

Physics, 2017 EC, entrance exam, version 2

Grade 12 · Physics · 2017 E.C.

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Time allowed: 120 minutes

Questions: 50

Total marks: 50

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1. Two trains are traveling towards each other on parallel tracks. Train X is moving west at 80 km/h, Train Y moving east at 60 km/h. If you are on Train X, what is the velocity of Train Y relative to Train X? (1)
- A. ✓ 140 km/h towards the east B. 60 km/h towards the west
C. 20 km/h towards the west D. 140 km/h towards the west

Answer: A

Relative velocity is the difference of two velocities. Take east as positive, so train Y has $v_Y = +60$ km/h and train X has $v_X = -80$ km/h because it travels west. Then $v_{Y/X} = v_Y - v_X = 60 - (-80) = +140$ km/h, and the plus sign means the direction is east. Option D carries the right number but the wrong direction. It comes from adding the two speeds and then keeping the heading of your own train instead of the heading the subtraction gives.

2. Which of the following is a correct action-reaction force pair? (1)
- A. The force of a ball hitting a wall and the force of gravity pulling the ball down.
B. ✓ The force of a car's tires pushing backward on the road and the road pushing the car forward.
C. The force of the bat hitting a ball and the force of air resistance on the ball.
D. The force of a swimmer's arms pushing water backward and the force of gravity pulling them down.

Answer: B

A Newton's third law pair comes from one single interaction and its two forces act on two different bodies. The tyres push backwards on the road and the road pushes the car forwards: same contact, equal size, opposite directions, different bodies. Option D is the tempting one, because pushing water backwards is a genuine action force, but its partner is the water pushing the swimmer forwards. The pull of gravity on the swimmer belongs to a separate interaction with the Earth.

3. A 0.25 kg ball moving at 4 m/s collides inelastically with a stationary ball of mass 0.75 kg. After collision they stick together. What is the kinetic energy lost? (1)
- A. 4 J B. 2 J
C. 3.5 J D. ✓ 1.5 J

Answer: D

Momentum is conserved through the collision. Before impact $p = 0.25 \times 4 = 1$ kg m/s, and the two balls move off together as one 1 kg body, so $v = 1/1 = 1$ m/s. Kinetic energy before is $\frac{1}{2}(0.25)(4)^2 = 2$ J and after is $\frac{1}{2}(1)(1)^2 = 0.5$ J, so $2 - 0.5 = 1.5$ J is lost to heat, sound and deformation. Option B (2 J) is the energy the moving ball started with, not the amount lost, and some of that energy survives as the motion of the pair.

4. A block weighing 200 N is placed on a frictionless inclined plane that rises to a height of 3 m over a distance of 12 m along the plane. What is the mechanical advantage (MA) of the inclined plane?
- A. 1.67 B. 3.00
C. ✓ 4.00 D. 6.00

Answer: C

For a frictionless inclined plane the mechanical advantage is the length of the slope divided by the height it lifts through: $MA = \frac{L}{h} = \frac{12}{3} = 4$. The 200 N weight is extra information that the formula does not need. Option B (3.00) is tempting because 3 m is printed in the question, but mechanical advantage is a ratio of two forces or two lengths and carries no unit, so a bare height cannot be the answer.

5. What is the main characteristic of a third-order lever? (1)
- A. The fulcrum is at one end, with the effort on the other end.
 - B. The load is positioned between the effort and the fulcrum.
 - C. It has a mechanical advantage greater than one.
 - D. ✓ **The effort is applied between the load and the fulcrum.**

Answer: D

Levers are classed by what sits in the middle. In a third class lever the effort is applied between the fulcrum and the load, as in the human forearm, a pair of tweezers or a fishing rod. Because the effort arm is then shorter than the load arm, this class always has a mechanical advantage below one and trades force for speed and range of movement. Option B describes the second class lever, where the load is in the middle, as in a wheelbarrow.

6. Considering the relationship between atmospheric pressure and altitude, which evaluation best explains the challenges faced by climbers at high elevations? (1)
- A. Climbers are less affected by low atmospheric pressure because they are physically fit.
 - B. **Decreased atmospheric pressure at high altitudes leads to reduced oxygen levels, which can impair physical performance and increase fatigue.**
 - C. Climbers do not need to acclimatize as atmospheric pressure has no significant impact on their performance.
 - D. High atmospheric pressure at altitudes enhances climbers' endurance and reduces fatigue.

Answer: B

Air pressure falls as altitude rises, so each breath of air holds fewer oxygen molecules and the partial pressure of oxygen in the lungs drops. Less oxygen reaches the blood and the working muscles, which brings on breathlessness, headache and quick fatigue. This is why climbers spend days acclimatising before attempting a high summit. Option D reverses the physics: atmospheric pressure decreases with altitude, it does not increase.

7. Which of the following is correct? (1)
- A. ✓ **Temperature is the measure of the average molecular kinetic energy of a gas**
- B. Internal energy of the system is independent of its mass or the number of molecules in the system
- C. Heat is energy that can be transferred from one object to another at equal temperature
- D. Temperature is a measure of the amount of energy that flows from hot to colder region

Answer: A

For an ideal gas the absolute temperature measures the average kinetic energy of the molecules, $\frac{3}{2}k_B T = \frac{1}{2}m\overline{v^2}$. Raise the temperature and the molecules move faster on average, whichever gas it is. Option D is the common mix up: the energy that flows from a hot region to a cold one is heat, while temperature is the property that decides which way that flow goes.

- 8.** The sound intensity at a distance of 2 m from a point source is 1 W/m². What will be the intensity at a distance of 4 m from the same source, assuming uniform spherical spreading?
- A. ✓ 0.25 W/m² B. 0.5 W/m²
- C. 1.0 W/m² D. 2 W/m²

Answer: A

A point source spreads its power over the surface of a sphere, so $I = \frac{P}{4\pi r^2}$ and the intensity falls with the square of the distance. Going from 2 m to 4 m doubles the radius, so the intensity drops by a factor of $2^2 = 4$, giving $I = 1 \div 4 = 0.25 \text{ W/m}^2$. Option B (0.5) comes from dividing by the distance ratio instead of by its square.

9. Which situation best shows the application of both experiential and non-experiential knowledge in solving a complex problem? (1)
- A. **A scientist uses experimental data from a lab experiment and theoretical models to refine their hypothesis.** ✓
- B. A teacher applies established classroom management techniques without considering past experiences with students.
- C. A lawyer follows court precedents and applies personal experiences from similar cases to argue in court.
- D. A nurse consults a medical handbook, but only follows their instinct when making decisions.

Answer: A

The question asks for one situation that uses both kinds of knowledge together. In option A the measured laboratory data is experiential knowledge, gained by observing, while the theoretical model is non-experiential, built by reasoning from principles rather than from what was seen. Bringing the two together to refine a hypothesis is the mix the question describes. Option C looks close, but court precedents are records of earlier real cases and the lawyer's own memory of similar cases is lived too, so both halves there are experiential.

10. How do physics graduates contribute to the healthcare sector? (1)
- A. Designing promotional campaigns for health care products.
 - B. Working in pharmaceuticals for drug development.
 - C. Managing healthcare institutions.
 - D. ✓ **Creating, reviewing and maintaining medical technologies in the field.**

Answer: D

Physics graduates work in hospitals as medical physicists. They design, test, calibrate and maintain the machines that image and treat patients, including X-ray and CT scanners, MRI, ultrasound and radiotherapy units, and they check that radiation doses are accurate and safe. Option B is tempting because drug development also belongs to healthcare, but designing and testing a medicine is the work of chemists and pharmacologists.

11. Which of the following defines a parallel vector? (1)
- A. A vector that is parallel to the ground.
 - B. ✓ **A vector that points in the same or exactly opposite direction to another vector.**
 - C. A vector that has zero magnitude.
 - D. A vector that always points toward the center of the Earth.

Answer: B

Two vectors are parallel when they lie along the same line of action, which means one is a multiple of the other. That covers both the case where they point the same way and the case where they point in exactly opposite directions. Option A confuses a relation between two vectors with one particular direction in space. Being parallel says how two vectors sit relative to each other, and has nothing to do with the ground.

12. The velocity of a particle moving with constant acceleration at an instant t_0 is 10 m/s. After 5 seconds, velocity is 20 m/s. The velocity at 3 seconds before t_0 is: (1)
- A. 8 m/s
B. ✓ 4 m/s
C. 6 m/s
D. 7 m/s

Answer: B

Constant acceleration means the velocity changes at a steady rate. Between t_0 and 5 s later the velocity goes from 10 m/s to 20 m/s, so $a = \frac{20-10}{5} = 2 \text{ m/s}^2$. Going backwards three seconds, the velocity was lower by $2 \times 3 = 6 \text{ m/s}$, so $v = 10 - 6 = 4 \text{ m/s}$. Option A (8 m/s) is what appears if the acceleration is subtracted once instead of once for each of the three seconds.

13. A ball is dropped from a height of 80 m. How long will it take to hit the ground? ($g=10 \text{ m/s}^2$) (1)
- A. 3.5 s
B. ✓ 4.0 s
C. 5.0 s
D. 6.0 s

Answer: B

The ball starts from rest and falls freely, so $h = \frac{1}{2}gt^2$. Putting the numbers in, $80 = \frac{1}{2}(10)t^2 = 5t^2$, so $t^2 = 16$ and $t = 4 \text{ s}$. Option C (5 s) is worth testing: in 5 s a freely falling body covers $\frac{1}{2}(10)(5)^2 = 125 \text{ m}$, which is well past the ground, so 5 s is too long.

14. A 5 kg box is resting on an incline of 30° . Coefficient of static friction = 0.58. What is the maximum static friction force before it slides? (1)
- A. ✓ 25 N
B. 15 N
C. 12.5 N
D. 10 N

Answer: A

The box is about to slide when the friction reaches its largest value, $f_{max} = \mu_s N$. On a slope the normal force is only the part of the weight pressing into the surface, $N = mg \cos \theta$. So $f_{max} = 0.58 \times 5 \times 10 \times \cos 30^\circ = 0.58 \times 50 \times 0.866 \approx 25 \text{ N}$. Option B (15 N) comes from using $mg \sin \theta$, the component that pulls the box down the slope, in place of the component that presses it into the slope.

15. If the force applied to an object is perpendicular to its displacement, what is the work done? (1)
- A. Maximum
B. Negative
C. Half of the maximum
D. ✓ Zero

Answer: D

Work is $W = Fd \cos \theta$, where θ is the angle between the force and the displacement. A perpendicular force means $\theta = 90^\circ$ and $\cos 90^\circ = 0$, so the work is zero however large the force is. This is why the tension in the string of a body moving in a circle, and the normal force on a box slid along a level floor, do no work. Option B applies when the angle is larger than 90° , that is when part of the force points against the motion, as friction does.

16. Which of the following scenarios illustrates heat transfer by convection? (1)
- A. A spoon becoming hot when placed in a hot bowl of food.
B. The sun warming the Earth through the vacuum of space.
C. A blanket keeping a person warm on a cold night.
D. ✓ A pot of water heating up from the bottom on a stove.

Answer: D

Convection carries heat by moving the fluid itself. Water at the bottom of the pot is heated, expands, becomes less dense and rises, while cooler water sinks to take its place, and the current that forms warms the whole pot. Option A is the tempting one, but a spoon in hot food carries heat through a solid by conduction, where the particles pass energy along without travelling with it.

17. Body A is ten times the mass and half the specific heat capacity of body B. If they receive equal heat, how do their heat capacities compare? (1)
- A. Heat capacity of A is 10 times greater
B. Heat capacity of B is 10 times greater
C. ✓ **Heat capacity of A is 5 times greater**
D. Heat capacity of B is 5 times greater

Answer: C

Heat capacity is mass times specific heat capacity, $C = mc$. Body A has ten times the mass and half the specific heat capacity, so $C_A = (10m)(\frac{1}{2}c) = 5mc$, which is five times $C_B = mc$. The equal heat given to each body is extra information here. Option A (ten times) counts only the mass and forgets that halving the specific heat capacity pulls the answer back down by a factor of two.

18. Two rods of length L and $2L$ with coefficients of linear expansion α and 2α respectively are connected so total length becomes $3L$. The average coefficient of linear expansion of the composite rod equals: (1)
- A. $(3/2)\alpha$
B. ✓ **$(5/3)\alpha$**
C. $(5/2)\alpha$
D. α

Answer: B

Compare the total expansion with the total length. The short rod grows by $L\alpha\Delta T$ and the long rod by $2L(2\alpha)\Delta T = 4L\alpha\Delta T$, so together they grow by $5L\alpha\Delta T$. The average coefficient is that growth divided by the whole length and the temperature rise: $\alpha_{avg} = \frac{5L\alpha\Delta T}{3L\Delta T} = \frac{5}{3}\alpha$. Option A, $\frac{3}{2}\alpha$, is the plain average of α and 2α , which would be right only if the two rods had equal lengths.

19. When ice melts into water at 0°C , what happens to the temperature of the system until all ice has converted? (1)
- A. Temperature increases continuously until 100°C .
B. Temperature decreases until all ice has melted.
C. ✓ **Temperature remains constant at 0°C despite heat addition.**
D. Temperature fluctuates between 0°C and 5°C .

Answer: C

While ice is melting, the heat going in is used to break the bonds that hold the water molecules in the crystal, not to make the molecules move faster. That energy is the latent heat of fusion, and because the average molecular kinetic energy does not change, the thermometer holds at 0°C until the last piece of ice has gone. Option A is tempting because heat is still being supplied and it feels as though the temperature must keep climbing, but the rise starts again only when there is no ice left to melt.

20. Two small spheres with charges $q_1 = 3\text{ }\mu\text{C}$ and $q_2 = -2\text{ }\mu\text{C}$ are placed 6 cm apart in vacuum. What is the magnitude of electrostatic force between them? ($k = 9 \times 10^9\text{ Nm}^2/\text{C}^2$) (1)
- A. 1.5 N
B. 9 N
C. 3 N
D. ✓ **15 N**

Answer: D

Use Coulomb's law, $F = \frac{kq_1q_2}{r^2}$, with the separation converted to metres, $r = 6\text{ cm} = 0.06\text{ m}$. Then $F = \frac{9 \times 10^9 \times 3 \times 10^{-6} \times 2 \times 10^{-6}}{(0.06)^2} = \frac{5.4 \times 10^{-2}}{3.6 \times 10^{-3}} = 15\text{ N}$. The minus sign on q_2 tells you the force is attractive; for the magnitude you use the sizes of the charges only. Option A (1.5 N) is what comes out if $(0.06)^2$ is written as 0.036 instead of 0.0036, so square the distance with care.

21. A chef is preparing food in a clay pot and iron pot of the same size on identical stoves. The food in clay pot takes longer to heat but stays warm longer. Best explanation? (1)
- A. **The clay pot has higher specific heat capacity, requiring more heat to raise its temperature but retaining it longer.** ✓
- B. The iron pot has a lower specific heat capacity, so it transfers heat to the food more slowly.
- C. The clay pot reflects heat, preventing rapid heating but ensuring gradual cooling.
- D. The iron pot traps heat inside, causing the food to heat up faster but cool down quickly.

Answer: A

Specific heat capacity is the heat needed to raise one kilogram of a material by one degree. Clay has a higher specific heat capacity than iron, so the same stove must pour in more energy before the clay pot warms up, and the pot then holds more stored energy to release slowly as it cools. That single property explains both halves of what the chef notices. Option D is tempting because the iron pot really does heat faster, but the reason is iron's low specific heat capacity and good conduction, not heat being trapped inside.

22. Designing a circuit to convert a galvanometer (full-scale 5 mA, resistance 30 Ω) into a voltmeter measuring up to 50 V. What series resistor is needed? (1)
- A. ✓ **9,970 Ω**
- B. 10,000 Ω
- C. 1,000 Ω
- D. 2,000 Ω

Answer: A

A galvanometer becomes a voltmeter when a large resistance is placed in series with it, so that the full range voltage drives no more than the full scale current through the pair. At full scale $V = I(R_g + R_s)$, so $R_s = \frac{V}{I} - R_g = \frac{50}{0.005} - 30 = 10,000 - 30 = 9,970 \Omega$. Option B (10,000 Ω) is the total resistance the branch needs, not the extra resistor; forgetting to take away the galvanometer's own 30 Ω is the usual slip.

23. Which statement best describes why inserting a dielectric increases capacitance? (1)
- A. The dielectric reduces the distance between plates.
- B. The dielectric allows higher voltage to be applied.
- C. ✓ **The dielectric polarizes and reduces the effective electric field between plates.**
- D. The dielectric increases the plate size, allowing more surface area.

Answer: C

Capacitance is $C = \frac{Q}{V}$. The molecules of a dielectric line up in the applied field and set up a field of their own pointing the other way, so the net field between the plates falls, and with it the voltage $V = Ed$, while the charge on the plates is unchanged. A smaller V for the same Q means a larger C , by the factor κ known as the dielectric constant. Option A is wrong because sliding a slab between the plates does not move the plates, so the separation d stays exactly as it was.

24. An ancient wooden artifact has only 25% of its original ^{14}C remaining. Half-life of ^{14}C is 5730 years. How old is the artifact? (1)
- A. 5,730 years
- B. ✓ **11,460 years**
- C. 17,190 years
- D. 22,920 years

Answer: B

Each half-life leaves half of what was there before. After one half-life 50% remains and after two half-lives 25% remains, so the wood has been through two half-lives. Its age is $2 \times 5730 = 11,460$ years. Option A (5,730 years) is one half-life, which would leave 50% of the carbon-14, twice what the artifact still holds.

25. What makes a body more stable according to Newtonian mechanics? (1)
- A. A narrower base support
 - B. The higher center of gravity
 - C. ✓ **A wider base of support and a lower center of gravity**
 - D. The material of the body

Answer: C

A body topples once the vertical line through its centre of gravity falls outside its base of support. Widening the base and lowering the centre of gravity both make that harder, because the body must lean through a larger angle before the line escapes the base. This is why a lorry with a high load overturns more readily than a low, wide one. Option A is the opposite case: a narrow base needs only a small tilt for the line to fall outside it.

26. Which comparison accurately highlights a fundamental difference between nuclear fission and nuclear fusion? (1)
- A. Fission involves combining light nuclei, fusion involves splitting heavy nuclei.
 - B. Both require high temperatures, but only fission produces radioactive waste.
 - C. Fission occurs naturally in stars, fusion is used in nuclear reactors.
 - D. ✓ **Fusion releases energy by combining light nuclei, whereas fission releases energy by splitting heavy nuclei.**

Answer: D

Fusion joins light nuclei, as hydrogen isotopes form helium in the Sun, while fission splits heavy nuclei such as uranium-235. Both release energy because the products are more tightly bound per nucleon than what went in. Option A names the same two processes with the labels swapped, which is why it is worth reading the wording once more before choosing here.

27. Which statement best explains the relationship between physics and chemistry? (1)
- A. Physics is primarily concerned with matter, while chemistry focuses solely on energy.
 - B. ✓ **Chemistry relies on the principles of physics to explain how atoms and molecules interact and behave.**
 - C. Physics and chemistry are completely independent fields with no overlap.
 - D. Chemistry is a branch of physics that deals exclusively with chemical reactions.

Answer: B

Chemistry describes how atoms bond, react and rearrange, and the rules behind that behaviour are physical: electric forces between charges, the energy levels that electrons may occupy, and the conservation of energy. Quantum mechanics and electrostatics explain why a bond forms at all and how strong it is. Option D goes too far in the other direction. Chemistry rests on the laws of physics, but it has its own concepts, methods and questions, so it is not a sub-branch of physics.

28. Which scenario best illustrates the application of nuclear medicine in diagnosing a medical condition? (1)
- A. A patient undergoes an MRI scan to assess brain activity.
 - B. ✓ **A physician uses a PET scan to visualize metabolic activity in a tumor.**
 - C. A doctor prescribes antibiotics for a bacterial infection.
 - D. A patient receives a physical examination to check for signs of illness.

Answer: B

Nuclear medicine works by putting a small amount of radioactive material into the patient and detecting the radiation it sends out from inside the body. In a PET scan a tracer that emits positrons is injected, and the scanner maps where the tracer gathers, showing which tissue is chemically most active. Option A is the tempting one, but MRI uses a strong magnetic field and radio waves and involves no radioactive material at all.

29. Which best explains how electrical properties of neurons facilitate communication? (1)
- A. Neurons use electrical signals only for muscle contraction, with no role in intercellular communication.
 - B. Electrical signals in neurons are uniform and do not encode different types of information.
 - C. **Action potentials depend on selective permeability of neuronal membrane, allowing specific ion ✓ movements that encode information.**
 - D. Neurons rely solely on chemical signals for communication, not electrical properties.

Answer: C

A neuron's membrane lets particular ions cross at particular moments, through channels that open and close with voltage. When the sodium channels open, sodium ions rush in and the inside of the cell briefly turns positive; potassium then leaves and the resting state is restored. This travelling change of voltage is the action potential, and its timing and rate carry the information. Option D denies the electrical side altogether, but while chemical transmitters do act across the synapse, the signal running along the axon itself is electrical.

30. Which type of radiation, related to physics in medicine, is frequently used in cancer treatment? (1)
- A. ✓ **Gamma-rays**
 - B. Radio waves
 - C. Alpha particles
 - D. Microwaves

Answer: A

Gamma rays are high energy electromagnetic radiation with great penetrating power, so they can reach a tumour deep inside the body from a source outside it. They ionise atoms along their path and damage the DNA of the fast dividing cancer cells, and beams from several directions are crossed on the tumour so that healthy tissue takes a smaller dose. Option C is tempting because alpha particles ionise strongly, but a sheet of paper or the outer layer of skin stops them, so from outside the body they would never reach the tumour.

31. Which statement best evaluates the effectiveness of infrared wave detection compared to visible light in night vision systems? (1)
- A. Infrared detection is less effective because it cannot penetrate fog or smoke.
 - B. **Infrared detection is superior because it detects heat emitted by objects, useful in low-light ✓ conditions.**
 - C. Infrared detection provides a clearer image than visible light under all conditions.
 - D. Infrared detection is only useful in military applications, not civilian.

Answer: B

Every warm object gives out infrared radiation of its own, and the warmer it is the more it emits. An infrared camera detects that emitted heat, so it needs no light falling on the scene and works in complete darkness, which is exactly what a night vision system is for. Option C overstates the case by saying infrared is clearer under all conditions. For fine detail and colour in good daylight, ordinary visible light gives the better image.

32. Which branch of physics is most crucial for understanding transmission of radio waves, microwaves, and infrared waves in communication technologies? (1)
- A. Thermodynamics
 - B. Quantum mechanics
 - C. Classical mechanics
 - D. ✓ **Electromagnetism**

Answer: D

Radio waves, microwaves and infrared are all electromagnetic waves. They are produced by accelerating charges, travel at the speed of light and follow Maxwell's equations, so the branch that covers how they are generated, sent and received is electromagnetism. Option B is tempting because quantum mechanics explains how single photons are emitted and absorbed, but the transmission of a signal through space and along an aerial is handled by classical electromagnetic theory.

33. At the peak of its trajectory, what is the vertical component of a projectile's velocity? (1)
- A. Maximum
B. Half of initial value
C. ✓ Zero
D. Constant

Answer: C

Split the motion into two independent parts. The horizontal velocity stays the same throughout the flight, while the vertical velocity is slowed by gravity on the way up. The highest point is the moment when the vertical velocity has been reduced to zero and is about to reverse, so the projectile is still moving there, but only horizontally. Option D describes the horizontal component, which is the part of the velocity the question does not ask about.

34. In projectile motion, which is the correct relation between total time of flight (T) and maximum height (H)? (1)
- A. $H = (1/4)gT^2$
B. $H = (1/2)gT^2$
C. ✓ $H = (1/8)gT^2$
D. $H = gT$

Answer: C

For a projectile that lands at the height it was launched from, the time of flight is $T = \frac{2u \sin \theta}{g}$, so $u \sin \theta = \frac{gT}{2}$. The maximum height is $H = \frac{(u \sin \theta)^2}{2g}$. Substituting, $H = \frac{(gT/2)^2}{2g} = \frac{g^2 T^2 / 4}{2g} = \frac{gT^2}{8}$. Option B, $\frac{1}{2}gT^2$, puts the whole flight time into the free fall formula, but the drop from the top back to the ground takes only half of it, $T/2$.

35. A fan blade starts from rest and reaches angular velocity 30 rad/s in 6 s with constant angular acceleration. (1)
What is angular displacement during this time?
- A. ✓ 90 rad
B. 120 rad
C. 180 rad
D. 210 rad

Answer: A

The angular acceleration is constant, so the average angular velocity can be used. It rises from 0 to 30 rad/s, so the average is $\frac{0+30}{2} = 15$ rad/s, and in 6 s the blade turns through $15 \times 6 = 90$ rad. The same answer comes from $\alpha = \frac{30}{6} = 5$ rad/s² and $\theta = \frac{1}{2}\alpha t^2 = \frac{1}{2}(5)(6)^2 = 90$ rad. Option C (180 rad) is the final angular velocity times the time, which would be right only if the blade had spun at 30 rad/s for the whole 6 s instead of building up to it.

36. A solid disk ($I = \frac{1}{2}mr^2$) and a hollow cylinder ($I = mr^2$) of same mass and radius roll down an incline without slipping. (1)
Which statement correctly compares their final velocities?
- A. ✓ Solid disk has greater final velocity.
B. Hollow cylinder has greater final velocity.
C. Both have same final velocity.
D. Cannot be determined.

Answer: A

Both objects start with the same potential energy mgh , and at the bottom that energy is shared between moving forward and spinning. For rolling without slipping, $v = \sqrt{\frac{2gh}{1+k}}$, where $I = kmr^2$. The disk has $k = \frac{1}{2}$, giving $v = \sqrt{\frac{4gh}{3}}$, while the hollow cylinder has $k = 1$, giving $v = \sqrt{gh}$, so the disk arrives faster. Option C is tempting because the two have the same mass, radius and starting height, but the mass and radius cancel out and what decides the race is how the mass is spread about the axis.

37. Rotating system: $m_1=2\text{kg}$ at $r_1=1\text{m}$, $m_2=3\text{kg}$ at $r_2=2\text{m}$, $m_3=4\text{kg}$ at $r_3=3\text{m}$. What is total moment of inertia I about the axis? (1)
- A. $34\text{ kg}\cdot\text{m}^2$ B. $38\text{ kg}\cdot\text{m}^2$
C. $42\text{ kg}\cdot\text{m}^2$ D. ✓ **$50\text{ kg}\cdot\text{m}^2$**

Answer: D

For a set of point masses the moment of inertia is $I = \sum mr^2$, so every distance enters squared. Here $I = 2(1)^2 + 3(2)^2 + 4(3)^2 = 2 + 12 + 36 = 50\text{ kg}\cdot\text{m}^2$. Option A ($34\text{ kg}\cdot\text{m}^2$) is what you get by pairing the masses with the wrong radii, taking $2(3)^2 + 3(2)^2 + 4(1)^2 = 18 + 12 + 4$, so match each mass to its own distance before squaring.

38. Which statement correctly summarizes all three of Kepler's Laws? (1)
- A. All planets have circular orbits; their speeds vary; their distances affect their speeds.
B. Planets orbit in straight lines, move at constant speeds, and have periods that depend on their masses.
C. ✓ **Planets orbit in ellipses, sweep equal areas, and have periods related to their distances from the Sun.**
D. All celestial bodies are attracted to each other; they move in random paths; and their speeds are equal.

Answer: C

Kepler's three laws, in order: each planet moves on an ellipse with the Sun at one focus; the line from the Sun to the planet sweeps out equal areas in equal times, so a planet moves faster when it is nearer; and the square of the period is proportional to the cube of the average orbital distance, $T^2 \propto a^3$. Option C states all three together. Option A is the tempting one because a planet's speed really does vary and really does depend on its distance, but it opens by calling the orbits circular, and the first law is exactly the finding that they are ellipses.

39. Two moons orbit a planet. Moon A has orbital radius R , Moon B has radius $4R$. How does orbital period of B compare to A? (1)
- A. Twice as long B. ✓ **8 times as long**
C. 4 times as long D. 2 times as long

Answer: B

Kepler's third law gives $T^2 \propto r^3$, so $T \propto r^{3/2}$. Moon B orbits at four times the radius, so its period is $4^{3/2} = (\sqrt{4})^3 = 2^3 = 8$ times that of moon A. Option C (4 times) treats the period as proportional to the radius, but the period grows faster than the distance because the outer moon has both a longer path to cover and a slower orbital speed.

40. Two masses 4 kg and 6 kg separated by 2 m . Gravitational force between them? $G=6.7\times 10^{-11}\text{ Nm}^2/\text{kg}^2$ (1)
- A. $4.0\times 10^{-11}\text{ N}$ B. $8.0\times 10^{-10}\text{ N}$
C. $2.0\times 10^{-11}\text{ N}$ D. ✓ **$4.0\times 10^{-10}\text{ N}$**

Answer: D

Newton's law of gravitation gives $F = \frac{Gm_1m_2}{r^2}$. Putting in the numbers, $F = \frac{6.7\times 10^{-11}\times 4\times 6}{2^2} = \frac{6.7\times 10^{-11}\times 24}{4} = 6.7 \times 10^{-11} \times 6 = 4.0 \times 10^{-10}\text{ N}$. Option A carries the right digits but the wrong power of ten, 4.0×10^{-11} , so finish by checking the exponent as carefully as the figures.

41. Kepler's third law is generalized by Newton by showing that it applies to: (1)
- A. Only planets orbiting the Sun B. ✓ **Any two orbiting bodies**
C. Only elliptical orbits, not circular D. Systems where gravity is negligible

Answer: B

Kepler found his third law by fitting the observed motion of the planets around the Sun. Newton later derived the same relation from his law of gravitation and his laws of motion, and that derivation says nothing special about the Sun, so it holds for any two bodies bound together by gravity. This is why the relation also works for the Moon around the Earth, for a satellite around any planet and for two stars orbiting each other. Option A states Kepler's original scope, which is precisely what Newton's work went beyond.

42. What is the primary cause of pressure in a gas?

(1)

- A. ✓ **Gas particles colliding with the walls of their container**
- B. The weight of the gas
- C. The volume of the gas
- D. The temperature of the gas

Answer: A

Gas molecules move constantly and in all directions. Each time one strikes a wall its momentum changes as it bounces back, and by Newton's second and third laws it pushes on the wall. Millions of such collisions every second add up to a steady average force per unit area, and that is the pressure. Option B is tempting because a gas does have weight, but that weight is tiny beside the collision effect, and it could not explain why the gas presses on the lid and the sides of a container as hard as on the floor.

43. Which correctly expresses the relationship between absolute pressure, gauge pressure, and atmospheric pressure?

(1)

- A. Absolute pressure = gauge pressure minus atmospheric pressure.
- B. Gauge pressure = absolute pressure plus atmospheric pressure.
- C. Atmospheric pressure = absolute pressure plus gauge pressure.
- D. ✓ **Absolute pressure = gauge pressure plus atmospheric pressure.**

Answer: D

A gauge that is open to the air reads the amount by which the pressure inside beats the air outside, so it reads gauge pressure. Absolute pressure is counted up from a perfect vacuum, so you recover it by adding the atmosphere back on: $P_{abs} = P_{gauge} + P_{atm}$. A tyre reading 200 kPa on the gauge is at about 300 kPa absolute. Option A subtracts instead of adding, which would make the absolute pressure of a tyre smaller than the gauge reading and would give a flat tyre a negative absolute pressure.

44. What force is needed on a hydraulic press piston of radius 2 cm to produce 7200 N on working piston of radius 6 cm?

- A. 2400 N
- B. ✓ **800 N**
- C. 1050 N
- D. 667 N

Answer: B

Pascal's principle says the pressure is the same at both pistons, so $\frac{F_1}{A_1} = \frac{F_2}{A_2}$ and the forces are in the ratio of the areas, which is the ratio of the squares of the radii. So $F_1 = F_2 \left(\frac{r_1}{r_2}\right)^2 = 7200 \times \left(\frac{2}{6}\right)^2 = 7200 \times \frac{1}{9} = 800$ N. Option A (2400 N) uses the plain ratio of the radii, $7200 \div 3$, and misses that area grows with the square of the radius.

45. A scientist measures pressure at depth 1 m = 50 kPa. At depth 3 m in same liquid, what can she conclude?

(1)

- A. ✓ **Pressure increases as depth increases.**
- B. Pressure decreases as depth increases.
- C. Pressure remains constant.
- D. No consistent relationship.

Answer: A

In a liquid at rest the pressure at depth h is $P = P_0 + \rho gh$, so it climbs steadily with depth because more liquid weighs down from above. Measuring 50 kPa at 1 m and then measuring again at 3 m in the same liquid will give a larger reading, and the conclusion to draw is that pressure increases with depth. Option C is tempting for a student remembering that pressure is equal at all points on the same horizontal level, but that rule holds across one level, not between two different depths.

46. A student uses an open-ended manometer. If mercury level is higher on gas side than open side, what is concluded? (1)

- A. Gas pressure is greater than atmospheric
B. Gas has no pressure
C. Gas pressure equals atmospheric
D. ✓ **Gas pressure is less than atmospheric**

Answer: D

In an open ended manometer the mercury is pushed down on whichever side presses harder. Mercury standing higher on the gas side means the gas is pressing less than the air on the open side, so the gas is below atmospheric pressure. In symbols, $P_{gas} = P_{atm} - \rho gh$, where h is the height difference. Option A is the opposite case: a gas above atmospheric pressure pushes the mercury down on its own side and up on the open side.

47. A cube with side 0.5 m submerged in fluid density 1200 kg/m³. Buoyant force? (1)

- A. ✓ **1500 N**
B. 500 N
C. 1200 N
D. 250 N

Answer: A

Archimedes' principle says the buoyant force equals the weight of the fluid pushed aside. A fully submerged cube displaces its own volume, $V = (0.5)^3 = 0.125 \text{ m}^3$, so $F_b = \rho Vg = 1200 \times 0.125 \times 10 = 1500 \text{ N}$. What the cube is made of does not enter the calculation. Option C (1200 N) is the density copied out as though it were a force, but a density in kg/m³ becomes a force only after it is multiplied by a volume and by g .

48. A liquid flows through horizontal pipe where diameter decreases from 10 cm to 5 cm. Velocity at larger section = 4 m/s. Velocity at smaller section? (1)

- A. 4 m/s
B. 8 m/s
C. 12 m/s
D. ✓ **16 m/s**

Answer: D

The same liquid flows through the whole pipe, so the volume passing every section each second is the same: $A_1 v_1 = A_2 v_2$. Area grows with the square of the diameter, so cutting the diameter from 10 cm to 5 cm leaves one quarter of the area, and the speed has to rise four times to carry the same flow: $v_2 = 4 \times 4 = 16 \text{ m/s}$. Option B (8 m/s) comes from doubling the speed because the diameter halved, but it is the area, not the diameter, that sets the rate of flow.

49. Which best describes turbulent fluid flow? (1)

- A. Velocity is constant at every point
B. Motion is smooth and predictable
C. ✓ **Fluid particles follow irregular, chaotic paths**
D. Fluid flows with well-defined layers

Answer: C

In turbulent flow the fluid particles follow irregular, crossing paths with eddies and swirls, and the velocity at any point keeps changing in both size and direction. Turbulence sets in at high flow speeds, in wide pipes and in fluids of low viscosity, and it mixes the fluid strongly. Option D is the tempting one because neat layers are the picture most students carry from this topic, but well defined layers describe laminar flow, and those layers are exactly what breaks up when the flow turns turbulent.

50. During operation of a high-pressure steam turbine, you detect unusual noises and vibrations. What is your immediate response?

(1)

- A. Increase steam flow to compensate.
- B. Continue operation and report later.
- C. ✓ **Reduce load and initiate immediate inspection.**
- D. Temporarily shut down and wait for anomalies to resolve.

Answer: C

Unusual noise and vibration in a high pressure steam turbine warns of a real fault such as imbalance, misalignment, a bearing problem or a damaged blade, and holding the machine at full load can turn that fault into a failure that injures people. The safe response is to bring the load down at once so that the stresses fall, then inspect and find the cause before deciding whether to run again. Option B is tempting for anyone worried about lost output, but continuing to run and reporting later leaves a growing fault turning at full speed.

END OF THE MARKING KEY

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