displacement. [2]

Question 1 continues...

(e) Below is an object's position versus time graph.



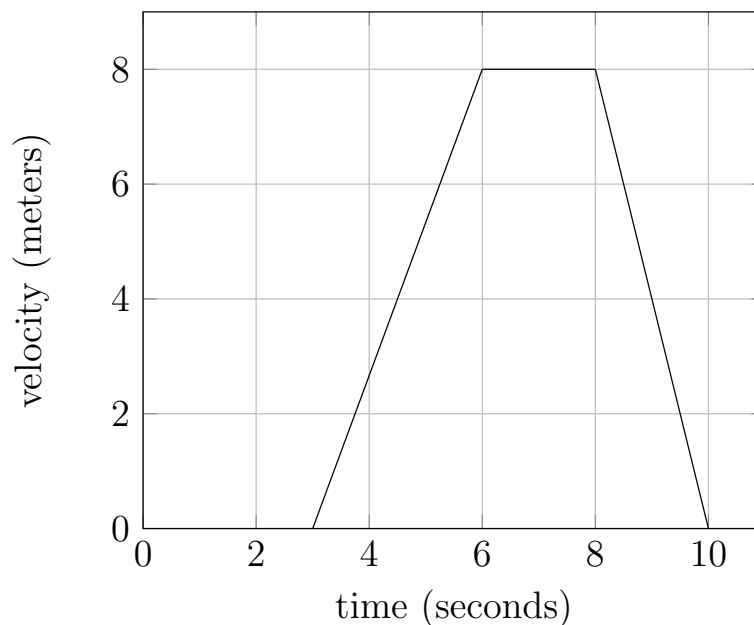
(i) When is the object's velocity positive? [1]

(ii) When is the object's velocity negative? [1]

(iii) Does the object return to its starting point? Explain. [1]

Question 1 continues...

(f) Below is an object's velocity versus time graph.



(i) When is the object not moving? [1]

(ii) When is the object's velocity constant? [1]

(iii) When is the object's velocity increasing? [1]

(iv) When is the object's velocity decreasing? [1]

(v) Does the object return to its starting point? Explain [1]

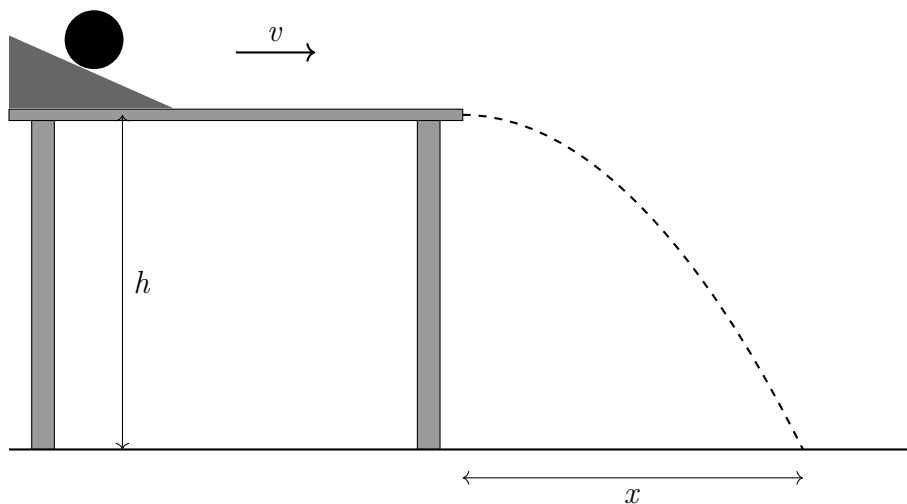
(g) Complete the following table with Yes or No answers. [2]

Collision	Kinetic energy conserved?	Momentum conserved?
Elastic		
Inelastic		

Total for Question 1: 17

2. Kinematics

- (a) A ball rolls down a ramp and leaves the edge of a table with a horizontal velocity v . From the right edge of the table, the ball travels a horizontal distance x . The table is a height h above the ground. Neglect friction.



- (i) How much time elapses while the ball is in free-fall?

[1]

- (a) $\frac{2h}{g}$
- (b) $\sqrt{\frac{2h}{g}}$
- (c) $2\sqrt{\frac{h}{g}}$
- (d) $2\sqrt{hg}$

- (ii) What is x ?

[1]

- (a) $\frac{2v^2}{g}$
- (b) $v\sqrt{\frac{2h}{g}}$
- (c) $\frac{2vh}{g}$
- (d) $2v^2gh$

Question 2 continues...

(b) **Free-falling marble:** After letting go of a marble it begins to fall toward the Earth.

(i) By how much does the vertical speed of the marble in free-fall change after one second? [1]

(ii) After two seconds, what is its speed? [1]

(iii) After a total of two seconds, how far has it fallen? [1]

(iv) Plot the marble's displacement versus time and describe the shape of your curve. [2]

Question 2 continues...

(c) **Two falling marbles:** You let two marbles fall, where one of them also has a constant horizontal speed of 1 m s^{-1} .

(i) After one-second, what is the vertical displacement of each marble? [1]

(ii) For the marble with the horizontal speed of 1 m s^{-1} , what is its horizontal displacement after one-second? [1]

(iii) How much time will it take each marble to fall a total vertical distance of 20 m? [1]

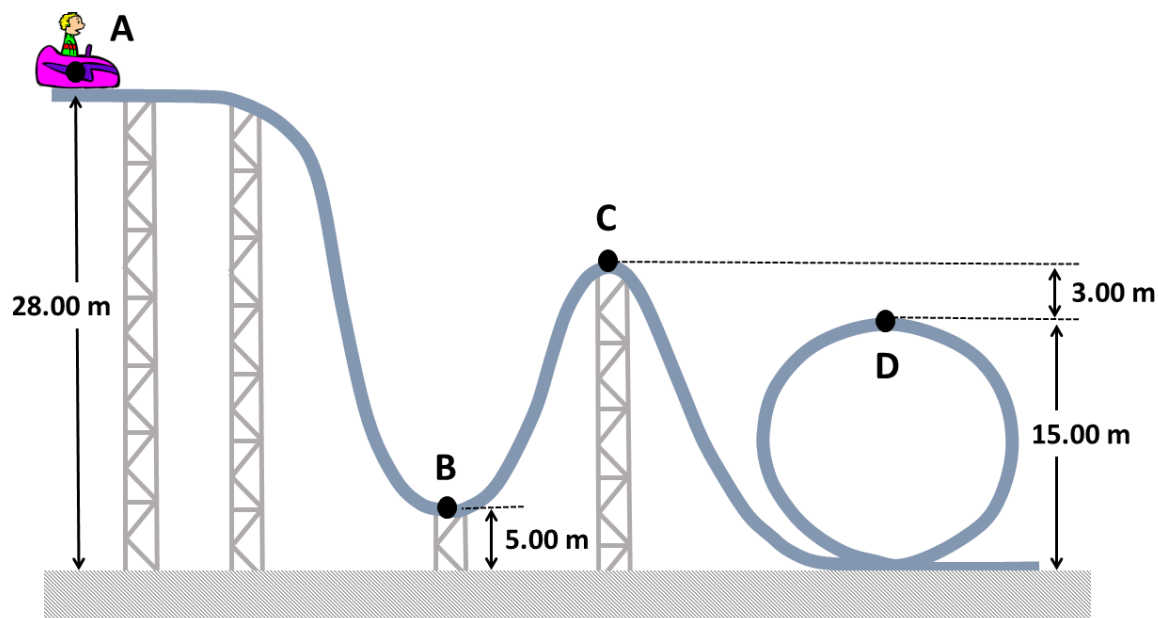
Total for Question 2: 10

3. **Conservation of Energy:** The following diagram shows a roller coaster track.

- (a) An 550 kg roller-coaster is released from rest at Point A. Using the principle of conservation of energy, calculate the kinetic energy and potential energy of the roller-coaster at positions A, B, C and D.

[8]

Neglect friction and air resistance. Show your working.



Position	Kinetic Energy (J)	Potential Energy (J)
A		
B		
C		
D		

- (b) What is the speed of the roller coaster at position B?

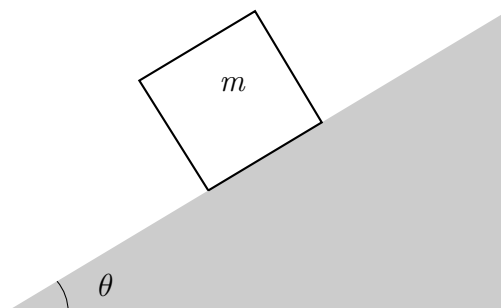
[2]

Total for Question 3: 10

4. **Friction:** The block in the diagram is sliding down the ramp.

(a) Including friction, draw the force vectors acting on this moving block.

[2]



(b) Given that the forces acting perpendicular to the incline surface are balanced, write an equation for the normal force that the surface exerts on the block, n .

[2]

(c) Find the friction force if the coefficient of kinetic friction is $\mu_k = 0.4$, the mass is $m = 5 \text{ kg}$ and the angle $\theta = 30^\circ$.

[2]

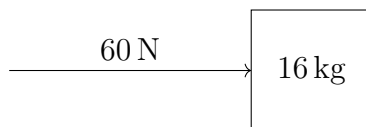
(d) Given that $\Sigma F_x = ma_x$, find the acceleration of the block.

[2]

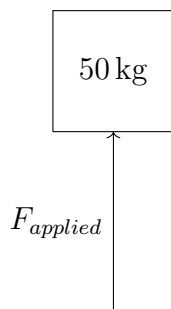
Total for Question 4: 8

5. **Work done:** Calculate the work done by the applied force in each of the following situations.

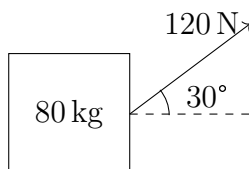
- (a) A 60 N force moves a 16 kg block to the right over a horizontal distance of 70 cm at constant speed. [2]



- (b) An applied force lifts a 50 kg block to a height of 5 m at constant speed. [2]



- (c) A 120 N force is applied at an angle of 30° to pull a 80 kg block horizontally over a distance of 8 m at constant speed. [2]



Total for Question 5: 6

6. **Hooke's Law & Spring Energy:** A spring can be used to weigh objects.

(Source: <https://www.scientificamerican.com/article/make-your-own-spring-scale/>)

A student hangs a bucket on the end of a spring. The spring is 510 mm long when hanging vertically without the bucket. When a plastic bucket of mass 400 g is hung on the end, the spring's length becomes 620 mm.

(a) Calculate the spring constant. Write the unit with your answer. [2]

(b) The student then adds ten \$1 coins to the bucket, one at a time. Each time a coin is added, the student finds that the resulting stretch of the spring is predicted by Hooke's law with the same spring constant. What does it mean that the behaviour of this spring is predicted by Hooke's law? [1]

(c) The student now empties the bucket, places a toy in it and the spring stretches a total length of 730 mm. Calculate the mass of this toy. [2]

(d) Calculate the energy stored in the spring when an object of mass 300 g is placed in the bucket on spring. [3]

(e) The 300 g object in the bucket is now hung on a stiffer spring which has double the spring constant. Discuss how this affects the extension and the elastic energy stored in the spring. [2]

Total for Question 6: 10

7. Conservation of Momentum:

- (a) You're standing on the center of a frozen, frictionless pond holding a massive physics textbook. You decide to throw it away to reach the edge of the pond.
- (i) If your mass is 100 kg, the book's mass is 10 kg, and you throw it horizontally with a speed of 10 m s^{-1} , what will be your resulting speed? [3]
- (ii) If the pond's diameter is 20 m, how long will it take you to reach the edge? [2]
- (b) Once again, you're standing on the center of a frozen, frictionless pond. This time, your friend throws you a massive physics textbook from the side of the pond, which you catch.
- (i) If your mass is 100 kg, the book's mass is 10 kg, and it is thrown with a horizontal speed of 10 m s^{-1} , what will be your resulting speed? [3]
- (ii) If the pond's diameter is 20 m, how long will it take you to reach the edge? [2]

Total for Question 7: 10

8. Rotational motion:

- (a) A wheel has a radius of 2 m. How far does a point on the circumference travel if the wheel is rotated through

(i) 30 rad [2]

(ii) 30° [2]

(iii) 30 revolutions [2]

- (b) If this wheel is now rotating at angular velocity, $\omega_0 = \pi \text{ rad s}^{-1}$,

(i) how long does it take to complete one revolution? [2]

(ii) what is the tangential velocity on the circumference of the wheel? [2]

(iii) The wheel starts to accelerate from $\pi \text{ rad s}^{-1}$ at a rate of $\frac{\omega_0}{5} \text{ rad s}^{-2}$. What will be the angular velocity after 10 seconds? [2]

(iv) after 10 seconds, how many revolutions does this wheel make given $\omega_0 = \pi \text{ rad s}^{-1}$, $\alpha = \frac{\omega_0}{5} \text{ rad s}^{-2}$ and $\theta_0 = 0 \text{ rad}$? [2]

9. **Gravitation:** Newton's Gravitational Law predicts the force of attraction between two massive objects that are some distance apart:

$$F_{\text{gravity}} = G \frac{m_1 m_2}{r^2}$$

- (a) Given F is in units of Newtons, m is units of kilograms and r is in units of meters, what are the units of the universal gravitational constant, G , in meters, kilograms and seconds? Show your working. [2]
- (b) If one of the objects doubles in mass, how much does the predicted force of attraction change between the two objects? [1]
- (c) If both objects double in mass, how much does the predicted force of attraction change between the two objects? [1]
- (d) If the distance between the two objects doubles, how much does the predicted force of attraction change between the two objects? [1]
- (e) If the distance between the two objects halves, how much does the predicted force of attraction change between the two objects? [1]

Question 9 continues...

- (f) Given Newton's laws predict that $F_{\text{gravity}} = m_1 a_1$, and assuming that $m_2 = m_{\text{Earth}} \approx 10^{25} \text{kg}$, $r = r_{\text{Earth}} \approx 10^7 \text{m}$ and $G \approx 10^{-10}$ hidden-units, [2]
- (i) what is the predicted gravitational acceleration a_1 of m_1 toward the Earth?

- (ii) what is the predicted gravitational acceleration a_2 of the Earth toward m_1 , [2]
 if m_1 equals your body mass?
 Hint: use Newton's law $F_{1,2} = F_{2,1}$, where $F_{1,2} = m_2 a_2$ and $F_{2,1} = m_1 a_1$

- (iii) Given your result for a_2 , if you jump off your bed and are in free-fall for $\sqrt{2}$ [2]
 seconds, how far does the Earth move toward you? Hint:

$$y = \frac{at^2}{2}$$

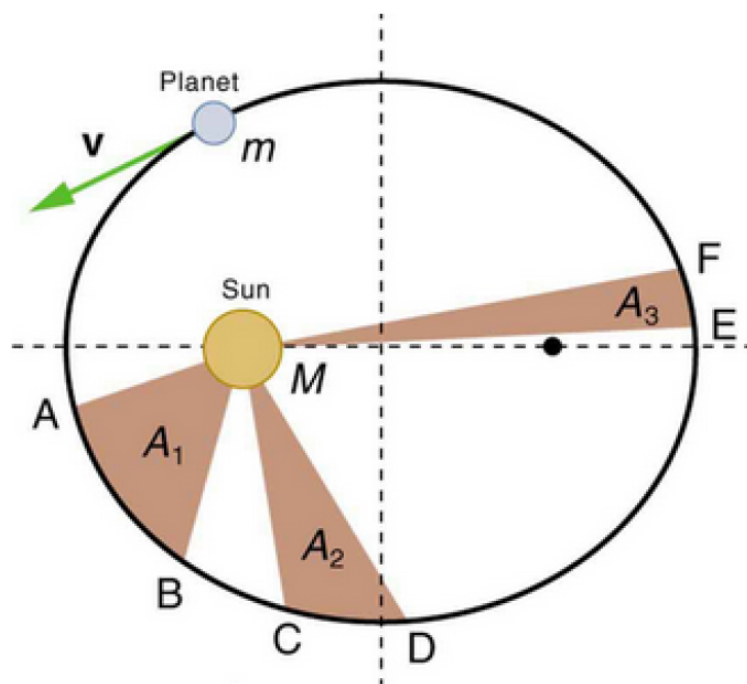
Total for Question 9: 12

10. **Kepler's Laws:**

(a) Given Kepler's laws, what is the predicted shape of the orbit of a planet around a star? [1]

(b) Below shows a planet's orbit around a star. [2]

Given Kepler's laws, if areas A_1 , A_2 and A_3 are equal, what is the relationship between the times taken to traverse from A to B, C to D and E to F?



(c) Here is Kepler's third law

$$\left(\frac{r_1}{r_2}\right)^3 = \left(\frac{T_1}{T_2}\right)^2$$

where T is the orbital period and r is orbital radius.

(i) The orbital period of Earth is 365 days and its orbital radius is 149.6 million km. Given the orbital radius of Mercury is 57.9 million km, what is its predicted orbital period? [2]

Question 10 continues...

- (ii) The Moon orbits the Earth every 27.321 days at an average distance of 3.84×10^5 km from the center of Earth.
- (a) Given the ISS (International Space Station) orbits the Earth every 92.68 minutes, what is its predicted distance from the center of Earth? [2]
- (b) Given $v = r_2\omega$, where ω is angular speed, what is the predicted speed of the ISS in units of km s^{-1} ? [2]
- (c) Given your result for the ISS's orbital radius, how high above the Earth's surface is the ISS predicted to be? [2]
- (d) How do your predicted ISS results compare with published results on NASA's or Wikipedia's ISS page? [2]
- (iii) Suppose US and NZ spacecrafts are freely orbiting the Earth in the same direction. If the altitude of the US craft is 200 km and the altitude of the NZ craft is 210 km, then which of the following is correct? [1]
- (a) the US craft gradually pulls ahead of the NZ craft.
- (b) the NZ craft gradually pulls ahead of the US craft.
- (c) crafts remain abreast of each other.

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Please ensure that you have completed your student details correctly where indicated in the fields provided on the front page of this assignment.

Extra paper for continuing your answers, if required. Clearly number the question.

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PHYS400 Foundation Physics A
Formula Sheet

$$\text{Uncertainty} = \frac{\text{Max.} - \text{Min.}}{2}$$

$$v = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{\Delta t}$$

$$a = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{\Delta t}$$

$$v_2 = v_1 + a\Delta t$$

$$\Delta x = v_1 t + \frac{1}{2}a\Delta t^2$$

$$v_2^2 = v_1^2 + 2a\Delta x$$

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

$$\omega = \frac{\Delta \theta}{\Delta t} = \frac{\theta_2 - \theta_1}{\Delta t}$$

$$\alpha = \frac{\Delta \omega}{\Delta t} = \frac{\omega_2 - \omega_1}{\Delta t}$$

$$\omega_2 = \omega_1 + \alpha\Delta t$$

$$\Delta \theta = \omega_1 t + \frac{1}{2}\alpha\Delta t^2$$

$$\omega_2^2 = \omega_1^2 + 2\alpha\Delta \theta$$

$$g = 9.81 \text{ m s}^{-1}$$

$$F_g = mg$$

$$\Sigma \vec{F} = m \vec{a}$$

$$f_s \leq \mu_s n$$

$$f_k = \mu_k n$$

$$F_c = ma_c$$

$$F = G \frac{m_1 m_2}{r^2}$$

$$G = 6.67 \times 10^{-11} \text{ N m kg}^{-2}$$

$$p = mv$$

$$W = F\Delta x$$

$$KE = \frac{1}{2}mv^2$$

$$PE_g = mgh$$

$$PE_{\text{spring}} = \frac{1}{2}kx^2$$