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Year 12 Physics
Module: Advanced Mechanics
1. Analysing Projectile Motion

Learn Summary:

1. Outline the resulting net force that acts on any object falling toward the Earth:

2. Outline the drag force as it applies to falling objects:

3. What is the equation that is used to determine the net force acting on a falling object?

4. Outline what is meant by the term terminal velocity:

5. What are three characteristics of projectile motion?

6. What two assumptions are made when analysing projectile motion problems?

7. Draw a diagram to illustrate how the vertical and horizontal velocity changes over time for a projectile:

8. List four assumptions that are made about the vertical and horizontal velocity for a projectile:

9. Draw a diagram to illustrate how the initial velocity of a projectile is resolved into the horizontal and vertical components. Include equations.

10. A 75kg skydiver jumps from a plane and accelerates toward the Earth.
a) What is the acceleration of the skydiver if we assume a constant drag force of 60N?

b) What is the skydivers vertical speed 5 seconds after jumping out of the plane?

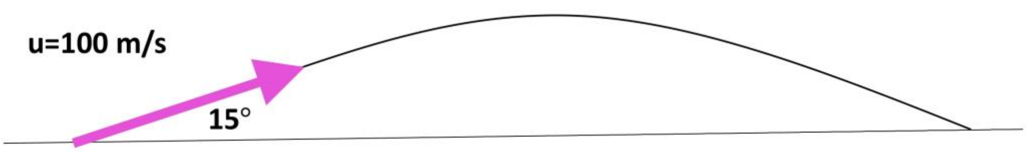
11. A projectile is launched with an initial velocity of 25m/s at an angle of 30° to the horizontal. Calculate the horizontal and vertical components of the projectiles velocity:

Practice:

1. A 150kg package is dropped from an army plane and accelerates toward the Earth.
a) What is the acceleration of the package if we assume a constant drag force of 195N?

b) What is the packages vertical speed 7 seconds after jumping out of the plane?

2. A projectile is launched with an initial velocity of 100m/s at an angle of 15° to the horizontal as shown below. Calculate the horizontal and vertical components of the projectiles velocity:



3. A projectile is launched with an initial velocity of 40m/s at an angle of 70° to the horizontal. Calculate the horizontal and vertical components of the projectiles velocity:

Learn Summary:

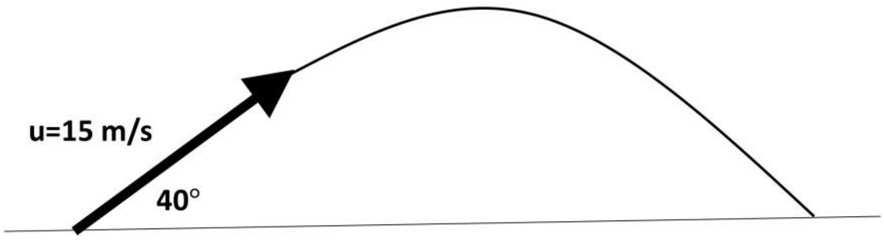
1. Outline the equations used to analyse projectile motion problems. Include a description of variables and units.

2. Outline what considerations are given to direction when analyzing the vertical and horizontal components of projectile motion:

3. Outline equations which are used for the following:

- Maximum height reached:
- Time of flight:
- Range:

4. A projectile is launched at 15 m/s at angle of 40° to the horizontal as shown below. It lands at the same height that it was launched.



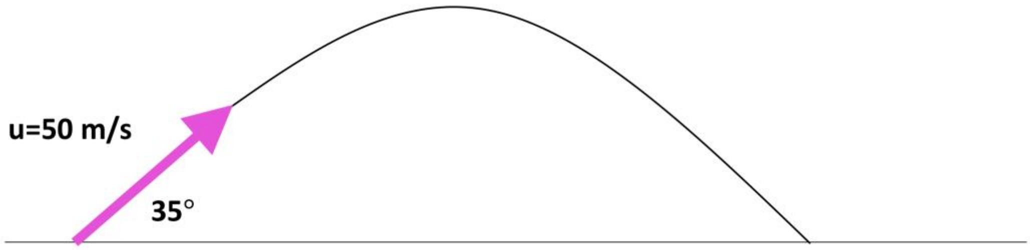
Calculate:
a) The maximum height:

b) The time of flight:

c) The range:

Practice:

1. A projectile is launched at 50 m/s at angle of 35° to the horizontal as shown below. It lands at the same height that it was launched.



Calculate:

a) The maximum height:

b) The time of flight:

c) The range:

2. A projectile is launched at 100 m/s at angle of 80° to the horizontal. It lands at the same height that it was launched. Calculate:

a) The maximum height:

b) The time of flight:

c) The range:

Learn Summary:

1. What are six steps that you could follow as a general technique for analysing projectile motion problems:

2. A projectile is hit with an initial velocity of 75m/s at angle of 30° to the horizontal. Determine:

a) How long will the projectile stay in the air (assume it strikes the ground at the same height it was launched)

b) How far will the projectile go before hitting the ground?

c) What will be the maximum height of the projectile?

3. A rock is thrown at a cliff 20m away with an initial velocity of 40m/s at angle of 25° to the horizontal. Determine:
a) How long will it take for the rock to hit the cliff:

b) At what height did the rock strike the cliff?

Practice:

1. A ball is kicked with an initial velocity of 12m/s at angle of 50° to the horizontal. Determine:

a) How long will the ball stay in the air (assume it strikes the ground at the same height it was launched)

b) How far will the ball go before hitting the ground?

c) What will be the maximum height of the ball?

2. A stone is thrown with an initial velocity of 15m/s at angle of 10° to the horizontal. Determine:

a) How long will the stone stay in the air (assume it strikes the ground at the same height it was launched)

b) How far will the stone go before hitting the ground?

c) What will be the maximum height of the stone?

3. A golf ball is hit at a cliff 150m away with an initial velocity of 70m/s at angle of 40° to the horizontal. Determine:

a) How long will it take for the ball to hit the cliff:

b) At what height did the ball strike the cliff?

4. A cannon is fired horizontally from the top of a 30m cliff into the ocean. The initial velocity of the cannon was 1000m/s. How far from the cliff does the cannon ball hit the water?

Learn Summary:

1. When does uniform circular motion occur?

2. Define period and distance as it relates to uniform circular motion:

3. Outline what is meant by the term centripetal acceleration:

4. How is centripetal acceleration calculated? Include a description of variables and units.

5. Outline what is meant by the term centripetal force:

6. How is centripetal force calculated? Include a description of variables and units.

7. Outline what is meant by the term average angular velocity:

8. How is average angular velocity calculated? Include a description of variables and units.

9. A ball is attached to a string and swung around in uniform circular motion. The length of the string is 1.2m and the mass of the ball is 0.25 kg. The ball completes one complete revolution in 0.4 seconds. Calculate:
a) the magnitude of the velocity of the ball

b) the centripetal acceleration

c) the centripetal force

10. The wheel of a bike completes 100 revolutions in 40 seconds. Determine the average angular velocity in:
a) rad/s

b) deg/s

Practice:

1. A toy plane is attached to a light cable and swung around in uniform circular motion. The length of the cable is 10m and the mass of the plane is 0.4 kg. The plane completes one complete revolution in 8 seconds. Calculate:

a) the magnitude of the velocity of the plane

b) the centripetal acceleration

c) the centripetal force

2. A toy slot car loops around a uniform circular track with a radius of 70cm. The mass of the slot car was 100g. The car makes one complete loop in 6.2 seconds. Calculate:

a) the magnitude of the velocity of the slot car

b) the centripetal acceleration

c) the centripetal force

3. A hammer thrower swings the hammer around is head in uniform circular motion. The length of the cable is 1.8m and the mass of the hammer is 3 kg. The velocity of the hammer is 5m/s. Calculate:

a) the centripetal acceleration

b) the centripetal force

c) the period of the hammer

4. A merry go round completes 10 revolutions in 2 minutes. Determine the average angular velocity in:

a) rad/s

b) deg/s

Learn Summary:

1. Describe the forces that act on a vehicle that is turning around a horizontal circular bend. Draw a diagram to support your answer:

2. How are the frictional force and the centripetal force related?

3. Outline the differences between a constant frictional force and a frictional force that is determined from the coefficient of friction. Include equations in your answer:

4. Describe the forces that act on a mass on a string swinging around in uniform circular motion. Draw a diagram to support your answer:

5. State the equation that is used to determine the net force acting on a mass on a string swinging around in uniform circular motion. Draw a diagram to support your answer:

6. Why are tracks or roads banked?

Banked tracks (ignoring friction):

7. Outline the forces acting on a vehicle in uniform circular motion on a banked track. Include a diagram to support your answer:

8. Draw labelled diagrams to break down the weight force and the normal reaction force into horizontal and vertical components:

9. State the equation that represents the vertical component:

10. State the equation that represents the horizontal component and how this relates to the centripetal force:

Banked tracks (considering friction):

11. Outline the forces acting on a vehicle in uniform circular motion on a banked track. Include a diagram to support your answer:

12. Draw labelled diagrams to break down the weight force, the normal reaction force and the friction force into horizontal and vertical components:

13. State the equation that represents the vertical component:

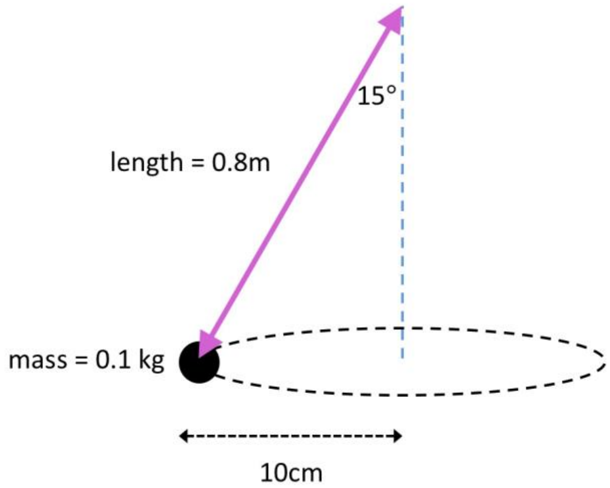
14. State the equation that represents the horizontal component and how this relates to the centripetal force:

15. A vehicle with a mass of 1000kg approaches a corner with a radius of curvature of 15m. What is the maximum speed that the car can turn the corner, if:

a) there is a constant friction force of 5000N

b) the coefficient of friction is 0.4

16. A ball with a mass of 0.1kg is swung around in uniform circular motion at an angle of 15° to the vertical as shown below. The length of the string is 0.8m and it makes a circle with a radius of 10cm.



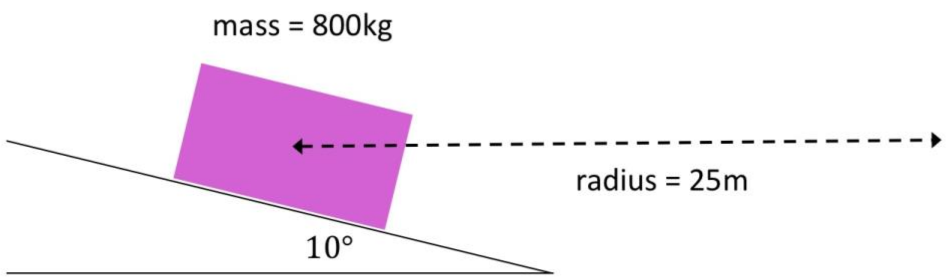
Calculate:

a) the tension in the string

b) the centripetal force acting on the ball

c) the magnitude of the velocity of the ball

17. A 800kg car travels around a corner with a radius of 25m in uniform circular motion. The road is banked at 10° as shown below.



Calculate:

a) The maximum speed the car can travel around the corner, ignoring friction:

b) The maximum speed the car can travel around the corner when there is a frictional force between the car and the road of 4000N:

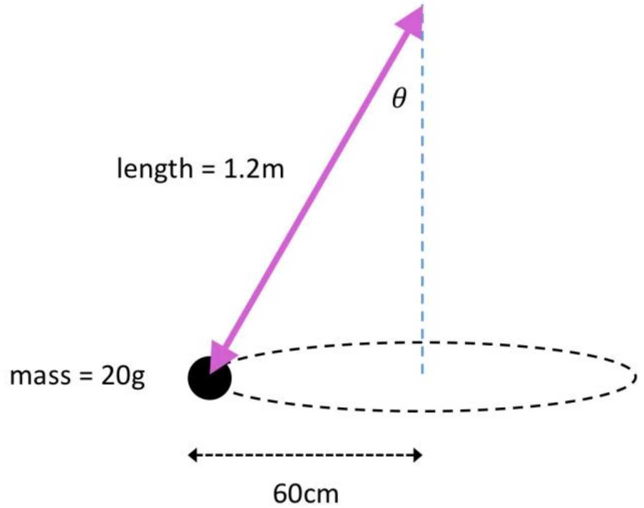
Practice:

1. A cyclist with a mass of 80kg approaches a corner with a radius of curvature of 12m. What is the maximum speed that the car can turn the corner, if:

a) there is a constant friction force of 720N:

b) on a wet day, the coefficient of friction is 0.3

2. A ball with a mass of 20g is swung around in uniform circular motion at an angle to the vertical as shown below. The length of the string is 1.2m and the radius of curvature is 60cm.



Calculate:

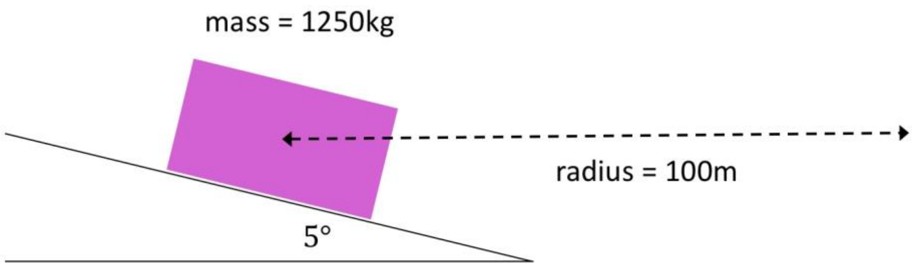
a) the angle between the string and the vertical

b) the tension in the string

c) the centripetal force acting on the ball

d) the magnitude of the velocity of the ball

3. A 1250kg car travels around a curved section of a highway with a radius of 100m in uniform circular motion. The road is banked at 5° as shown below.



Calculate:

a) The maximum speed the car can travel around the corner, ignoring friction:

b) The maximum speed the car can travel around the corner when there is a frictional force between the car and the road of 5000N:

Learn Summary:

1. How do we correctly define work considering vectors?

2. Draw a diagram to illustrate the motion of an object in uniform circular motion and the centripetal force:

3. Explain how we get the situation where the angle, θ, between the force and the direction of motion is 90°:

4. Outline how we resolve the equation for work as it applies to uniform circular motion and what the result of this is:

5. What is the relationship between work and kinetic energy as it applies to uniform circular motion?

6. Write three points to summarise work and energy as it applies to uniform circular motion:

Learn Summary:

1. Define and outline what torque is:

2. Draw a labelled diagram to illustrate torque:

3. What are the three factors that affect torque?

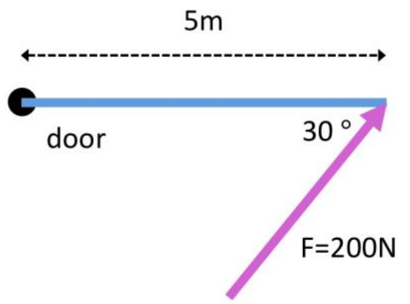
4. If the applied force is at right angles to the line between the pivot point and the force, how is torque calculated? Include a description of variables and units:

5. Draw a diagram to illustrate when the force is not applied at right angles to the line between the pivot and the force:

6. How is torque calculated in these situations?

7. A perpendicular force of 10N is applied to a spanner that is 45cm long. What is the magnitude of the torque that is generated?

8. A force of 200N is applied to an industrial door that is 5m wide at an angle of 30° as shown below. Calculate the torque that is generated:



Practice:

1. A perpendicular force of 80N is applied to a wrench that is 75cm long. What is the magnitude of the torque that is generated?

2. A force of 1000N is applied at an angle of 10° to an anchor system that is 3.2m wide. Calculate the torque that is generated:

3. A force of 40N is applied to a door to achieve a torque of 31.5 Nm. What angle is the force applied if the door is 2.1m wide?

Learn Summary:

1. What is the relationship for the magnitude of the gravitational force acting between two objects? Include a description of variables and units:

2. Draw a diagram to illustrate the relationship between M, m and r:

3. How is the gravitational field strength at the surface of a planet or moon calculated? Include a description of variables and units:

4. Draw a diagram to illustrate this relationship:

5. How is the gravitational field strength calculated for ab object at altitude? Include a description of variables and units:

6. Draw a diagram to illustrate this relationship:

7. What are the constants for the mass and the radius of the Earth?

8. Use the following data to determine the magnitude of the gravitational attraction between the Earth and the Moon:

Mass of the Earth = 6.0×10^{24} kg
Mass of the Moon = 7.4×10^{22} kg
Average Earth – Moon distance = 3.84×10^{8} m

9. Use the following data to determine the gravitational field strength on Mars:
Mass of the Mars = 6.39×10^{23} kg
Radius of Mars = 3.39×10^{6} m

10. Use the following data to determine the gravitational field strength in a low Earth orbit of 2000km:
Mass of the Earth, $M_E = 6.0 \times 10^{24}$ kg
Radius of Earth, $r_E = 6.371 \times 10^{6}$ m

Practice:

1. Determine the gravitational force of attraction between two 10kg bowling balls separated by a distance of 50cm:

2. Use the following data to determine the gravitational field strength on the Moon:
Mass of the Moon = 7.4×10^{22} kg
Radius of Moon = 1737 km

3. Felix Baumgartner jumped to Earth from an altitude of 39,045 meters, in what was known as the Mission to the edge of space. Determine the gravitational field strength he would have experienced just before he jumped:
Mass of the Earth, $M_E = 6.0 \times 10^{24}$ kg
Radius of Earth, $r_E = 6.371 \times 10^{6}$ m

Learn Summary:

1. Starting with: $F_c = F_g$
Derive an expression for the orbital velocity of a planet orbiting the Sun:

2. Draw a diagram to illustrate the relationship between, M, m, r and v_0:

3. Outline the equation for determining the orbital velocity of a satellite:

4. Outline the equation for determining the period of a satellite:

5. Calculate the orbital velocity of the Moon given the following information:
Mass of the Earth = 6.0×10^{24} kg
Mass of the Moon = 7.4×10^{22} kg
Average Earth – Moon distance = 3.84×10^{8} m

6. A satellite orbits the Earth at an altitude of 400km. Use the following information to calculate:
Mass of the Earth, $M_E = 6.0 \times 10^{24}$ kg
Radius of the Earth, $r_E = 6.371 \times 10^{6}$ m

a) the orbital velocity of the satellite:

b) the period of the satellite:

Practice:

1. Calculate the orbital velocity of the Earth around the Sun given the following information:
Mass of the Earth = 6.0×10^{24} kg
Mass of the Sun = 1.99×10^{30} kg
Average Sun – Earth distance = 1.5×10^{11} m

2. A 200kg satellite orbits Mars at an altitude of 350km. Use the following information to calculate:
Mass of the Mars, $M_M = 6.42 \times 10^{23}$ kg
Radius of the Mars, r_M = 3390 km

a) the orbital velocity of the satellite:

b) the period of the satellite:

c) what happens to the orbital velocity and the period if the mass of the satellite is doubled?

3. An Earth satellite has an orbital velocity of 10000 km/hr. Calculate the altitude of this satellite given:
Mass of the Earth, $M_E = 6.0 \times 10^{24}$ kg
Radius of the Earth, $r_E = 6.371 \times 10^{6}$ m

Learn Summary:

1. At what altitudes do near Earth satellites orbit the Earth?

2. What is the Van Allen radiation belt?

3. Quantitatively outline the properties of a near Earth satellite orbiting at 250kms:

4. What are near Earth satellites used for?

5. Describe two examples of well-known near Earth orbit satellites:

6. Outline the differences between geostationary and geosynchronous satellites:

7. What are geostationary satellites used for?

8. Derive an equation to determine the period of a satellite independent of its orbital velocity:

Practice:

1. Calculate the orbital speed of a geostationary satellite:

2. The Hubble space telescope has an altitude above Earth's surface of 540km. Calculate its:
a) orbital period:

b) orbital velocity:

Learn Summary:

1. Outline the relationship between Tycho Brahe and Johannes Kepler:

2. Outline Kepler's first law. Draw a diagram to support your answer:

3. Outline Kepler's second law. Draw a diagram to support your answer:

4. Outline Kepler's third law. Include a description and an outline of the equations and their relationships in your answer:

5. Titan is a moon of Saturn. It has an orbital period of 15 days and 22 hours and an orbital radius of 1,200,000km. Calculate the mass of Saturn:

6. Mars has two moons: Phobos and Deimos. Phobos has an orbital period of 7.66 hours and an orbital radius of 9376 km. Calculate the orbital radius of Deimos if it has an orbital period of 30.35 hours:

Practice:

1. Ganymede, a moon of Jupiter, has an orbital radius of 1,070,000km and a period of 7.155 Earth days. Calculate the mass of Jupiter:

2. Calculate the orbital period of Mars if it has an orbital radius of 228,000,000 km and the mass of the Sun = 1.99×10^{30} kg:

3. A planet with a period of 80 Earth days orbits a star. A second planet in the same system orbits the star at a radius which is equal to 5 times the radius of the first planet. Calculate the period of the second planet:

4. The mass of the Earth = 6.0×10^{24} kg and the orbital radius of the Earth = 1.5×10^{11} m. Calculate the orbital period of Neptune if it has an orbital radius of 4.5 billion km. Do not use the mass of the Sun in your calculation:

Learn Summary:

1. What is the equation for potential energy for objects near the surface of the Earth?

2. Why is this equation not useful for objects that are far away from Earth?

3. What is the equation for gravitational potential energy for objects where the gravitational field is not constant? Outline the variables and their units.

4. Outline why the equation is negative:

5. Show how the equation for gravitational potential energy is derived:

6. What is escape velocity?

7. What is the equation for escape velocity?

8. Show how the equation for escape velocity is derived:

9. Given the following data, determine the gravitational potential energy of the Moon within the Earth's gravitational field.
Mass of the Earth = 6.0×10^{24} kg
Mass of the Moon = 7.35×10^{22} kg
Earth–Moon distance = 3.84×10^{8} m

10. Calculate the escape velocity for Earth (assume mass of the Earth = 6.0×10^{24} kg and radius of the Earth = 6.371×10^{6} m).

Practice:

1. Calculate the gravitational potential energy of Jupiter as it orbits the Sun given the following information:
Mass of Jupiter = 1.90×10^{27} kg
Mass of the Sun = 1.99×10^{30} kg
Jupiter–Sun distance = 7.78×10^{11} m

2. Determine the escape velocity of the Moon, given that its mass is 7.35×10^{22} kg and its radius is 1737 km:

3. The escape velocity of Venus is 10360 m/s. Determine its radius if it has a mass of 4.87×10^{24} kg:

4. How would the value of the escape velocity change if the mass of the Earth was 3 times its actual mass. Justify your response algebraically.

Learn Summary:

1. Outline what is meant by the total mechanical energy of a system in reference to satellites or planets:

2. Show how the equation for total mechanical energy is derived:

3. Outline how Kepler's First law is considered when dealing with gravitational potential energy:

4. Use an equation to explain how the change in gravitational potential energy is calculated:

5. A communications satellite orbiting the Earth at an altitude of 350km has a mass of 1250kg. The radius of the Earth, $r_E = 6.4 \times 10^6$ m and the mass of the Earth, $m_E = 6.0 \times 10^{24}$ kg. Calculate:
a) The total mechanical energy of the satellite
b) The speed of the satellite

6. A meteor orbiting the Earth with an orbital radius of 8.2×10^7 m moves to a lower orbit of 5×10^7 m. Calculate the change in gravitational potential energy if the meteor has a mass of 25kg. Mass of the Earth, $m_E = 6.0 \times 10^{24}$ kg.

Practice:

1. A surveillance satellite orbiting the Earth at an altitude of 420km has a mass of 900kg. The radius of the Earth, $r_E = 6.4 \times 10^6$ m and the mass of the Earth, $m_E = 6.0 \times 10^{24}$ kg. Calculate:
a) The total mechanical energy of the satellite
b) The speed of the satellite:

2. A space shuttle was orbiting the Earth at an altitude of 500km. A satellite was sent from the shuttle to a final orbit at an altitude of 7500km. Calculate the change in gravitational potential energy if the satellite has a mass of 200kg. Mass of the Earth, $m_E = 6.0 \times 10^{24}$ kg.

3. A meteorite fell toward and struck the Earth from an altitude of 30,000km. Calculate the change in gravitational potential energy if the meteorite had a mass of 10kg.
The radius of the Earth, $r_E = 6.4 \times 10^6$ m and the mass of the Earth, $m_E = 6.0 \times 10^{24}$ kg.